The Virginia Master Gardener Handbook

2015 Edition

Virginia Cooperative Extension
Virginia Tech • Virginia State University
www.ext.vt.edu

The Virginia Master Gardener Handbook

2015 Edition (rev 9/18)

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Taken from VCE Publication 426-699 and revised 2015

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Welcome to VCE Master Gardenering

Chapter 1

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This material has been prepared for the use of the Virginia Master Gardener in his or her volunteer experience with Virginia Cooperative Extension. Portions of this publication are revised from Chapter 17 of The Virginia Master Gardener Handbook (2009). The original version of this chapter (1994) was edited by Sheri Dorn, Former State Coordinator, VCE Master Gardener Program under project advisor Diane Relf, Extension Specialist, Environmental Horticulture.

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Foreword

Welcome to the Virginia Cooperative Extension Master Gardener volunteer program! The Extension Master Gardener (EMG) program is a volunteer education partnership with Virginia Cooperative Extension (VCE) dedicated to working with the community to encourage and promote environmentally-sound horticulture practices through sustainable landscape management (SLM). SLM provides many benefits, such as protecting water quality, improving air quality, and increasing property values; making your area a more attractive and desirable place to live and work.

Because of your interest in educating and improving your community through horticulture, you are joining a unique group of volunteers trained under the auspices of Virginia Cooperative Extension to provide an effective network of horticultural programs and activities to enhance communities, protect the environment, and educate others. The Extension Master Gardener training program provides you with the organizational and horticultural training to launch community horticulture education programs to benefit your locality. As an Extension Master

Gardener, you will contribute to the improvement of horticultural practices in your community. You will also work with other organizations and agencies to share knowledge and coordinate efforts, thus providing the greatest benefit to the community.

As an EMG volunteer, you are an educator working on behalf of Virginia Cooperative Extension. Just like employees you are expected to work within Virginia Cooperative Extension policy; these same policies apply equally to everyone associated with the Extension Master Gardener program. These policies require you to conduct educational programs with an identifiable goal, keep records, and report on progress toward reaching that goal and the project's community impact. These reports will be used to inspire other EMGs to conduct similar programs, to solicit funds from foundations and industry to support your program efforts, and to demonstrate to local and state agencies the value and impact of EMG programs.

The purpose of this chapter is to explain the history and philosophy of Cooperative Extension and the Extension Master Gardener program, and how to volunteer as an Extension Master Gardener.

Cooperative Extension

Introduction

In all states where the program exists, EMGs are trained and supervised through a partnership with Cooperative Extension, which created the Extension Master Gardener program. When an individual works as an Extension Master Gardener, he or she acts as a representative of Cooperative Extension. So, what is Cooperative Extension?

What is an EMG?

An EMG is an individual whom, after receiving specialized training in environmental horticulture through cooperative programming with Virginia Cooperative Extension, acts on behalf of VCE as a volunteer educator within his or her community. These volunteer educators serve as partners with VCE to promote, inform, and work with communities, leaders, industry, and individuals presenting programs on all aspects of horticulture to protect and enhance the environment, including turf, landscape, vegetables, trees and shrubs, and pest management practices.

What is Cooperative Extension?

Cooperative Extension serves as a link between land-grant universities and the community by disseminating the latest information and research and providing outreach to the average citizen.

History of Cooperative Extension

Prior to the Civil War, very few college curriculums addressed the problems of citizens who made their livelihood from

agriculture. In 1862, Congress passed the Morrill Act, which provided for a university in every state that would educate citizens in agricultural and mechanical fields. These colleges are known today as "land-grant universities."

Congress soon realized that to be effective, the educational function of land-grant universities must be supplemented with a research capability. Consequently, it passed the Hatch Act in 1887. This act provided for the establishment of facilities where colleges could conduct research into agricultural, mechanical, and related problems faced by rural citizenry. (In Virginia, Extension Master Gardeners sometimes assist with the research done at these research stations.)

Finally, in order to spread the benefits of the land-grant universities throughout each state, Congress passed the Smith Lever Act of 1914. This act provided for the establishment of Cooperative Extension. As a result of the Smith Lever Act, there are now Cooperative Extension offices in every county in Virginia (and many cities) that serve to"extend" to the public the information developed on the campuses and research stations of the land-grant universities. In fact, Cooperative Extension agents are considered university faculty since their roles are primarily educational.

One provision of the Smith Lever Act is that the cities and counties being served by Cooperative Extension pay a portion of the operating costs of Cooperative Extension in that locality. The Act also provided federal funding for Cooperative Extension through the US Dept. of Agriculture. Because of this funding arrangement, Cooperative Extension is a true partnership between local, state, and the Federal government. Cooperative Extension Programs must reflect the needs for educational programs of the communities they serve and these needs are determined by the local units through the periodic application of a detailed situation analysis of the community.

Mission & Vision of VCE

Mission Statement of VCE: "Virginia Cooperative Extension helps lead the engagement mission of Virginia Tech and Virginia State University, the commonwealth's land-grant universities. Building local relationships and collaborative partnerships, we help people put scientific knowledge to work through learning experiences that improve economic, environmental, and social well-being." (from the VCE web page http://www.ext.vt.edu/about/mission.html).

VCE is all about Virginians working with Virginians in communities, homes, and businesses. A product of cooperation among local, state, and federal governments, VCE operates 107 county/city offices to create a communication network among all the people of the Commonwealth. VCE representatives are Cooperative Extension educators,

led by local agent and campus faculty, taking knowledge from the Virginia State and Virginia Tech land-grant universities and their nationwide sister institutions to everyday people facing everyday problems.

Helping people solve their own problems through educational programs is VCE's business. Help is provided through issue-based programs conducted in workshops, seminars and demonstrations, over the phone, in research-based publications, online, and in radio and TV programs to reach people in their homes, workplaces, and local communities. What is taught varies from place to place as local people participate in the design, implementation, and evaluation of needs-driven programming. Cooperative Extension is committed to providing access to unbiased, scientific information related to locally defined issues; a presence in local communities; the establishment of strong partnerships and collaborative coalitions; and innovative service to the Commonwealth.

Organization of VCE

There are a number of components that make up the structure of VCE including the local offices and agents, local Extension Leadership Council, the district office, the state office, and Virginia Tech University.

Local Extension Unit

The local Extension office is the local doorway to our land-grant universities for the public and Extension Master Gardeners. Each Extension office, or unit, in Virginia conducts programs in four program areas: Agriculture and Natural Resources (including horticulture), Family and Consumer Science, 4-H Youth Development, and Community Viability. An Extension agent is assigned to work with each area. Extension Master Gardeners generally work most closely with the Agriculture and Natural Resources (ANR) agent, but are encouraged to use their horticultural skills to conduct programs in cooperation with Family Consumer Science, 4-H, and Community Viability agents.

Extension Leadership Councils (ELCs)

Each Extension office has a Leadership Council that is a partnership between local citizens and civic leaders who provide feedback and direction to ensure that Extension educational programs will be relevant in their community, will be forward thinking, and will combine VCE resources with others in an effective manner to meet the needs of the citizens. Many Extension agents ask Extension Master Gardeners to serve on these boards and others similar in nature. Educational programs conducted by EMGs should be in line with the goals identified by the local ELC.

District and State Office

Virginia's 107 Extension units are divided among four districts. District staff includes a district director (see Appendix A for a list

of district director names and addresses) who provides administrative and program development assistance to the local unit offices. These four districts are, in turn, responsible to state-level administrators at the land-grant university. The state Extension administrators are liaisons between the state Extension service and the U.S. Department of Agriculture, which oversees and evaluates state Extension programs. (See the VCE Organization Chart, Appendix A for further detail.)

Virginia Tech

Extension units are also closely linked to Virginia Tech. In addition to administrative and program development assistance, the land-grant universities provide many other types of support to the local Extension office. This is essential, since no Extension agent can know the answer to every question posed by the public. Consequently, universities employ experts, called Extension Specialists, in specific areas, such as horticulture, soils, turf, plant diseases, insect problems, etc. Specialists provide in-service training, subject matter support (written and online resources), and other necessary types of support to agents in the field. They are responsible for statewide program development, design, and reporting.

In Virginia, most of the administrative and program development support for the EMG program comes from the State Office of the Extension Master Gardener Coordinator at Virginia Tech. The staff in this office address horticultural concerns of consumers of horticultural products and services through several programs, mainly the Extension Master Gardener program and the Healthy Virginia Lawns program. Of specific concern to EMG programming, the Office of the State Master Gardener Coordinator also develops materials and publications, such as The *Virginia Cooperative Extension Master Gardener Coordinator Manual*, for use by coordinators administering local Extension Master Gardener programs and EMG volunteers who are coordinating education programs. In addition, the office publishes the quarterly *InSeason* newsletter, and maintains horticultural information on VCE and EMG associated web pages.

Volunteers in Extension

Volunteer involvement is one of the most important and unique aspects of Cooperative Extension. This is in keeping with Extension's philosophy that active citizen participation in planning and implementation insures program success. Volunteers working jointly with faculty and staff are a valuable resource and an integral part of the education mission of VCE. EMGs are part of this family of volunteers as they are education partners with VCE. EMGs are NOT a clientele group of VCE. It is also important to note that Extension Master Gardener volunteers serve at the sole discretion of Virginia Cooperative Extension. VCE may at any time, for whatever reason, decide to

terminate the volunteer's relationship with the organization or to make changes in the nature of their volunteer assignment.

Every year, VCE is joined by tens of thousands of volunteers, including Extension Master Gardeners, who contribute over one million hours and contacts. VCE works closely with hundreds of private and public sector agencies and organizations to complement and supplement our resources so that Virginia is better served in this collaborative way.

The Extension Master Gardener program provides a resource for all VCE program areas and for professionals from many other agencies. EMGs provide communities with locally identified programs, including answers to individual questions via help desks and plant clinics; online tools, radio, and newspaper; educational programs to meet targeted needs, such as the establishment of community gardens for schools, low income, and elderly persons; education for the preservation of historic landscapes; urban tree planting programs; and guidance in making the natural environment accessible to all residents regardless of disabilities, incomes, or where they live.

EMGs primarily interact in program delivery with a Horticulture Extension agent and/or local Master Gardener Coordinator who has been appointed or approved by VCE and the local Extension office. However, any Extension agent (state or locally funded) can act in an advisory capacity to EMG groups and approve of the activities and programs chosen to be affiliated with Extension and conducted under the auspices of the local unit office. 4-H, Family and Consumer Science (FCS), and Community Viability agents are urged to work with EMGs on relevant, gardening-based programs.

Creation of the EMG Program

The Extension Master Gardener program was created by Extension to meet an enormous increase in requests from home gardeners for unbiased, research-based horticultural information. This increase was a result of the urban and transient nature of modern American life. Fifty years ago, an Extension agent dealt with the questions of a few hundred farm families. In many regions, however, land that once constituted a single farm now encompasses several subdivisions, increasing the number of families an Extension office must serve by hundreds. In addition, people from all over the country and all corners of the world now call Virginia home; new residents are likely to be unfamiliar with the grasses, shrubs, trees, pests, etc. that comprise the microenvironment of their new urban, suburban, or rural homes. They often call their local Extension office for advice on what to plant and how to care for it.

Consequently, the Extension Master Gardener program was created in 1972 in

the state of Washington. Since then, it has spread to 50 states. EMGs have become a vital part of Extension's ability to provide consumers with up-to-date, reliable knowledge so they can enjoy and protect the value of the natural environment around their homes. In addition, Extension Master Gardeners work with professionals, such as teachers, activity therapists, and others who work with people, thus carrying the benefits of horticulture to a much broader population than homeowners alone. The EMG program has also become a fun and useful volunteer activity that has given its participants a sense of community spirit, accomplishment, and intellectual stimulation.

Local Master Gardener Coordinators (MGCs) serve as liaisons between the Office of the State Master Gardener Coordinator and the local EMG program. MGCs organize the local program so that through their efforts (or by delegation of responsibility to other individuals) training, supervision, and evaluation of EMG volunteers are provided. In addition, they ensure Extension Master Gardener programs are initiated and/or maintained in each participating unit so that the program serves as a resource for effective programming for all VCE program areas.

Program Financial Support

The EMG program is supported by several types of funds, primarily handbook sales and grant monies.

Upon acceptance into the EMG training program, each individual usually pays a course fee, a portion of which goes to the State Office of the Extension Master Gardener Coordinator for the purchase of a copy of *The Virginia Master Gardener Handbook*, the training textbook. In addition to the receiving the handbook, this purchase also provides registration of the individual in state records as an Extension Master Gardener, documentation of status for substantiating liability coverage for volunteer activities as an EMG on behalf of VCE, and a subscription to *InSeason* for as long as the individual remains an active EMG in Virginia.

The handbooks are purchased from the Office of the State Master Gardener Coordinator at Virginia Tech. In addition to covering the cost of revising, printing, and shipping the handbook, these funds support additional staff and projects in the office of the state EMG Coordinator. It also supports leadership development trainings throughout the state to provide training, advice, and support to local programs. The production of *InSeason* and the development of new EMG program resources, including guides for volunteering; management guidelines; advanced EMG training programs and other support resources are also supported by these funds.

Through sales of *The Virginia Master Gardener Handbook*, EMGs assist in underwriting the annual training event,

EMG College, and allow flexibility to seek grant dollars for additional program support. Reports on EMG volunteer contributions and accomplishments are used to substantiate grant proposals for additional resource development and other forms of program assistance (hence, the importance of reporting EMG accomplishments!). Combined, these efforts benefit the Extension Master Gardeners directly by increasing support for expanding educational programs and the continuing development of horticulture information resources available to EMGs and the general public.

Success as an EMG

Being an Extension Master Gardener

EMG volunteer opportunities are unique in that they provide opportunities to build the local community through education about environmentally-sound horticulture and to improve quality of life through horticulture for special populations, such as low income, elderly, or physically challenged. EMG volunteer opportunities increase individual knowledge of horticulture through activities that help the community and assist VCE in its mission to provide knowledge for the Commonwealth. Individuals joining VCE as an Extension Master Gardener are joining a local group of volunteers that is part of a state group, which is part of a national group of distinguished volunteers recognized for their knowledge, skills, and for the significance of the work they do in improving their communities.

The next section will further explain the identity and responsibilities of the individual EMG volunteering on behalf of Cooperative Extension.

Steps to Becoming an EMG

There are five levels of EMG status. Each status level is determined by level of training and internship (community education service) experience. The levels include: EMG Trainee, EMG Intern, Extension Master Gardener, Advanced EMG, Emeritus EMG.

Upon entering the EMG program, the volunteer is entering into a contract. In essence, he/she agrees that in return for the training received, he/she will volunteer an equal number of hours with Extension in an approved internship experience to be completed within one year of the contract date. Failure to complete this obligation means the individual does not receive the title of EMG, is not entitled to wear the Extension Master Gardener badge, and cannot participate in EMG activities. All individuals receiving EMG training must be able to commit to a minimum of 100 hours within 12 months. A minimum of 50 hours will be spent in classroom instruction, and an additional 50 hours (minimum) hands-on internship will be spent on field experience in horticulture-based, education programs.

Before volunteers are accepted into the EMG training program, the local coordinator or training coordinator should make sure that there are volunteer opportunities available that fit the schedules of the trainees. Some jobs require work day hours and other volunteers can perform tasks that can be done after-hours, such as research, writing, correspondence, and record keeping. Specific job descriptions for volunteer internships should be available so volunteers know exactly what is expected of them and to ensure that program needs are met. Appendix B includes sample job descriptions that assist the volunteer in completing his/her obligations and in assisting VCE with identified needs.

Extension Master Gardener Trainee: *One who is currently in classroom training to become a EMG but has not yet taken or satisfactorily passed the examination(s) on course material. No more than three classes can be missed and all required course work must be made up.*

Extension Master Gardener Intern: *One who has completed the EMG program classroom training requirement, achieved 70 percent or better cumulative average on the final examination, and is currently fulfilling the initial internship experience of 50 hours educational efforts/work time.*

During the minimum 50-hour internship, at least 40 hours must consist of public or community educational efforts (programs or activities), and up to 10 hours may be administrative activities for the business of the EMG program (such as planning and conducting next year's EMG class, being an officer of the local EMG association, or editing the local EMG newsletter or other pre-approved administrative tasks). 50 hours is the minimum time for the internship phase; local EMG programs have the option to require longer internships.

To properly track all of the efforts that EMG volunteers contribute to VCE, information will be recorded on a regular basis. All EMG activities of Interns and all other EMG categories must be entered into the state-wide record system by the volunteer through the on-line Volunteer Management System (VMS) program. If you do not have access to the internet, you may report your activities to the person designated to enter time in these circumstances. An individual will be dropped from active status if the individual's records are not recorded in the VMS. This can jeopardize recognition records and registration at the annual EMG College. If an individual does not meet the initial intern volunteer requirements, then he or she is not an Extension Master Gardener.

Extension Master Gardener: *One who has completed the full EMG training program - classroom and internship - and is actively volunteering with VCE, fulfilling the program*

requirements necessary to remain active.

EMGs who desire to stay with the program after completing their initial training and volunteer internship commitments are required to complete an annual re-enrollment process. This process insures that all EMGs are trained in current, up-to-date information. Re-enrollment consists of 28 hours annually spent in training and service, as described in the following paragraphs.

A minimum of eight (8) hours of continuing education training is required annually (hours to be spent in further developing and sharpening horticultural and educational program delivery skills). This training obligation can be met through continuing education programs offered through the Virginia Master Gardener Association; lecture-style presentations at local EMG monthly meetings; advanced training credits earned through participation in the annual EMG College in June at Virginia Tech; completion of advanced-level EMG training programs, such as Master Gardener Tree Steward; and similar educational opportunities, or college credits. Educational training activities must be approved in advance by the local EMG coordinator. In the case that a volunteer participates in a specialized EMG training program, such as Tree Steward, the education hours can be prorated over a three-year period.

Twenty (20) hours of work time/educational programming and/or administrative service are required annually to meet the annual service requirement. These activities should be approved in advance by the local EMG coordinator and, for liability purposes, appropriate Extension personnel. EMGs should continue to report their volunteer hours and keep track of their volunteer contributions as they did when they were interns.

When a person ceases active volunteering with VCE and/or no longer pursues continuing education, he or she also relinquishes the title of Extension Master Gardener. When these requirements have not been met, the EMG is considered inactive. Inactive status is temporary and is available for a one- or two-year period upon request of the individual and approval of the local coordinator. Coordinators may choose to review this status annually and may require additional training to reactivate an individual to EMG status. The individual is subject to removal from mailing lists and is not eligible to attend advanced training programs during the inactive period.

Advanced Extension Master Gardener:

One who has received specialized training in any of the advanced-level EMG training programs and has completed the program requirements.

Specialized training is available in various areas including arboriculture (Tree

Steward), water quality (Water Steward), and firewise landscaping (Landcare Steward). Other project specialization areas will include composting, integrated pest management, 4-H/youth horticulture and horticulture therapy. These advanced training modules provide EMG volunteers the opportunity to expand the influence of VCE through leadership in their communities and enables EMGs to get involved in and lead programs concerning a community's greatest assets.

Advanced-level training has three goals:

* To provide a type of training that integrates programming and technical expertise.
* To promote cooperative community efforts.
* To enhance the community.

Advanced-level training materials are available for purchase from the Office the State Master Gardener Coordinator, 407 Saunders Hall, Blacksburg, VA, 24061-0327; (540) 231-2714.

Emeritus Extension Master Gardener:

A dedicated EMG who "retires" due to health or other reasons after 1000 hours of service or as determined by the coordinator and/or Extension agent.

This is a high honor status and should have limited use. This title is specifically used for individuals who can no longer complete the requirements for remaining an active EMG, but who have earned continued affiliation with the program. EMGs can be nominated for this status, but it is bestowed solely at the discretion of the local VCE office.

Master Gardener College

The EMG College is an annual advanced training program typically held the third weekend in June on the Virginia Tech campus. All active EMGs who have completed initial internships are invited to participate. This conference provides EMGs the chance to remain current on program issues and horticulture training, and it encourages volunteers from across the state to share ideas and experiences.

Policies and Procedures

Use of the Title "Extension Master Gardener"

After completion of the requirements to become an EMG volunteer, the official title shall be Virginia Cooperative Extension Master Gardener (usually shortened to Extension Master Gardener). Use of this title is a privilege, and this title is to be used only by individuals trained in the EMG program while volunteering under

[1] Source: http://www.cdc.gov/nchs/data/databriefs/db219.htm
[2] Sources: -Finkelstein EA1, Trogdon JG, Cohen JW, Dietz W. Annual medical spending attributable to obesity: payer-and service-specific estimates. Health Aff (Millwood). 2009 Sep-Oct;28(5):w822-31. doi: 10.1377/hlthaff.28.5.w822.; -Trogdon JG, Finkelstein EA, Hylands T, Dellea PS, Kamal-Bahl. Indirect costs of obesity: a review of the current literature. Obes Rev.2008;9(5):489–500.

the auspices of VCE. The relationship of the Extension Master Gardener to Virginia Cooperative Extension should be clearly stated in nametags, signs, and other identification. The EMG Coordinator (volunteer or paid staff) serves as the immediate supervisor for a EMG. The ultimate responsibility for EMG volunteers and the ability to approve activities and projects falls to the local Extension agent.

The EMG program is operated under the guidance of VCE to provide unbiased, research-based, environmentally- sound, horticulture information to the public; and any implied commercial endorsement resulting from use of the EMG title is improper. Therefore, the title may not be used for commercial publicity or private business. Participating in a commercial activity, association with commercial products, or giving implied VCE endorsements to any product or place of business is a violation of EMG program policies. Extension Master Gardeners may only identify themselves as such while volunteering in conjunction with official/ approved VCE programs or activities, such as a plant clinic conducted at a retail store, NOT for business or personal gain.

EMG training and experience may be given as qualifications when seeking employment; however once employed, credentials may not be displayed by the EMG or the employer. Individuals who wish to use their horticulture training for distinction in the workplace should pursue Virginia Nursery & Landscape Association (VNLA) certification by exam. The VNLA course work is very similar in nature to the EMG training and is specialized for the horticulture industry.

Enrollment, Re-Enrollment, Background Screenings

At the start of the enrollment process a prospective Extension Master Gardener volunteer must complete a detailed application and be interviewed by the local Master Gardener Coordinator or an appointed representative. All new EMG volunteers must agree to a criminal background screening as required by VCE policy. Prospective Extension Master Gardener volunteers will be considered enrolled after the responsible Extension Agent or other designated person reviews this material and approves the application.

Membership must be renewed annually by submitting a re-enrollment form. The criminal background screening must be renewed every three years while the volunteer is still active in the Extension Master Gardener Program. These forms are available from the local MGC.

There may be additional requirements for any Extension Master Gardener volunteers working with youth, see the paragraph on **Working with Youth.**

Volunteer Contribution Areas

There are four (4) categories for recording

EMG volunteer contributions.

1. **Volunteer Time;** this refers to the time a volunteer spends engaged in an education program for a client or a group of clients. It includes time spent organizing materials and arranging for other volunteers to work on the project, time spent actually presenting or engaged in the project, and review or evaluation of the project after it is complete. It may also include non-educational and administrative work such as coordinating volunteers, serving on certain committees, keeping local EMG records of activities, and other activities that the responsible Extension agent deems to be contributing to the goals and mission of the local Extension program. Active EMGs are expected to report a minimum of 20 hours of volunteer time per calendar year.

2. **Continuing Education (CE) Time**; this refers to the time spent in advanced training, education conferences, or other settings that qualify as additional training beyond the initial basic training. Active EMGs are expected to report a minimum of 8 hours of CE time per calendar year.

3. **Miles Driven**; while this does not contribute to the individual's status as a Extension Master Gardener, it is important to record this data so that it can be included in the overall impact of the efforts that EMGs have on the Commonwealth of Virginia.

4. **Contacts**; it is vitally important that the number of people served by EMGs and the demographic make-up of each audience be reported. The number of people we serve represents the impact of Extension Master Gardener educational programs on the citizens of Virginia. The demographic information shows that all EMG programs are presented fairly and equally to all of Virginia's citizens. For additional information on contacts reporting, please contact your local MGC.

Working with Youth

Any Extension Master Gardener that works with youth must receive special training from their local 4-H agent. This training includes orientation to the 4-H program, introduction to the "Above Suspicion" policy, and explanation of the 4-H enrollment forms. It is the EMG volunteer's responsibility to inform their agent of youth program activities. Volunteer time and number of youth contacts should be reported to the 4-H Agent *and* in the VMS (or to the designated or record keeper). Only horticulture-related educational projects can count towards EMG programming time.

Reporting System

EMGs may keep track of their hours spent on educational efforts as an EMG volunteer in a notebook or calendar. However, these hours must be reported through the on-line Volunteer Management System (VMS) for the hours to count toward the volunteer's service (an image of the online time entry

form appears in Appendix C). The written time sheet should only be used by the volunteer as an aid to keep track of his/her contributions. EMGs should not be lax in reporting volunteer time; they deserve recognition for their efforts. Reporting of EMG accomplishments also justifies the expenditure of money to funding agencies, such as grant sources and local governments.

EMGs should not be modest about their volunteer contributions; they should discuss and promote what they do. One way to do so is through reporting in the VMS. Reporting promotes EMG accomplishments and results, describes helpful resources that are being used, indicates the impacts EMG efforts are having in the local community, and discusses what EMGs intend to accomplish in the future. EMG hours tracked on time sheets are totaled and used to provide annual recognition for EMG service.

These volunteer reports are also used to complete many types of annual reports. Extension agents report EMG accomplishments on the VCE Plan of Work, primarily under Sustainable Landscape Management. These figures are then used by the State EMG Office to quantify the efforts and accomplishments of the program throughout Virginia. This data is used to complete additional reports to VCE administration, legislators, and grant funders. These reports are largely used in getting competitive grants to support the work done in the State Office of the Extension Master Gardener Coordinator, such as the development of advanced training (ex: the Tree Steward training manual, training presentations, and teacher's guide). VCE/VT also uses state-wide reported information to work with local governments to increase local funding support. The time sheets and records that EMGs keep have far greater importance than most individuals realize.

Volunteer work is usually done within the geographical area served by the Extension unit office conducting the training. EMGs trained in a multi-county program, however, should make arrangements with their local MGC to volunteer in the communities in which the Extension Master Gardener resides. EMGs who volunteer in counties other than those in which they trained should let their training coordinators know of their activities, but for inclusion in annual VCE reports, the volunteer activities should be reported under the county in which the activities were conducted.

Pesticide Recommendations

EMGs know that the use of chemicals in the garden is usually a last resort. An experienced EMG may suggest a non-chemical treatment if the cultural problem is one that is not specifically covered by the Pest Management Guide, provided the recommendation is a research based Extension publication from another source. If they give advice that includes

the use of chemicals, however, EMGs must follow the VCE Pest Management Guide recommendations. Part of the training of EMGs includes use of these Pest Management Guides (PMGs). The PMGs represent the most up-to-date knowledge of VCE concerning the use of chemicals and the LEGAL recommendations meeting all government agency standards for labeled use of pesticides in Virginia. Use of other pesticide recommendations is not approved. Any questions about use of chemicals in commercial operations must be referred to an Extension agent.

Extension Master Gardeners must be very careful about giving chemical recommendations because the registration and use of pesticides are governed by the United States Environmental Protection Agency and the Virginia Department of Agriculture and Consumer Services. Under the amended Federal Insecticide, Fungicide, and Rodenticide Act (Federal Environmental Control Act of 1972), **it is illegal to use a pesticide on a crop unless the crop is listed on the pesticide label**. The given rate of application on the label may not be exceeded. Fines and other penalties vary according to the laws broken. EMGs ***must*** follow the VCE Pesticide Policy, as stated in Appendix D. The VCE Pesticide Policy applies to all VCE faculty, staff, and volunteers.

Liability Coverage

VCE/VT extends liability coverage to representatives of the university in conducting business related to/on behalf of the university. This includes coverage of EMGs volunteering on behalf of VCE, under the Commonwealth of Virginia self-insurance program, as authorized by Section 2.1-526.8 of the Code of Virginia. This insurance program covers employees and volunteers ***while participating in Extension Master Gardener programs approved by Extension personnel for cases of negligence or liability only***. Any medical problem, however, arising from volunteer work for VT/VCE is the individual EMG's responsibility through his/her own personal health care coverage. Questions regarding VCE/VT liability coverage should be directed to the Office of Risk Management at Virginia Tech (540-231-7439). This information should be presented to EMGs through an annual risk management training program presented by the Extension Agent or the MGC.

VCE Master Gardenering Rewards

Volunteers are not compensated financially, but the rewards are realized by the gratitude of the people served in their communities. Extension Master Gardeners should know that their work is valued and appreciated by their fellow workers in the Extension office as well as district and state staff. Certainly, the number of citizens who come to EMGs with plant problems indicates that they and their knowledge are needed and greatly appreciated. EMGs should be

proud of the positive impact they have on the quality of the environment. The title and status of being an EMG is highly regarded. Earning the title demonstrates an individual's knowledge, skills and dedication to community service. The sense of accomplishment and pride in a job well done are assets that only Extension Master Gardeners volunteers can collect.

Creating a Lasting Impact

Extension Master Gardeners as Educators

EMG volunteer educators are trained community leaders working with people to increase knowledge and understanding of environmentally-sound horticulture. Being an EMG volunteer educator is making an investment in the local community and its people. EMG volunteers offer services and skills without monetary compensation so that others may benefit. This volunteer service has far-reaching results, such as the improvement of community resources (like water quality), positive impacts on environmental quality through sustainable landscape management, and improved health and quality of life for individuals in the community. When Extension Master Gardeners educate citizens of Virginia in sustainable landscape management, they empower people with improved horticulture skills, and they bring the benefits of horticulture to many people. In preparation for volunteering, EMGs personally gain training and knowledge in horticulture and leadership skills. Volunteering develops new skills and identifies new personal strengths while bettering the community.

A successful Extension Master Gardener program is based on careful thought and formation of a comprehensive action plan tailored to needs of the local community so that Master Gardenering efforts are focused, educational programs rather than random acts of education that may or may not benefit the community. The local MGC and program planning committee work together to identify community needs that the Extension Master Gardener program can meet. EMG volunteers then work to meet these needs through a variety of activities. These activities build public awareness of the importance of horticulture to people, increase interest in environmentally-sound horticulture activities, and involve other community volunteers necessary for the ultimate success of the program. Educational programming based on identified community needs makes the EMG program more effective in bringing the many benefits of environmentally-sound horticulture to the community.

Educational Programming

Educational programming is a complete approach to teaching people about environmentally-sound horticulture and sustainable landscape management. It has three equally important stages: planning, implementing, and reporting. Once the planning is completed, the actions are

carried out, then the event is evaluated to determine whether or not goals were accomplished and methods were effective for the given resources, goals, etc. Depending on the event, reports can be prepared for the particular results achieved or notes can be made for inclusion in the end-of-year reports for Extension. An EMG counts all time involved in that process (planning, implementing, reporting) as educational programming/ work time. This means volunteers do fewer projects, but projects are conducted more thoroughly.

Planning an EMG educational activity starts with identifying achievable goals or outcomes that support the overall goals of the local VCE program. Then the audience, topic, and appropriate actions are identified. Identified actions supporting educational programming generally involve educational tools and activities. Tools aid teaching the audience, and some examples of tools include posters, pamphlets, and brochures that illustrate a point or technique. Individuals may use the information from these teaching tools to replicate the technique in his or her own garden. Activities, such as physical demonstrations, lectures, and hands-on participation from the target audience also enhance the learning process. Success in teaching is indicated by identified outcomes, such as increase in knowledge (pre-post tests) and adoption of practices (pre and follow-up surveys).

Extension Master Gardeners are teachers of the community, rather than gardeners offering free horticultural services to the community. Teaching others to garden involves more effort than doing the gardening personally, much like teaching a child to clean his or her room is often harder than actually doing it. EMGs that actually do gardening work rather than teaching others how to garden are like parents still cleaning a 35-year-old child's room. The child never learns how to do the cleaning as long as it is always done for him or her. Similarly, citizens of Virginia will be less likely to change their horticultural behaviors if they are not given opportunities to learn for themselves. To have maximum impact on water quality and other identified issues, EMG efforts should focus on teaching citizens of Virginia to garden and practice horticulture in an environmentally-sound way.

Extension Program Areas

In VCE's efforts to provide knowledge for the Commonwealth, VCE educational programs are conducted in each of the main Extension emphasis areas including Agriculture and Natural Resources, 4-H, and Family and Consumer Science.

Agriculture and Natural Resources

Horticulture, particularly environmental horticulture, falls under Agriculture and Natural Resources, and this is the area in which EMGs most frequently work.

The environmental horticulture program addresses the issue of environmentally-sound landscaping practices that are economically viable and acceptable to members of the community.

Proper selection, installation, and maintenance of plants are essential to economically and effectively reduce erosion, landfill overload (about 15 to 20 percent is yard waste), right-of-way maintenance, air pollution, and many other problems associated with rural and urban development. The program utilizes workshops, demonstration sites, newsletters, Internet information, and certification training to provide research-based information to public and private landscapers, landfill operators, school ground managers, developers, park and golf course superintendents, retail nurserymen, and garden center staff whose skills protect the environment, enhance human health, and contribute to economic stability.

4-H Programs

4-H is the comprehensive youth development program of VCE. Youth between the ages of 5 and 18 engage in hands-on learning experiences under the guidance of adult or teen 4-H volunteers trained by 4-H agents. 4-H programs use experiential learning opportunities to teach the latest research-based subject matter knowledge and to foster skill development in effective citizenship, leadership, and other life skills. The ten areas of 4-H curriculum focus are: Animal Sciences; Communications and Expressive Arts; Environmental Education and Natural Resources; Jobs, Careers and Economics; Plant and Soil Sciences; Citizenship; Consumer and Family Sciences; Health, Nutrition and Wellness; Leadership and Personal Development; and Science and Technology. Youth also participate in educational experiences at six 4-H educational centers. 4-H has both a school-based delivery model and a community-based delivery model so maximum access to Virginia's youth is provided. The specific learning experiences a 4-H member participates in are shaped locally and supported at the state and national levels. 4-H members learn how to make decisions, manage resources, work with others, and utilize effective communication skills. 4-H serves as an effective prevention educational program. Involvement in 4-H reduces the potential for dysfunctional involvement in the community by youth.

Extension Master Gardeners should use horticulture projects and horticultural activities to conduct citizenship, community beautification, and other projects, including plant science and industry projects, within the 4-H clubs. **All VCE youth programs must be coordinated with the 4-H agent.**

Family and Consumer Sciences Programs

Nutrition and Wellness

Nutrition, health, and wellness educational programming relates to food and nutrition and food safety. Poor diet and inactivity, which often leads to obesity, was the second leading cause of death in the U.S. in 2000.

In a 2015 report from the Center for Disease Control[1]:

* The prevalence of obesity was 36.5% (crude estimate) among U.S. adults during 2011–2014.
* The prevalence of obesity among U.S. youth was 17.0% in 2011–2014
* Overall, the prevalence of obesity among preschool-aged children (2–5 years) (8.9%) was lower than among school-aged children (6–11 years) (17.5%) and adolescents (12–19 years) (20.5%)
* From 1999–2000 through 2013–2014, a significant increase in obesity was observed in both adults and youth

Diet related diseases include diabetes, heart disease, hypertension, strokes, cancers, pulmonary conditions, and mental disorders. The medical care costs of obesity in the United States are high. In 2008 dollars, these costs were estimated to be $147 billion. The annual nationwide productive costs of obesity obesity-related absenteeism range between $3.38 billion ($79 per obese individual) and $6.38 billion ($132 per obese individual)[2].

Nutrition and wellness programs provide education so people can make informed decisions and adopt food and nutrition practices that will promote optimal growth, health, and productivity and reduce disease risks and health care costs. Audiences for these programs include school age youth, child care providers, teachers, parents, and limited resource families. Workshops, exhibits, and fact sheets are among the delivery methods used by trained staff.

To contribute to nutrition and wellness programs, EMGs can establish a community or school vegetable garden to teach gardening for nutrition, especially to target audiences listed above.

Family and Human Development

Families are an integral building block in the structure of the economics and social fabric of Virginia. Our families face a variety of challenges, issues, problems, and opportunities in our constantly changing world. The primary goal of this programming is to enhance the functioning of Virginia's citizens to achieve improved levels of self-sufficiency and effectiveness in everyday living within their families and communities. The target audiences include families with children and with aging members and special needs families, such as those dealing with welfare and the court systems. Other programming provides education for providers of child care, enhancing child care in the community, and the ability of child care providers to earn income. Workshops, newsletters, and fact sheets are examples

of delivery methods used. Involvement of participants in small groups through which personal, on-going attention is provided makes VCE family programs uniquely successful.

To contribute to family and human development programs, EMGs provide leadership in developing after school gardening programs and other educational programs for preschools, nursing homes, and senior citizens groups.

Community Viability (CV)

Virginia Cooperative Extension specialists in Community Viability work with Extension agents, campus-based faculty, organizational partners, communities, and individuals to further opportunity and build capacity in five program areas:

* Leadership and Planning,
* Community Enterprise and Resiliency,
* Community Food System and Enterprises,
* Community Planning, and
* Emerging Community Issues.

Examples of this work include training county elected officials, educating entrepreneurs, facilitating collaborative projects, supporting the growth of community food systems and local economies, enhancing agent skills and community capacity in facilitation and leadership, conducting problem-driven research, and creating publications and tools that address critical community needs.

EMGs can contribute in the area of Community Food Systems by providing education programs on vegetable and fruit gardening and production. However, the other areas may offer opportunities as well.

Meeting the Goals of VCE

The VCE program planning and reporting system includes long-term goals and annual program proposals. The foundation upon which program proposals are developed is strategic issues. Strategic issues are identified by specialists, agent faculty, and others through a collaborative strategic program planning process. Program proposals for client-focused programs are developed by campus-based Program Teams (PT) after identifying foreseeable or anticipated problems appropriate for VCE programming, using information from strategic issues analyses and other pertinent information (e.g., research, successful programs, past programming experience, etc.).

Program proposals serve as a communication and planning tool for developing, delivering, and reporting VCE programs. They are used to communicate information about programs within the system, such as priority issues, planned time, measurable indicators for program impacts, and reporting expectations. They

serve as a planning tool by communicating PT support for programs, including suggested educational strategies, in-service training, etc. Program proposals are also used to communicate with external audiences, such as the state legislature and federal government, about VCE client-focused programs.

Once approved, the program proposals are distributed to all staff. All units and personnel respond ("buy in") to the appropriate program proposals by providing a brief local situation statement, estimates of program participants, and amount of time planned on the proposal. Personal or team action plans and individual staff development plans are also prepared. The strategic issues analysis, program proposals, personal and team action plans, and staff development plans become the Plan of Work for VCE (a written list of objectives and action statements). At the end of the programming year, an annual accomplishment report is developed for each program proposal. In addition, units and staff are able to amend, or update, their plan of work annually, or as needed.

Most Extension Master Gardener program goals and interests closely compliment the work of Consumer Horticulture agents. Many Extension agents work towards objectives that have been listed under the subject of Sustainable Landscape Management in the formal Plan of Work. They may also work to create programs to meet objectives listed under Water Quality and Waste Management. The programming goals and objectives of the Plan of Work should be very similar in nature to goals and objectives created for EMG educational programs. The following is a summary of Plan of Work VCE goals and objectives that apply to programming conducted by Extension Master Gardeners.

VCE Plan of Work

Sustainable Landscape Management (SLM)

Goals: For individuals/businesses/agencies in the non-agricultural sector (including residences, public and private landscapes, right-of-ways, parks and golf courses, landfills, schools, developers, utilities, etc.) to acquire skill in SLM (with emphasis on IPM) that protects the environment, enhances human health, and ensures economic stability.

Programming Direction and Impact:

Environmental Stewardship

These educational programs work to increase awareness and knowledge of responsible landscape management and natural resource conservation.

More specifically, included are all aspects of the landscape: soil, plants, water, insects, diseases, and wildlife. It aims to foster a better understanding and the proper use of pesticides, fertilizers, other landscape inputs, as well as equipment in order to add the greatest value with

minimal negative impact to the managed landscapes. Environmental Stewardship targets plant selection, water quality, yard waste management, erosion control, and other related issues.

Economic and Social Impacts of Horticulture

These educational programs focus on horticulture's importance and impact on daily life.

More specifically, this objective encompasses ecosystem services as well as the economic impacts of green infrastructure and planted landscapes on local communities and economies. It addresses the proper design, installation, and maintenance practices that provide economic benefits to both the individuals and the community. With youth, it seeks to increase the understanding of the value of horticulture, provide skills for horticulture based activates, and to increase responsibility and leadership. For others, by increasing this understanding, the educational programs promote knowledge and skills that further personal health as well as a healthier workplace and community. Programs such as horticulture therapy work in nursing home facilities, rehabilitation hospitals, and hospices in order to increase the quality of life. Included in this program is health related topics, such as proper use of toxic chemicals, how protection against skin cancer, and safe use of garden equipment.

Food Security

These educational programs aim to increase awareness of the benefits home food production, food systems, and locally grown foods.

More specifically, this SLM focuses on teaching the skills and knowledge required for growing food, managing community gardens, and contributing to food banks and kitchens. These programs also look at broad topics, such as the intricate nature of food systems and their relationship and importance in our day to day life. Health–related issues such as obesity and diabetes are also addressed through the program.

Program Areas for EMGs

The Extension Master Gardener program was originally created to meet the community need for answering consumer horticulture questions. In recent years, local EMG programs have begun to identify and address additional community needs. EMGs have explored and implemented programs dealing with water quality, recycling, the effects of plants on human well-being, and the community. In this light, the EMG program is clearly one of the most relevant and important volunteer programs offered by Cooperative Extension. Some examples of EMG program emphasis to meet community needs include:

Answering Consumer Horticulture Questions - Extension Master Gardeners

have done a superb job of assisting local Extension units in the dissemination of horticultural information to the gardening public by conducting plant clinics and gardening classes, answering telephone questions, and many other means of information transfer. Additional information on answering environmental horticulture questions is found in Appendix E.

Environmental Impact - EMGs have become an important link in Extension's efforts to slow pollution of the Chesapeake Bay by non-point pollution from urban runoff. Using materials developed by the Office of the State Extension Master Gardener Coordinator, EMGs educate citizens all across Virginia on proper fertilizer and pesticide management in the home landscape through the Healthy Virginia Lawns initiative.

Increasing Life Quality - Many particularly worthwhile EMG projects have been aimed at disadvantaged citizens, youth, and our aging population. Educational activities have included demonstrations of pruning and planting in low-income areas; working with the elderly to develop food gardens; working with residents to landscape a shelter for abused women; and delivering horticulture programs, such as "Ready, Set, Grow" to schools.

Community Landscaping - Extension Master Gardeners are valuable resources to Virginia communities concerned with improving the quality of life and protecting the environment through landscaping. EMGs teach the community about environmentally-sound horticulture practices by involving the community in planting and labeling trees, rejuvenating the landscapes of historic sites, and other community projects.

EMG Program Administration - EMGs have successfully acted as administrators and managers of their own EMG programs, producing newsletters, organizing training, and even continuing Extension programming in offices without a horticulture agent.

Extension Research - In recent years, EMGs have played an increasingly valuable role in Extension research efforts, working in agricultural experiment stations and at the Virginia Tech research farm, as well as participating in surveys.

Educational Efforts vs. Free Labor

Often, EMGs are asked to be **free laborers** in horticultural activities because of their training and knowledge. These types of activities, such as maintaining a public or historic garden, or designing a landscape, do not directly educate the community and are **inappropriate activities for EMGs.** There are ways, however, to accomplish these activities through educational efforts to benefit the community. The following examples offer suggestions for transforming these activities into educational projects for teaching members

of the community.

Maintaining a Public or Historic Garden (Planting, Weeding, And Watering)

EMG Educational Efforts

* If the goal of the owners of the garden is to have free labor for maintenance of an authentic historic garden or an aesthetic garden, then the proper role of the EMG as educator is to help establish a cadre of "weed-pulling volunteers," such as "Friends of the Gardens," or recruit 4-H civic clubs, etc. to do the actual garden maintenance. While an EMG may choose to become a "Friend of the Garden," hours donated don't count.
* If EMGs are given the option of planning activities to be conducted at a garden site, they should treat a public garden as an outside classroom for teaching purposes, not for gardening or beautification purposes. Appropriate audiences should be identified and events planned accordingly.
* Use a public garden site (such as historic gardens, demonstration gardens, etc.) to conduct public workshops to illustrate the essence and purpose of the garden, such as proper weed control techniques, how and why to mulch, proper plant selection, historical meaning and value of the garden, social values of a community garden, or environmental ethics.
* Use signage at the site to point out the on-going demonstration, such as an unmulched plant on the left and a mulched plant on the right. The sign or a pamphlet free for the taking should describe proper procedures for mulching, why the plants are behaving the way they are, etc.
* Bring groups of people, such as 4-Hers, to the garden to give a presentation on earth stewardship or water quality protection. Demonstrate gardening techniques that promote environmental awareness, and have a hands-on work session where the individuals are allowed to participate in the activities.
* Although some hands-on maintenance of an educational garden will be required, most of that type of effort should come in the form of educational programming. Public gardens should be used for teaching the community.

Non-EMG Activities

* Gardening for the sake of gardening. If you do not include educational components in your activities at the demonstration site, then it is simply a garden maintained by free labor and **does not count** as EMG volunteer efforts.

Designing and Installing a Landscape for the Town Square

EMG Educational Efforts

* Involve school groups, 4-H clubs, other identified groups of people in an environmentally-sound design contest, using proper design concepts as judging criteria.
* Use the design process as the subject of a weekend workshop (i.e., on water-wise landscaping practices) for homeowners. Meet again to have a workshop on proper planting techniques. Participants may gain an appreciation for economics and the social value of plants to the community.
* In time, the site can be used in an integrated pest management workshop or similar educational program.
* A garden may be installed as part of an effort to teach about personal impact and responsibility. It is especially critical that such a garden be constructed with, **NOT FOR**, the learner.

Non-EMG Activities

* Design and plant the bed as a group of EMGs

only.

* Taking on projects that are tourism-based gardens or for beautification alone. If this opportunity is not being used to teach the public, it is NOT considered educational programming/work time. Tourists walking by and observing the attractiveness of a container garden on Main Street is NOT considered educational programming (but MAY be contributed time if it meets ELC goals). In such cases, it would be better to teach an identified group, such as a civic club, and have it assist in maintaining these types of gardens.

Leading Garden Tours

EMG Educational Efforts

* Educate the public about environmentally-sound horticulture practices. For example, use a plant identification tour to teach about right plants for right places.

Non-EMG Activities

* Tour or conduct tours for the sake of looking at pretty plants.

Plant Sales

EMG Administrative Efforts/Work Time

* Have an identified purpose for raising the funds. If proceeds are for a specific event, such as building a compost demonstration site at which presentations will occur, then hours become administrative efforts/work time. Even better, the plant sale should incorporate a plant clinic or some other educational component.

Non-EMG Activities

* If the plant sale is something the EMGs do for personal enjoyment or to raise money for non-program activities (i.e., picnics or trips) with no identified purpose or outcome, then it is free labor and does not count toward EMG volunteer service hours.

Master Gardener Hosted Tour Trips

EMG Educational Efforts

* Count for educational programming when the audience is other than EMGs. For example, EMGs take a group of homeowners to Green Spring Gardens Park in Fairfax, Virginia, to view and discuss the demonstration gardens there. It is an opportunity to educate the public.

Extension Master Gardener Re-Enrollment Training

* When the Extension Master Gardener is the person being educated, these hours, if approved by the local MGC, can count toward continuing education training requirements (minimum of 8 hours annually).

Volunteer Coordination & Management

Extension Master Gardener programs cover a wide array of audiences and subject matter. In order to reach so many it is important to work as a team and have strong support. This section discusses some of the ways that EMGs work as a team and how administration and management help organize efforts.

Team Building

(Part of this section evolved from "Developing Effective and Efficient Local Committees" by Delwyn A. Dyer, Professor Emeritus an Oscar Williams, Director, Institute for Volunteer and Leadership Development, Virginia Tech).

Good leadership and structure within the EMG program will increase effectiveness, ability to accomplish goals, and credibility within the local community. Effectiveness

as a group depends on the ability to build strong teams that share in accomplishing the goals of the whole organization and the development of a system of transitional leadership.

In order to be successful, a volunteer organization, such as the Extension Master Gardener program, depends on teamwork for several reasons. First, most tasks require the expertise and energy of a group working together. No one person can do all the work alone. Second, effective team work helps build commitment and loyalty to the group. Third, being a part of a group or team fills a need for camaraderie and support, insuring that members feel needed and important to the group. Fourth, decisions made by groups tend to be more effective, well thought out, and creative than those made by one person. Team development is important, then, to group success and depends on the effort and commitment of each leader and team member.

A well-functioning team should possess the following qualities:

* A strong sense of purpose, with clear goals understood by all members.
* Good group decision-making ability.
* Mutual respect and acceptance of the contribution of each member.
* Good communication skills, including the ability to listen to the input of others.
* Clear roles. Members should understand how they fit into the group. Roles should be flexible so when the need arises, old roles can be modified to fit new situations. The roles should clearly demonstrate how they progressively lead to greater responsibility.

What is an Effective Team

Teams make up the backbone of a larger organization, serving as working groups to solve specific problems. Such groups implement the organization's programs; devise ways and means of carrying out business; in specific cases, establish policies and plans and execute the affairs of the body; and evaluate the organization's effectiveness. A team is a device for dividing into manageable components and distributing certain responsibilities and specific work of the larger group. A team is limited in the scope of the job it has to do and in its resources, that is, the finances, experiences of its membership, technical resources available, and time allotted for the completion of the task.

Purposes of Teams

Simply stated, the general purpose of teams is to assist the parent organization by taking on responsibility for and giving specific attention to certain details, problems, or concerns facing the parent body. Specifically, their purposes vary according to the specific needs for which they were created. Examples of specific needs include consideration of budgeting problems, publicity ventures, membership campaigns, and program implementation teams training of future leaders. **Whenever**

teams are appointed, their specific tasks should be clearly defined in writing.

As a local EMG program develops, increasing numbers of volunteers will become involved in many projects. This will create many additional management tasks, such as record keeping, recruitment, training, and other responsibilities. It is impossible for the local MGC, paid or volunteer, to manage all of these responsibilities single-handedly. Volunteer involvement must be organized and responsibilities delegated in order to realize the goals of the program. The best way to do this is to form teams with clearly identified goals, objectives and tasks to handle different responsibilities. Effective teams should be the most important working force of the EMG program; and they will be if team members are selected for the contributions they can make, not merely because it is their time to serve. Every member of the group should have an opportunity to serve on a team, but a member should be placed on a team in which he/she has interest or potential to make a contribution.

Creating EMG Teams

In the normal routine of an Extension Master Gardener program, there will be tasks and responsibilities relating to:

* Educational programming
* Volunteer recruitment and training
* Publicity or media involvement
* Soliciting contributions, both monetary and in-kind
* Completing evaluations of and reports on educational efforts.

It is most helpful to develop at least five teams to focus on the routine tasks: an Educational Program Team, a Recruitment and Training Team, a Public Relations Team, a Resource Development Team, and an Evaluation and Reporting Team. These teams will assist in delegating responsibilities related to managing an EMG program and will help ensure completion of projects.

As the program becomes more developed, the group may need to form other teams to meet special needs. The teams suggested here, however, are necessary to perform basic functions, as they provide a means of carrying out business in these five essential areas.

1) Educational Program Teams

Determining and planning educational efforts focused on meeting the needs of individual communities is in keeping with the mission of Virginia Cooperative Extension and will ensure the achievement of VCE and EMG program goals and objectives. Ideas extracted from a well-rounded, community-oriented committee are of vital importance in developing and directing programs toward the educational needs and wants of the local residents. There will be several different educational program teams to guide different local EMG educational programs. Initial members may be the original planning

team members who initiated the local EMG program. Over time, team composition should change to include individuals who have the ability to offer insight into educational program planning and possess the determination to ensure the success of volunteer efforts. This team, especially, should regularly communicate and work with Extension personnel to ensure that the efforts of EMGs compliment the programmatic efforts of Extension and to maximize the points of intersection of EMG interests and objectives with those of local Extension personnel.

This team will require sub-teams to manage specific programming areas. Three members of the Educational program team should serve as chair for sub-teams representing each of the three educational objectives in the Sustainable Landscape Management Plan of Work including: environmental stewardship, economic and social impacts of horticulture, and food security. The sub-teams will be composed of individuals representing educational activities in each of these areas. This structure increases communication among the various participants. **Agents from all areas in which EMGs are conducting programs should meet with this team regularly.**

2) Recruitment and Training Team

Volunteers recruited from the community in which a program/project is implemented will be the single-most important resource for the EMG program. These community members are the source of renewed energy for EMG projects and programs and also bring with them new ideas, contacts, and resources. It is important, then, that volunteers are continually brought into the program, and once recruited, they must be given proper training to be an Extension Master Gardener. One person alone cannot handle all of these tasks, especially as the program grows and more volunteers become a part of the program. For this reason, a Training and Recruitment Team needs to be formed. This team can then, as a group, decide what is the best strategy for recruiting new people from the community, developing the training program, coordinating speakers, ordering books, facilitating training classes, and other tasks related to recruitment and training of new EMGs. A team leader, or the team as a whole, should communicate regularly with the local MGC to determine what specific volunteer opportunities are available and prepare written job descriptions, such as the sample descriptions in Appendix B, before recruitment begins. This committee should also ensure that recruitment and training activities bring in appropriate volunteers for accomplishing the goals of the local group.

3) Public Relations Team

Putting the group's activities in the public eye will work wonders for the program. Increased visibility will increase community involvement in the form of volunteerism, contributions, participation

in activities, and increased awareness of issues. Media coverage is vital to the program's success. For organizational purposes, a Public Relations Team is needed to focus specifically on increasing the visibility of the accomplishments and impact of the local EMG program in the community, as well as involving the community in educational efforts. Working with the news media, creating an advertisement campaign, and making public presentations are all part of public relations. Again, these are large tasks better undertaken by a group rather than a single person, and a Public Relations Team is ideal to handle these matters.

4) Resource Development Team

To actually carry out projects and programs, materials and sometimes money will be needed. Soliciting in-kind contributions ("stuff") from local businesses is the most effective and lucrative way of obtaining the things needed to carry out the functions of the group. Even after the group has received contributions, such as office supplies, free printing services, plant material and other gardening supplies from local nurseries, free use of a public meeting room, and the like, there may still be a need for actual monetary funds for other services or materials that cannot be contributed. Fund-raising activities may need to take place. A Resource Development Team must be created to take care of these needs by soliciting contributions and raising funds, both within the community and possibly from larger foundations. Members of this team should work closely with the Evaluation and Reporting Team to ensure that contributors are properly thanked and receive follow-up and final reports.

5) Evaluation and Reporting Team

One of the most difficult tasks of an organization is to keep records of what activities were conducted, how effective they were, and their long-term impact. These records, which include facts and figures, surveys, and short anecdotes, are essential to keeping the group focused on its mission and insure that goals are met. Records are essential to motivate the membership as they demonstrate the progress being made toward a shared goal. The records are critical in getting continued support from the community and are of highest quality and are most when a team works together to develop them.

Extension Master Gardener Support

As discussed in the first section of this publication, there are numerous sources of support for EMGs within Cooperative Extension including local Extension agents, the Virginia Tech Extension Specialists, the Office of the State Extension Master Gardener Coordinator and the State Extension Master Gardener Coordinator. Master Gardener Associations are also an important resource and support organization.

Master Gardener Associations

As Virginia's EMG program grew, many graduates felt the need for an organization that could provide continuing education, communication, and social interaction with other volunteers. In the winter of 1988, an Advisory Board consisting of EMG volunteers and Extension agents was appointed to investigate the formation of such an organization. After a year of study, the Advisory Board recommended that a state EMG association be formed.

In 1990, the Virginia Master Gardener Association was incorporated. By 1993, it had achieved status as a 501(c)(3) nonprofit, tax exempt, non-stock corporation, with a mission "to foster communication, education and fellowship among those involved in the Virginia Cooperative Extension Master Gardener Program and to support and promote the Program". Membership is open to all EMGs, whether trainees, interns, or active or emeritus volunteers, and to Extension employees. Annual dues are required, and a lifetime membership is available.

The state Association is governed by a board consisting of a President, Vice President, Secretary, Treasurer, immediate past President, Chairs of all standing committees, and a representative from VCE. Members of the Association within local units or groups of units that train together select a representative to the board who attends state meetings and serves as the link to local EMG programs by reporting activities of their unit and keeping their unit advised of activities around the state.

The Virginia Master Gardener Association (VMGA)sponsors continuing education programs for EMGs during the year at various locations throughout the state. It staffs an Extension Master Gardener and horticulture booth at the State Fair and has held a state EMG conference. It offers programming suggestions for the Office of the State Master Gardener Coordinator's EMG College and, in general, serves as an informal advisory group for the state program. Through its bimonthly newsletter, VMGA Report, information about programming and activities is shared among the many local groups. A communications network has been set up to provide time-urgent information sharing and to publicize EMG activities. The Association expands and strengthens the program by offering assistance to EMG units when they need support in setting up local associations, establishing training classes for new EMGs, fund-raising, and project development. In addition to the VMGA, many local associations have been formed with similar purposes.

* **The primary role of an association is to support its members**. Appropriate activities for an association are recreational and social exchange among members; professional development by educational programs for members; and activities to make it possible for members to better reach their goals (for example, grants for attending educational events or for establishing EMG educational

programs). **Associations do not sponsor public education events.** Public educational events are sponsored by VCE and conducted by EMGs (in some cases with support from associations).

* **New EMGs are trained through VCE**. Members of associations often coordinate and participate in training of new EMGs but in doing so, they are serving in their role as a EMG not as a member of an association.
* Associations that are incorporated or so highly organized as to function as incorporated are "external" to VCE and their activities (**unless linked directly to VCE goals and approved by VCE personnel**) are not covered by VCE liability. Just as Riverbend Nursery would not be liable for issues arising from a Virginia Nursery and Landscape Association activity attended by their employees, VCE and Virginia Tech are not responsible for an association-sponsored activity. Associations that are independently incorporated are legally and financially responsible for any action that they take without documented and authorized support from VCE or VT. Questions regarding VCE/VT liability coverage should be directed to the Office of Risk Management at Virginia Tech (540) 231-7439.
* **VCE has no policy requiring all of the EMGs (in a local, regional, or state-wide area) to pay dues and join an association.** This is a personal choice and can not be used to influence their EMG volunteer involvement.

Associations can provide organizational benefits and motivation for EMGs, which are valuable in the successful and rewarding continuation of local and state-wide EMG activities. Local agents may select to use a non-incorporated or incorporated "association" model to serve as middle managers for EMG volunteers; however, it is critical that differentiation be made between the roles of the association and the roles of VCE and the EMG teams.

Summary

Welcome to VCE Master Gardenering provides an overview of the Extension Master Gardener Program. Additional program information is available on the EMG website, http://blogs.lt.vt.edu/mastergardener/, the VCE Intranet at http://www.intra.ext.vt.edu/anr/horticulture/environmental/mastergard/index.html or by contacting your local MGC or the State Extension Master Gardener Coordinator with questions.

The Extension Master Gardener Program provides volunteers with an opportunity to perform a valuable service to the community and environment and to receive instruction and training in horticulture. The partnership between VCE and EMGs continues to grow and bloom through increased participation and expansion of programming. The challenge of educating the public about sustainable landscape management is tremendous but accomplishable through dedicated work and the EMG team spirit.

Appendix A

VCE Administration Information

Senior District Director
Lonnie Johnson, Jr.
VT/UVA Richmond Center
2810 N. Parham Rd, Suite 300
Richmond, VA 23294
(804) 527-4251
lojohns2@vt.edu

Virginia's Four Districts

District	Central District	Northern District	Southeast District	Southwest District
Physical Address	Charles R. Hawkins Research Center 230 Slayton Ave Danville, VA 24540	Virginia Cooperative Extension Northern District Office 2322 Blue Stone Hills Drive Suite 140 Harrisonburg, VA 22801	Virginia State University Douglas Wilder Building, Suite 109 Petersburg, VA 23806	One Partnership Circle, Suite 126 Southwest Virginia Higher Education Center Abingdon, VA 24210
Mailing Address	VCE-Central District Office 150B Slayton Ave Danville, VA 24540	same as above	VCE-Southeast District Office P.O. Box 9400 Petersburg, VA 23806	VCE-Southwest District Office P.O. Box 1955 Abingdon, VA 24212-1955
Phone Number	434-766-6761	540-432-6029	804-524-5465	276-619-4330
Localities Served	Counties of Amelia, Amherst, Appomattox, Bedford, Brunswick, Buckingham, Campbell, Charlotte, Cumberland, Dinwiddie, Franklin, Goochland, Greensville, Halifax, Henry, Lunenburg, Mecklenburg, Nelson, Nottoway, Patrick, Pittsylvania, Powhatan, and Prince Edward; and the Cities of Danville, Lynchburg, and Martinsville	Counties of Albemarle, Alexandria, Arlington, Augusta, Bath, Caroline, Clarke, Culpeper, Fairfax, Fauquier, Fluvanna, Frederick, Greene, Highland, King George, Loudon, Louisa, Madison, Orange, Page, Prince William, Rappahannock, Rockbridge, Shenandoah, Spotsylvania, Stafford, and Warren	Counties of Accomack, Charles City, Chesapeake, Chesterfield, Essex, Gloucester, Hanover, Henrico, Isle of Wight, James City, King & Queen, King William, Lancaster, Mathews, Middlesex, New Kent, Northampton, Northumberland, Prince George, Richmond, Southampton, Surry, Sussex, Westmoreland, and York. And the cities of Hampton, Newport News, Norfolk, Petersburg, Portsmouth, Richmond, Suffolk, and Virginia Beach)	Counties of Alleghany, Bland, Botetourt, Buchanan, Carroll, Craig, Dickenson, Floyd, Giles, Grayson, Lee, Montgomery, Pulaski, Roanoke, Russell, Scott, Smyth, Tazewell, Washington, Wise, and Wythe

Note: The most current directory information can be located on the internet at http://www.ext.vt.edu/offices/index.html

Virginia Cooperative Extension

Virginia Tech • Virginia State University

Publication VCE-231NP
Revised January 2015

Land Grant Universities: Virginia Tech, Virginia State

District Offices

Unit Offices

Agricultural Research & Extension Centers (ARECs)

1-Shenandoah Valley 2-Alson H. Smith, Jr. 3-Middleburg
4-Eastern Virginia 5-Eastern Shore 6-Southwest Virginia
7-Reynolds Homestead Forest Resources 8-Southern Piedmont
9-Tidewater 10-Hampton Roads 11-Virginia Seafood

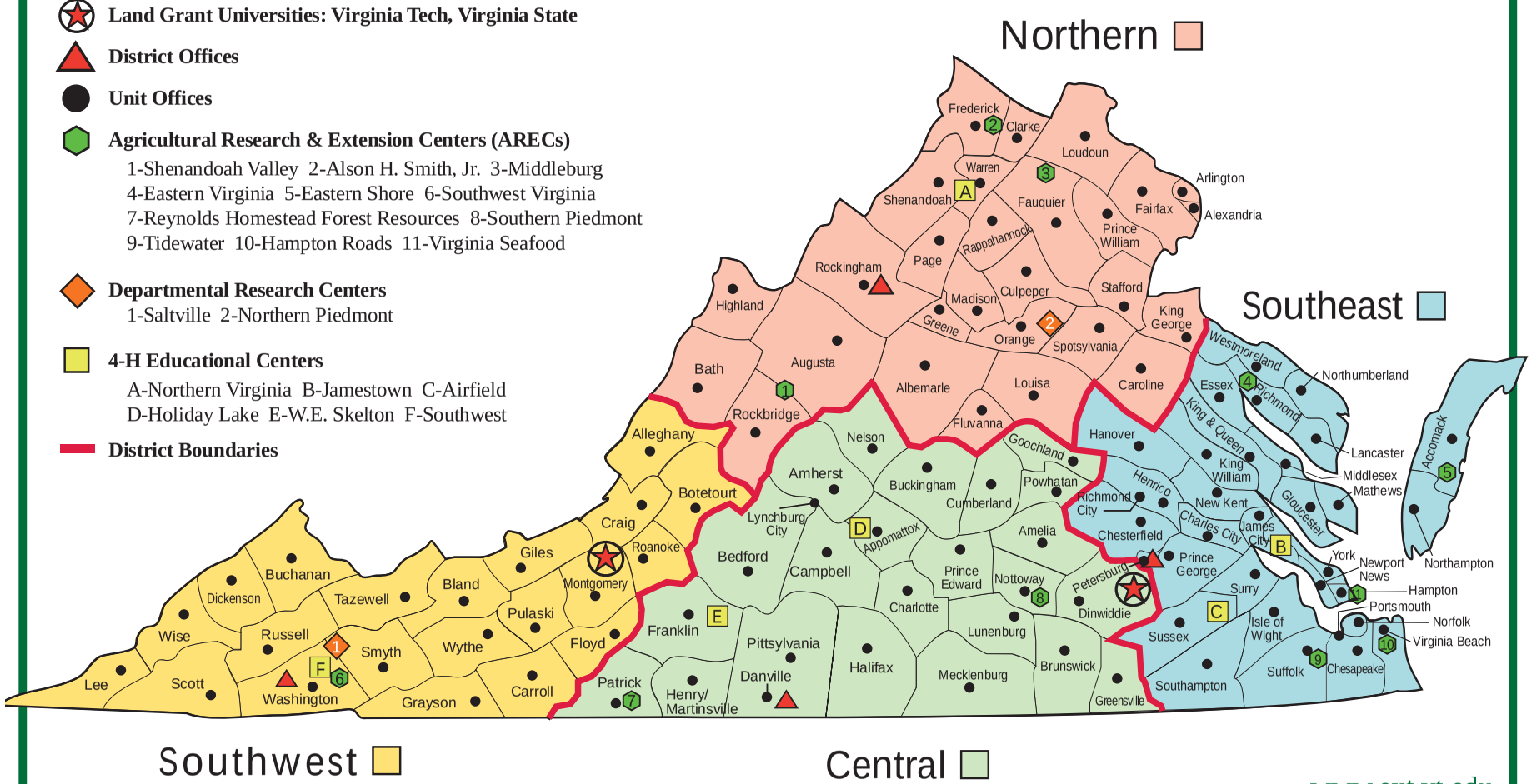
Departmental Research Centers

1-Saltville 2-Northern Piedmont

4-H Educational Centers

A-Northern Virginia B-Jamestown C-Airfield
D-Holiday Lake E-W.E. Skelton F-Southwest

District Boundaries



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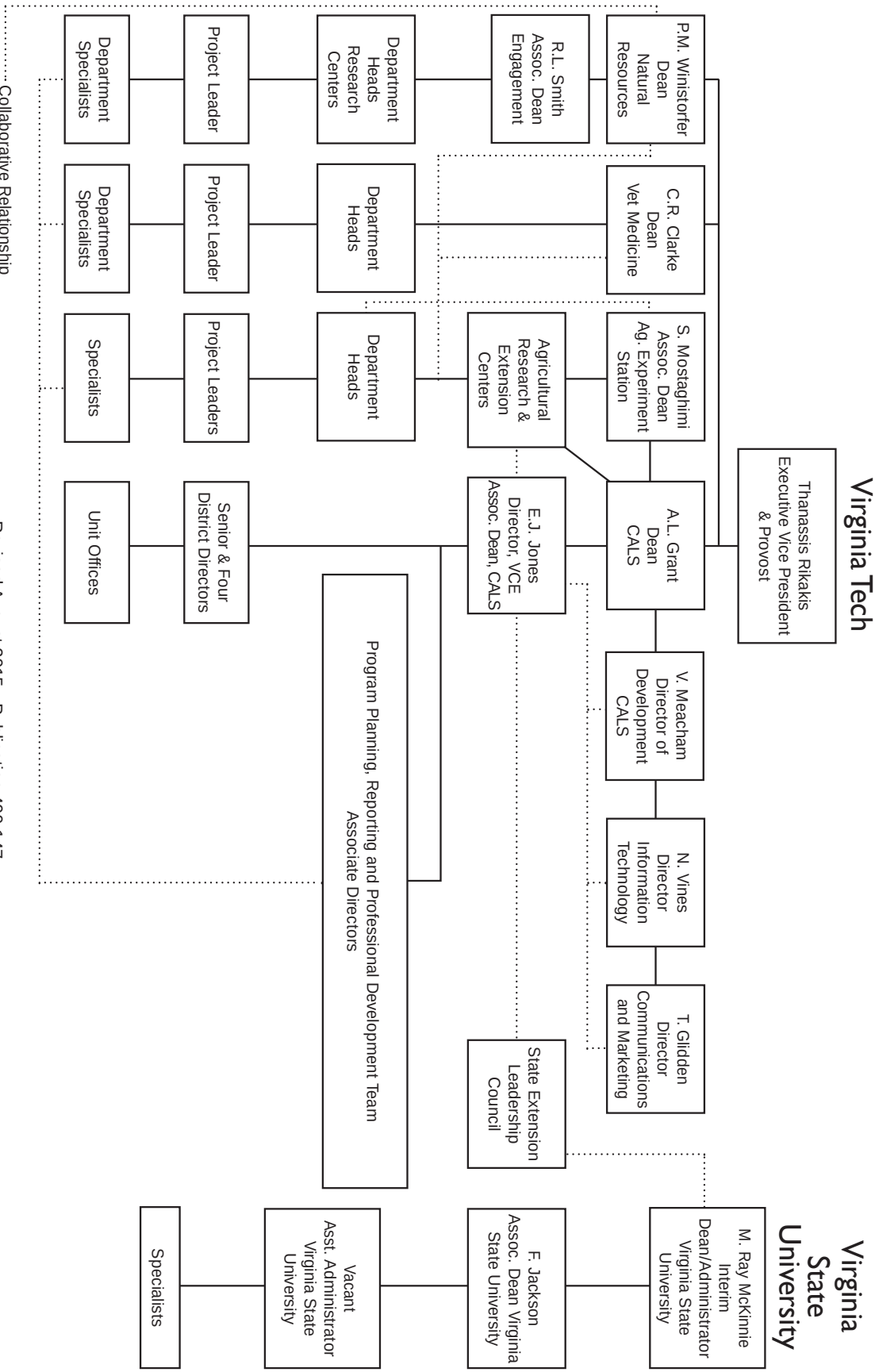
Virginia Cooperative Extension

Virginia Tech • Virginia State University



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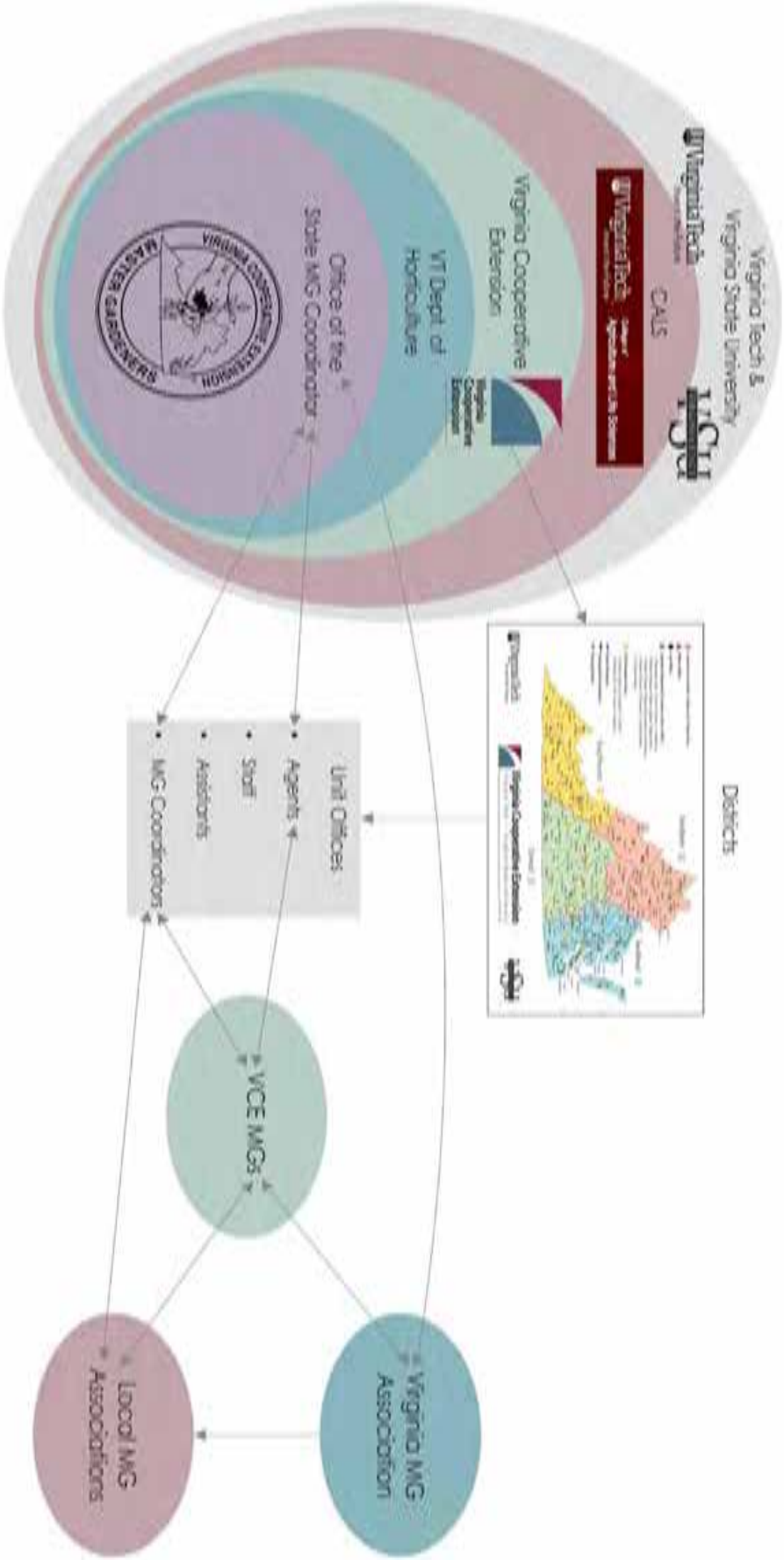
Organization of VCE & MGs



Appendix B

Sample Job Descriptions

Job Title: Volunteer Extension Master Gardener Coordinator Appointed by VCE Agent or VCE District Director

Location: At home and/or extension office

Duties: Set the positive standard for expectation and achievement among EMG volunteers. Meet regularly with the basic organizational teams (Educational Program Team(s), Recruitment and Training Team, Public Relations Team, Resource Development Team, and Evaluation and Reporting Team) to delegate responsibilities related to managing an EMG program and ensure that program activities are achieved and meet local needs and keep with the mission and goals of VCE. Attend periodic coordinator training opportunities available through the Office of the State Extension Master Gardener Coordinator, Virginia Tech. Train incoming volunteer EMG coordinator.

Reporting time and duration: The coordinator is responsible for regularly communicating with the local Extension office to ensure Extension awareness and approval of EMG activities. The coordinator will oversee reporting of EMG accomplishments to the local Extension Agent and to the State Extension Master Gardener Coordinator as requested to document local accomplishments and impacts. Oversee report of EMG activities, accomplishments, and impacts to the Extension office for inclusion in the annual Extension report.

Expected results: The coordinator is expected to facilitate the local Extension Master Gardener program so that it meets the needs of the local community in keeping with the mission and goals of VCE. The local MGC also acts as a liaison between the Office of the State Extension Master Gardener Program and the local program.

Resources: Educational Program Team(s), Recruitment and Training Team, Public Relations Team, Resource Development Team, and Evaluation and Reporting Team. Periodic coordinator training offered through the Office of the State Extension Master Gardener Coordinator,Virginia Tech. *VCE Master Gardener Coordinator Manual, Policies for the Virginia Master Gardener Program*, *VCE Master Gardener Program Management Guidelines*.

Job Title: Plant Clinic Staff

Location: Libraries, Recreation centers, Shopping centers, Extension offices, County/State fair, Other appropriate locations

Duties: EMGs will be available at prearranged sites and times to examine and diagnose plant specimens and problems brought in by citizens and make recommendations in compliance with Extension recommendations and approved practices.

* Form a plant clinic group/committee, and elect a chairman who will coordinate activities.
* Work with local MGC or Extension agent(s) to establish regular sites for plant clinics.
* Establish the frequency of plant clinics and the number of hours EMGs are to spend at the clinic.
* Determine suitability of fees for clinics conducted at business sites (i.e., for every EMG hour spent in plant clinics at Lowe's, $7 is donated to the local association fund, and in turn, funds are used to support a local school gardening grant program).
* Work with Extension staff, local MGC, and EMG graphic artist to create plant clinic promotional materials.
* Keep records of all clients seen, problems diagnosed, and recommendations given.
* Forward to Extension agent(s) any materials that EMGs cannot diagnose.
* Assist with setup and take-down as well as with staffing plant clinics.

Reporting time and duration: Extension Master Gardeners will conduct plant clinics at specified frequencies, at designated locations and report time spent on clinic work to the Evaluation and Reporting Team.

Expected results: Residents will receive help with horticultural problems and volunteers will increase their knowledge of insect pests, diseases, cultural problems and *diagnostic techniques.*

Resources: The *Virginia Master Gardener Handbook*, VCE Web pages (http://www.ext.vt.edu), current Pest Management Guide

Job Title: Compost Team Member

Location: Compost site, Extension office

Duties: Work with the compost team coordinator to provide the public with educational lectures and demonstrations about general compost practices at the compost site and other locations, as needed. Provide materials as requested by the Extension office for demonstration purposes. Assist the compost team coordinator in recruiting and scheduling community volunteers to turn, water, and add materials to compost bins, as needed. Participate in team meetings for planning, evaluating, and reporting. Assist the coordinator in training incoming compost team members.

Reporting time and duration: Provide monthly progress reports to compost team coordinator. Compost site to be maintained from early spring to late fall. EMG composting team should meet regularly as necessary throughout the year for planning, reporting, and evaluating.

Expected results: The EMG compost team members should use the compost site as a teaching facility and ensure that community volunteers are active in the maintenance of the site. The site should be maintained in a manner that will provide the public with "how to" knowledge of composting by viewing the bins outside of regularly scheduled educational programs and demonstrations at the site.

Resources: Public library reference materials, Extension reference materials, *Virginia Master Gardener Handbook,* Advanced Master Gardener--Yardwaste Manager Handbook, VCE web site (http://www.ext.vt.edu).

Job Title: EMG Volunteer for 4-H Garden Project

Location: Extension office, Classroom, Gardens

Duties: Work as volunteer for the 4-H Garden Project. Participate in training for all 4-H garden volunteers. Work with past EMGs to provide training for the new volunteers, if needed. Coordinate activities with the 4-H Extension agent and/or 4-H office. Contact appropriate 4-H volunteers for resolutions of problems, if any. Procure all necessary materials for the 4-H garden project portion involved with horticulture. Report activities, accomplishments, and impacts to the local MGC and the 4-H Extension agent for inclusion in the annual Extension report.

Reporting time and duration: The 4-H Garden Project EMGs are to report to the 4-H Extension agent or other identified coordinator on a weekly basis and to the Evaluation and Reporting Team while the project is ongoing. Projects may vary in duration.

Expected results: Involve as many children as possible in horticulture activities to enable children to learn and experience the joy of growing plants. Help children apply that knowledge to improve their homes and communities.

Resources: Virginia Master Gardener Handbook; 4-H materials from the 4-H office and Extension office; 4-H guidance sheet from the Extension office.

Other Job Titles

Other job titles may include:

* Community Landscape Project Coordinator
* County Fair Project Coordinator
* Horticultural News Writer
* Demonstration Garden Coordinator
* Community Garden Coordinator
* Compost Demonstration Coordinator

Appendix C

Reporting System

Keeping track of EMG volunteers, projects and hours is very important for communication and for accountability. This information can be used to justify programming and aid in grant applications. The VCE State Volunteer Management System (VMS) was developed to standardize reporting information and help keep up with volunteers and volunteer service. A screen shot of the time entry log is given on the next page. Volunteer hours must be entered into VMS or they will not apply to the individual EMGs service records nor for the local VCE unit accomplishments. A record keeper may be appointed by the local EMG coordinator to keep track of the records as they are entered into the system and to enter data for EMGs who do not have internet access. Remember to keep track of all the details not only to insure recognition of accomplishments but also to serve as a resource for future projects. Consult the VMS User's Guide for more information.

Data Required for Adding Hours (to be completed by individual EMGs on VMS):

Event Description: Enter something to relate to the specific project the report applies to

Event Date: Enter the date the volunteer activity occurred, enter each date separately

Apply to Project: Select the specific EMG approved project from the drop-down menu

Miles Driven: Enter round-trip mileage, do not enter if individual did not drive

Volunteer Hours: Enter hours of volunteer service performed on this project, this applies to hours earned where the EMG was teaching or supporting other EMGs or Extension personnel in providing an education program to others

Continuing Education: Enter on CE hours if the EMG was one who was learning form this project

Population Served:

Enter contacts divided into the demographics provided as accurately as possible

To prevent duplication, only one individual should enter contacts for each project

Add Volunteer Hours For Jane Smith

Event Description	
Event Date	
Apply to Project	Select a Project REQUIRED
Miles Driven	0
Volunteer Hours	0
Continuing Education	0

Population Served

Contact Ethnicity	Male Adult	Male Youth	Female Adult	Female Youth
White				
Black				
American Indian				
Hispanic				
Asian				
Hawaiian / Pacific Islander				
Unknown				

Save Hours

Appendix D

VCE Pesticide Policy Statement, #93-001

Extension Pesticide Policy Involving EMGS

Extension programs involving the use of pesticides or advising the public on the use of pesticides carry high liability for the VCE Service, Virginia Tech, Virginia State,
local government, and the Commonwealth. Pesticide policy statements have been written for the purpose of protecting these organizations as well as the faculty, staff, and volunteers working under the umbrella of VCE. This statement has been written with the intent of preventing pesticide misuse or misinformation and protecting the public from potential harm associated with these mistakes.

Extension Master Gardeners are defined as volunteer Extension representatives who work with environmental horticulture and urban agricultural programs in the local Extension units. EMGs come under this policy because they often provide recommendations for the use of chemical controls for pests of plants. They might also be involved in pest control in local demonstration plots and exhibits. This policy statement addresses volunteers who provide information involving chemical pest control recommendations and those who use pesticides.

Insurance Coverage for EMG Activities

Extension Master Gardeners are covered under the Commonwealth of Virginia self-insurance program as authorized by Section 2.1-526.8 of the Code of Virginia which is based on a comprehensive general liability manuscript policy form. This insurance program covers employees and volunteers while participating as an Extension Master Gardener.

EMGs are **not** covered under this insurance for pesticide use or pest control recommendations conducted outside of VCE programs. For example, if EMGs misuse pesticides as part of their personal activities, they are not covered under the liability insurance of the Commonwealth. If EMGs are involved in a business that provides similar services, such as pest control or lawn care, they are expected to cover this form of liability under their business liability insurance.

EMGs Providing Chemical Pest Control Recommendations

EMGs providing chemical pest control recommendations must adhere to the printed recommendations provided by the pest control specialists at Virginia Tech and published as the *Pest Management Guide for Home Grounds and Animals* (PMG). This

guide is printed every year with updates provided by the authors between printings as necessary. EMGs are **not** permitted to provide recommendations to other groups, such as agricultural producers, nor are they permitted to use non-homeowner PMGs for recommendations to any group.

Although there are many other sources of pesticide recommendations available, many are proprietary in nature (i.e., company literature, the *Ortho Problem Solver*™, etc.) and should **not** be used as a replacement for the PMG. They can be used as a reference, but any official recommendation to the public **must** come from the PMG.

Extension Master Gardeners must be instructed by VCE personnel or other EMG leaders on how to use the PMG. Its use should not involve changing or adding to the chemical pest control recommendations in any way. It is permissible to provide advice and personal knowledge as long as it does not involve a change in the chemical recommendation. The recommendation of non-chemical alternatives is permitted as long as it is cleared with a local Extension agent. Also, EMGs must be provided with training on pesticide safety and pest control as outlined in the *Virginia Master Gardener Handbook*.

Many EMGs have decided to become certified as private applicators. This certificate is legal for personal use, but according to federal and state pesticide law is not appropriate for use by EMGs *in their roles as volunteer staff of VCE*. This does not imply that Extension agents cannot assist their Extension Master Gardeners in becoming certified as private applicators. However, the private applicator certificate is established only for those using restricted-use pesticides and in the business of raising agricultural commodities. It is presently the position of the Virginia Department of Agriculture and Consumer Services that EMGs are not required to be certified under their present capacity as volunteers. VCE concurs with this position.

EMGs Applying Pesticides as Part of Their Volunteer Activities

It is possible that some EMGs are involved in the application of pesticides in demonstration plots or exhibits as part of their volunteer activities. In these cases, they are required to be certified as either registered technicians or commercial pesticide applicators as required by the Virginia Pesticide Control Act. They are certified in a category of applicators associated with their activities [most likely Ornamental Pest Control - Outdoor (Category 3A), Ornamental Pest Control - Indoor (Category 3B), and/or Turf Pest Control (Category 3C)]. New applicators are required to start as registered technicians until they accumulate one year in service. The registered

technician requirement involves a minimum of 40 hours of on-the-job training before they can take the registered technician exam. After this experience, they can remain registered technicians, or they may take the category exams to become a commercial applicator. Only persons with one year's experience as a registered technician or equivalent experience or training can become a commercial applicator. After receiving their certificates, all certified applicators must recertify every two years by accumulating credits gained from attending approved training courses.

This process of certification can be very burdensome for volunteers. The process is not as simple as it was several years ago. Most Extension agents and EMGs will find that it is not worth the trouble associated with these requirements to get involved in the application of pesticides as a EMG activity. It is best that these activities be left to VCE technicians, agents, and other VCE employees who are already certified to apply pesticides under the laws of the Commonwealth. If an EMG is not a certified pesticide applicator, then he or she should not apply pesticides in the role of an EMG.

Further Clarification

Since this policy is a complicated one, there may be the need for further clarification. For more information, EMGs should contact their local MGCs or Environmental Horticulture Extension agents. If further clarification is needed, agents should contact the person listed below:

Dr. Michael J. Weaver
Director, Virginia Tech Pesticide Programs
302 Agnew Hall (0409)
Blacksburg, VA 24061
mweaver@vt.edu
(540) 231-6543

Appendix E: Communication

Keys to Successful Implementation

Diagnosing Plant Problems

As an EMG, you will work with many types of people. These people will be coming to you with questions and problems concerning horticulture. In order to fully understand the client's problem and suggest a solution to that problem, you must be able to communicate effectively. This can be a challenge, since the object of discussion, the client's garden or plant, is often not present, and you must deduce the problem from a

verbal description of the trouble.

Effective communication is not just a matter of speaking clearly and listening closely. As you listen to a client's description of his ailing indoor plant, you are trying to understand a situation that you have not experienced. It is very easy to leave out details when we describe something that is familiar. The client may not know that the color of the leaf edges or the proximity of heating ducts to the plant are important clues to the plant's problem. You can improve communication by asking questions.

By thinking of all the possible symptoms and conditions that might match up with the described ailing plant, you can pose questions that should yield enough information to find the solution. It is a good idea to summarize your findings and present them to the client. Don't be afraid to say something like, "I am going to describe, in my own words, the condition of your plant as I understand it. Stop me if I have it wrong." After all, we are not talking books - we're all merely human, and what we mean and what we say are not always the same. Being human, we have ways of interpreting meaning from voice changes, gestures, facial expressions, and general body language, as well as words. The important point is to express our own understanding so the client can compare it with his knowledge of the situation.

There is a stumbling block to communication other than incomplete information from the client - the EMG's horticultural expertise. This can be a problem in at least two ways. The volunteer can know so much about a topic that he or she does not bother to listen to everything the client has to say. Or, the problem may be identified and possible solutions discovered, but the EMG cannot describe necessary procedures in terms the client can understand. Germination, propagation, and fertilization are all very nice terms, but they are quite useless if they draw blank looks. There is nothing wrong with basic, down-to-earth terms like grow, dig, and water - go ahead and use them.

Remember, no one knows everything. As an EMG, you know a great deal about horticulture, but remember that one of the most important things you know is how to find answers. In your work at plant clinics or at the Extension office phone, you will have access to excellent resource material. If your client's problem is too complex to readily solve with your knowledge and the aid of the resource material, take the person's name, address, and phone number, then find the time to answer the question thoroughly or see that it is answered by the Extension agent or a specialist.

Using the Telephone

When working with clients by telephone, communication can be even more difficult because there are no visual clues to meaning. Listen carefully, and ask many questions. Be sure to familiarize yourself with the office procedures for telephone use. Your local MGC or someone on the staff should be able to provide you with such information as what to say when answering the phone and how to log calls.

Every time you make or receive a telephone call as an EMG, you are representing VCE. The impression you create can be a lasting one and may determine whether or not the person you are speaking with will continue to turn to Extension for assistance.

When the telephone rings, answer promptly - quick service helps build a reputation of efficiency. Identify yourself - it helps personalize the call and gets the conversation off to a good start. Be friendly by being a good listener so the caller will not have to repeat what is said. Be considerate by not carrying on two conversations at once. Callers should not be made to feel they are competing with people in the office for your attention.

Sound as good as you are. Show that you are wide awake and ready to help the person on the line. Use simple, straightforward language. Avoid technical terms and slang. Speak directly into the telephone, pronouncing words clearly. Talk at a moderate rate and volume, but vary the tone of your voice.

When you must leave the line to obtain information for the caller, it is courteous to ask, “Will you wait? Or shall I call you back?” If the person chooses to stay on the line, use the hold button (if your telephone has one) or lay the receiver down gently. Should it take longer than you expected to gather material, return to the line every 30 seconds or so to assure the caller you’re working on the request. When you have the information, thank the caller for waiting. Transfer a call only when necessary, but if you must, explain why you’re connecting the caller with someone else. Be sure the caller wants to be transferred.

If he/she does not, offer to have someone call back.

When answering for someone else, be tactful. Comments such as “He hasn’t come in yet” or “She’s just stepped out for coffee” can give the wrong impression. It’s better to say “Mr. Jones is away from his desk right now. May I ask him to call you?” When you take a message, be sure to write down the name, time, date, and telephone number. Don’t hesitate to ask the individual to spell his name or repeat his number. Put your name on the message in case there are additional questions before the call is returned.

You will occasionally speak with a caller who may be having a bad day and takes it out on you. Remain calm, and don't take the comments personally. As long as you are trying, in a courteous manner, to help a caller, you are doing your job. Retain your sense of humor and give the caller your sincere attention.

Because people are calling you for information, you need to know how to utilize Extension publications on horticulture. Printed material is recognized as a means of saving the time of county staff members and specialists. However, publications should not be treated as free products. Find out what the office's policy is on publications and how conservative you need to be in their distribution. Ordering and distribution of Extension publications are now computerized, and supplies can be obtained quickly.

Writing Tips

Extension Master Gardeners have plenty of opportunity to use writing skills. Some EMGs help produce publications for local gardening needs, others prepare scripts for presentations, and some write newsletters and columns for the local newspaper. Timely horticultural information is available to you for news releases and columns. This information is stored on Virginia Tech's web site (http://www.ext.vt.edu) and is easily accessed with the Extension office's computer terminal. The section on using the computer explains how to obtain this material.

Organization and simplicity help you achieve a well-written product. A great deal of time and crumpled paper can be saved by starting with a clearly defined purpose and outline. An easy way to understand the purpose of your writing is to create the title. A good title tells, in a few words, what the subject of the work is. "All about Grapes" indicates a great deal of material is going to be covered: history, varieties, culture, and uses of the fruit. If you are only writing about the culture or the pruning, say so. Do not mislead the audience. Once the title is written, you know how you should limit the topic and what should be covered. The roughest outline is better than none, and its bare-bones structure makes it easy to see the logic of the work you are about to create. It is much easier to repair holes in the logic at the outline stage than later, when hard-won paragraphs or even pages may have to be removed. It's a lot like pruning - easier done when there are no leaves on the tree. Make an outline after the topic has been captured in a title.

After the title and outline are complete, the writing can proceed. Address each topic on the outline, and soon the job will be finished. Remember to include a topic sentence for each paragraph. Explain each topic on the outline and back up what you say with

information from professionals. If you really get stuck, examine the idea you are trying to express. Perhaps there is nothing more to say about it than the sentence that is already there. Perhaps it is irrelevant or misplaced in the outline. If all else fails, put the work aside and take a break. A change of scenery and a little time away from the words can do wonders for clearing the head. When you come back to the work, the problem may be perfectly clear and the solution obvious.

Simplicity is essential to clear writing. Even though vague phrases invade business letters, newswriting, television, and radio, there is no need to promote the trend. For instance, "We would like for you to stop by our office" can be replaced with "Please come into our office." The same message is conveyed with greater clarity using half as many words. If you find yourself struggling over a choice of words, try telling someone what you want to say. As you say it, listen to yourself because you are probably using the words you need to write the same explanation. Avoid slang, jargon, and flowery or obscure vocabulary. You won't go wrong with the simplest English words used correctly. The goal of good writing is to communicate, not to confuse.

An interesting sentence carries a strong verb and few adjectives. If you must shorten a piece of writing, you can sacrifice adjectives and gain simplicity along with space. Articles (a, an, the) are often unnecessary. Some languages do not have articles at all; we can probably do without some of ours.

Perhaps the most common misunderstanding about writing is that it will be easy. While it is true that some people are more adept at writing than others, those who write well usually admit that it takes work. Just as good gardeners must get their hands dirty, good writers spend hours rewriting and use dictionaries and grammar books constantly. They are not looking up words you've never heard of either. They are checking the actual meaning of "cultivate" or whether or not there is a hyphen in "damping-off." Make sure there is a good dictionary in the office and **use** it.

Sometimes new publications need to be produced or existing ones adapted for local conditions. If the agent you are working with decides you can develop new materials for distribution, check office files for old publications and/or write the appropriate specialist. Some already available materials may only need slight modification. Remember that proper letterheads and indicia are necessary on all materials sent out via franking privileges. After the publication is complete, send copies to appropriate specialists at the Horticulture Department at Virginia Tech and Virginia State University so they may be shared with other units.

When producing new materials from old, be certain not to infringe upon a copyright. Most Extension materials are not copyrighted and may be used for Extension purposes. If you want to use copyrighted material or even parts of that material (this includes art work) written permission must be obtained from the publisher and often from the author or artist as well. A very useful publication for EMGs is the *Media Handbook for Volunteer Groups*, Extension publication 478-002. It contains helpful information about the media and how to deal with people in that business, as well as examples of press releases and public service announcements.

Public Presentations

Because Extension provides information and educates the community, you will have plenty of opportunity to appear before the public in your capacity as a EMG, if you so desire. Not only do EMGs meet the public at plant clinics, but many become so knowledgeable about a specific horticultural interest that they are also invited to give talks to clubs and groups. This is a wonderful way to help Extension, as agents are often in demand for such talks. Agents and EMGs are also called upon to provide workshops, demonstrations, and tours.

Most public presentations have four components: title, introduction, body, and summary. The title should be short, descriptive, and interest-catching, but most of all, it should tell what the subject is. The introduction tells the audience who you are and elaborates on the goal/content of the talk. This part of the presentation is often the key to success or failure as it sets the tone for the remainder of the program and should "hook" the interest of the audience. The body of the presentation contains the substance and should satisfy the curiosity that brought the audience to the presentation. Use research supported information, and cite references whenever possible. The summary states the major points of the presentation in a logical sequence without details. This part should be short and clear. Following a presentation, be prepared to answer questions. Repeat questions for the audience when they are difficult to hear or understand, then answer them.

Public presentations take preparation to be successful. Don't be fooled by a casual delivery. Many people who appear to be relaxed and able to effortlessly speak before groups have actually spent many hours achieving this effect by preparing and practicing.

To plan a presentation consider:

* Who the audience is

* Their general knowledge of the subject
* How technical the subject is
* Timeliness
* Appropriateness
* Purpose
* Materials
* Length of presentation

After collecting materials, studying, and reviewing notes, REHEARSE. Observe these points carefully during rehearsal:

* Ensure that all charts, graphs, and posters are easy to see and read
* Ensure that the audience can hear you from anywhere in the room
* Arrange the materials used in the demonstration so that they are accessible and easy to reach without fumbling and delay
* Do not make unnecessary apologies. Avoid saying "This is the first time I've done this," or "I'm not used to speaking before groups."
* Do the best job you can. The audience doesn't expect you to be perfect, and you are probably much better than you think you are.

If you are giving a demonstration with another person, are the delivery and action coordinated or does one team member do so much that the other's participation seems unnecessary?

Developing an Exhibit

If you are preparing an exhibit for public presentation here are some basic concepts to keep in mind when planning and setting it up:

* Choose one idea that can be explained in a simple, catchy statement. Use few printed words.
* Have a single center of interest to which the eye is drawn.
* Develop the story completely using as few items as possible. Clutter is not good for an exhibit.
* Create a design that is orderly, interesting, and artistic.
* Attract attention with movement, color, light, sound, or a clever title and attractive design, but not with all of these.
* Make sure that charts, posters, and other visuals are attractive, neat, clean, and easy to read.
* Judge exhibit by asking if it attracts attention, arouses interest, conveys a message, is well constructed for a neat and orderly appearance.
* Select people to tend exhibits who are well informed, can meet the public easily, and create a

favorable impression.

Advertising public presentations is very important. Too often, well-prepared programs fail to reach a large audience due to lack of adequate advertising. Word of mouth is not sufficient. Public events can be announced in newsletters, newspaper feature articles or regular columns, paid advertisements, radio or television public service announcements, and on posters displayed in appropriate locations. Sometimes it is helpful to find a local sponsor, such as a shopping center, a bank, or the chamber of commerce, to assist in financing and advertising an event. Be certain that all arrangements with sponsors are clearly defined and responsibilities are agreed upon ahead of time. When advertising outdoor events, such as garden tours or community garden walk-throughs, where no indoor facilities are available, include an alternative time and date in case of bad weather.

Preregistration can serve as an indicator of expected attendance. Some agents report good response for workshops that require prepayment of minimal fees to cover costs of materials. Participants appear to be more motivated and interested after making a financial commitment.

Radio and Television

Extension agents and EMGs have been presenting educational radio and television programs for many years. If you have interest or experience in this area, you might want to volunteer to do a program or to work on the production of a program. Before producing a radio or television program, remember that while you will reach a large audience with one presentation, you will also increase demand for information from the Extension office as new people become aware of its existence.

First, let's look at radio program production. Before approaching a radio station with your ideas, consider the identity of the audience you want to reach. What is their age, sex, and marital status? Are they renters or homeowners? What time of day are they likely to listen to the radio for information? Radio stations know who their listeners are and what they like. Find the best station for your information by matching your audience with the radio station they are most likely to hear.

Maximum impact can be obtained by a different program each day in the same time slot. People can then habitually tune in to find out what gardening tips you are offering. Plan a message approximately 30 seconds to 3 minutes in length. Longer messages cause listeners to lose interest.

Make a list of proposed topics and review with a local Extension agent to identify questions and concerns that might result. When doing a radio program as an EMG, utilize educational subject matter content, not opinion or editorial comments.

After identifying the audience and preparing the program, make arrangements to meet with the program director at the station you have chosen. Take one or two sample programs with you. Some stations prefer to use their own personnel to prerecord messages from a script you have prepared. Others choose to have you record the message using their facilities. Beware of the live call-in or talk show format. These can lead to drawn out and uninteresting rambling sessions and can put the person with the answers on the spot if the question is unclear or controversial. Plan to record one or two weeks worth of programs at each visit to the studio.

Whatever the format, the message should be clear and concise.

* Use common English and simple sentence structure.
* Keep stories or examples to a minimum, using them only to emphasize or clarify a point.
* Short (30 seconds to 3 minutes) time slots should address only one topic.
* Radio presentations are usually one-way conversations and are most effective when delivered in a somewhat conversational manner. Ad-libbing from a carefully prepared set of notes comes across better than reading from a script.
* Speak clearly, emphasizing important points. Avoid talking fast. Even in a short message, main points and especially control recommendations need to be repeated or else summarized at the end.
* Provide a means for obtaining additional information. This may increase the office work load, but it also increases the audience you are reaching. However, it is not a good idea to offer specific publications on the radio. The demand may exceed the supply and the station is often picked up in other counties or states.

Television broadcasts need to be well prepared in advance, as do radio programs. However, the added visual dimension of the medium must be taken into consideration. Be certain the material you are presenting is best for television, i.e., it can be made visually informative or entertaining. Demonstrations are good for television. Television is good when visual examples are useful: healthy versus diseased plants, characteristic markings on insects, variety of color or petal shape in flowers. Find out ahead of time if the station can and will use your slides, films, or video tapes. Before you get to the studio:

* Outline the material in a script. It does not have to be a word for word account, but should be in

logical order and contain all the points you want to make.

* Approach script writing as a story telling experience. Tell an interesting and informative story.
* As always, use simple English words correctly. Avoid slang and jargon.
* Scripts should be like public presentations made in person, with a title, introduction, body, and summary.
* Use only the visuals that help tell the story, and eliminate the others.
* Avoid detail in graphs and charts.
* Prepare parts of the demonstration ahead of time if necessary.
* Obtain necessary media releases for photos and music.
* Rehearse in front of a mirror: check timing, eliminate any bad habits (headbobbing, frowning, fidgeting).
* Watch out for bad verbal habits (using too many ahs, ums, or oks), and eliminate them.

A relaxed appearance is best, so wear appropriate but comfortable clothing. A brand-new outfit is not the best idea; you may find yourself uncomfortable and begin to adjust your clothing or look unhappy. Avoid white, plaids, bright colors, shiny fabrics, and bold patterns. Noisy or shiny jewelry can distract viewers from the material you are presenting. A fresh hairstyle or cut can look unnatural. Ask the television station personnel for additional tips on dress and makeup. Don't feel embarrassed about this admitted concern for your appearance. Television is a visual medium, and the way you look is an important part of a successful production.

When you get to the studio, go over the script with the director. Decide on cues and positions and make a final check to be certain your slides and graphics are in order. A quick run-through will reveal any upside-down or backward images.

During the filming, speak in a natural tone. Relax. Imagine you are talking to a person just a few feet away. Maintain eye contact with the camera, unless advised otherwise. If you make an error, correct it naturally and without fuss. Just as in live presentations, don't apologize. Tell the viewers of other ways to obtain information on your subject. Most of all, enjoy the experience.

Using the Computer

Computers are essential for educational communication in today's society. Computers are important tools to answer questions and find information. If you would like to use the computer to do volunteer work and have or would like to develop computer skills,

the Extension office is equipped with the hardware, software, and materials you need to do the job. Every unit office in Virginia has a computer with access to information on the internet. The internet has a wealth of consumer/environmental horticulture information. VCE maintains a web page (http://www.ext.vt.edu) to assist EMGs in answering horticulture questions which includes almost all Extension publications. This material is easily accessed and can be printed for local use. Please see Appendix F for a listing of Extension web-based resources. The internet also provides access to information from all of the country and the world. Remember, when using other resources, that you need to follow all VCE guidelines and recommendations when working with clientele.

In addition to being a source of information, computers can be used to produce high quality educational materials (newsletters, web pages, brochures), interact with and respond to the public (e-mail, listservs), and maintain records. The Virginia Master Gardener Volunteer Management System located at http://blogs.lt.vt.edu/mastergardener/ is an internet-based program that allows for easy maintenance of records and facilitates communication of achievements at the state level.

Appendix F

Resource List

Virginia EMG Website

There are a number of resources available to you on the EMG website: http://blogs.lt.vt.edu/mastergardener/.

Resources on the website include:

* News, including Weekly updates, Newsletters, and the EMG Annual Report
* Forms and Tutorials for EMG programming
* Publications
* Marketing Toolkit
* PowerPoint templates
* Signs and Banners
* Links
* Information for prospective volunteers

* Information for local EMG coordinators

Internet Sites

Virginia Master Gardener Program

http://blogs.lt.vt.edu/mastergardener/

Virginia Cooperative Extension

http://www.ext.vt.edu/

Virginia Cooperative Extension publication list

http://www.pubs.ext.vt.edu/index.html

Insect Identification Lab

https://www.insectid.ento.vt.edu

Virginia Tech Horticulture Department

http://www.hort.vt.edu

eXtension Online

http://www.extension.org

Ohio State WebGarden and Gardening database

http://webgarden.osu.edu/

Plantanswers,Texas A&M - Horticulture Info for Texas MGs answering consumer questions

http://www.plantanswers.com

International Flower Bulb Centre

http://www.bulb.com

Texas A&M "KinderGarden" Juvenile Garden Information

aggie-horticulture.tamu.edu/kindergarden/kinder.htm

American Public Gardens Association

https://publicgardens.org

UVM Fruit

http://www.uvm.edu/~fruit/

Herb Growing and Marketing Network's HerbNET http://www.herbnet.com

Perennial Plant Association

http://perennialplant.org

USDA-ARS Pesticide Database

http://www.ars.usda.gov/Services/docs.htm?docid=14199

National Arbor Day Foundation

http://www.arborday.org

US Department of Agriculture Homepage

http://www.usda.gov

Database of IPM Resources

http://www.ipmnet.org/index.htm

Weed Science Society of America

http://www.wssa.net/

Univ. of Minnesota Sustainable Urban Landscape Information

http://www.sustland.umn.edu/

Univ. of Maryland HGIC's Plant Diagnostic Web Site

http://plantdiagnostics.bugwood.org/

National Gardening Association Plant Finder

http://www.garden.org/plantfinder/

Regional IPM Centers

http://www.ipmcenters.org/

Note: Internet addresses (URLs) are CASE SENSITIVE. If not typed exactly correct, you will be unable to access the site.

Remember: If giving pesticide recommendations, VCE-MGs are required to give VCE Home and Grounds PMG recommendations ONLY.

Appendix G

VMS Resources

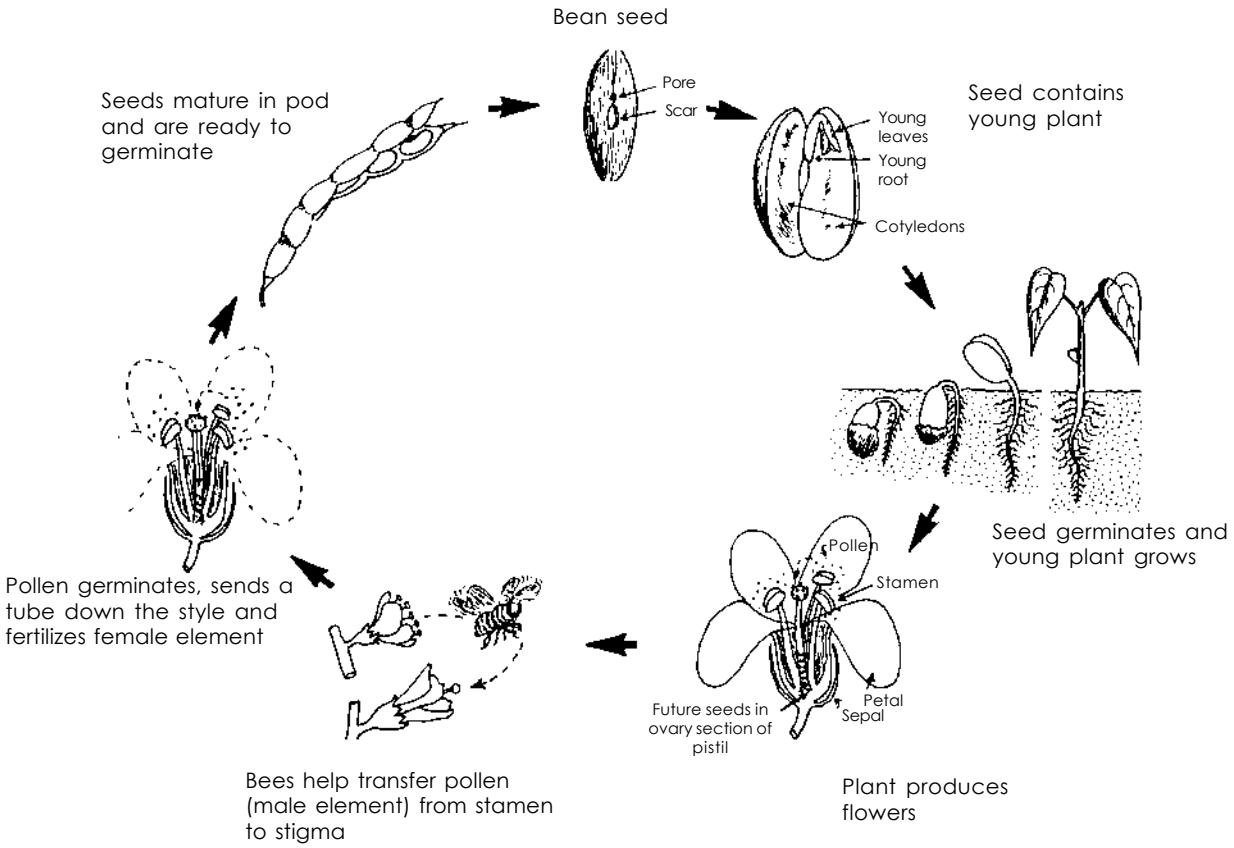
The Volunteer Management System (VMS) is the online reporting system used by EMGs to report program activities, hours, and contacts. The User Guide for the VMS can be found at http://blogs.lt.vt.edu/mastergardener/master-gardener-coordinators/volunteer-management-system/vms-user-resources/

Chapter 2
Basic Botany

Basic Botany

Chapter 2

Typical Cycle of a Flowering Plant



Basic Botany

Chapter 2

Revised by *Lisa Sanderson, Extension Agent, Agriculture and Natural Resources (2015)*
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Horticulturists work with a wide array of different plants, both as garden friend or foe, including mosses, ferns, nonbearing plants, and flowering plants. Their differences are enjoyed with the diversity they bring to the garden and landscape, yet on close observation many similarities become evident. These similarities in basic plant structures and functions, along with the environmental factors that affect plant growth, are the basis of this chapter. By necessity, the coverage will relate to the higher flowering plants because they are most significant in the garden and landscape. While this will involve extensive terminology, recognize that the purpose is not to develop a botanist's vocabulary but rather to enhance understanding of botanical references in the future, and to gain a perspective on the botanical basis for horticultural practices discussed in later chapters.

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Contents

Taxonomy: Biological Classification

Taxonomy is defined as the science of biological classification of plants and animals. It is the methodology of systematic botany (and zoology), putting plants (and animals) in the form of superior and subordinate groups. The purpose of taxonomy is to develop a convenient and precise method of classifying human knowledge. This method thus preserves knowledge and makes it accessible. In this chapter, we will learn how plants are classified, then learn how to go about identifying a plant by the use of a leaf key.

Classification of Landscape Plants

There are many ways to classify or categorize the thousands of plants used in the landscape. The validity of any system depends on consistency, clarity, and utility. For example, the classification of plants based on use, such as ornamentals in contrast to edibles, seems logical until you consider some species which are both ornamental and edible. Other ways of classifying plants, such as through the relationships of their growth habits, are also descriptive though frequently not a basis for easy differentiation; for example, differences between some trees and shrubs or between evergreen, semievergreen, and deciduous trees and shrubs may depend on geographical location. We can look at classifications based on practical criteria, such as use in landscape projects and the growth habit of a plant. Other divisions include length of life (annual, biennial, or perennial) and type of stem tissue (woody or herbaceous).

Among woody plants, a major distinction is made between those that lose their leaves during part of the year (deciduous) and those with leaves that persist during the entire year (evergreen). There are also those that hold their leaves late into the winter when others are leafless, but eventually lose their leaves or turn brown (semi-evergreen). In fact, even evergreen plants ultimately lose their leaves, though it is usually after new leaves have been formed. Some evergreens hold their leaves only one year, but most hold them two or more years.

In addition to the very general horticultural classifications outlined previously, plants are further differentiated for landscape purposes by size, growth habit, usage, and adaptability to specific environmental conditions. These classifications are all given in Chapter 16: *Woody Landscape Plants* and Chapter 17: *Herbaceous Landscape Plants.*

Finally, landscape plants are classified according to tolerance of various environmental conditions or on the basis of their requirement of certain conditions. This is particularly true of plants with growth that is unique to a specific habitat, such as bog plants and indoor or outdoor plants. Major categories related to environment are tropical, subtropical, and temperate. Within each of these categories and locations, plants are classified either as hardy or tender, depending on whether or not the plant will survive the winter of a particular region. These, along with the scientific classification, ought to provide you with sufficient background to build upon as you become increasingly experienced.

Scientific Classification

Various methods of classifying plants have been used throughout history, including some of the approaches already mentioned, but it was the effort of Carolus Linnaeus (1707-1778) that revolutionized plant classification and gave form to the present scientific system. This system uses structural (morphological) similarities and differences, particularly in the reproductive organs, as a basis for classification. These plant parts are the least likely to be influenced by environmental conditions and, therefore, provide stable distinguishing features.

Plant classification begins by dividing the plant kingdom into major divisions, separated on an evolutionary basis. The division that will be of importance to you is the most advanced division containing the so-called higher plants. This division, known as Tracheophyta, are plants with roots, stems, leaves, and vascular systems. Further divisions can be illustrated by using as an example the pink flowering dogwood (*Cornus florida* var. *rubra*).

The pink flowering dogwood is described by each of the following categories. The precision of the description increases as the list descends.

Kingdom: Plant
- Division: Tracheophyta
  - Class: Angiospermae
    - Subclass: Dicotyledoneae
      - Order: Cornales
        - Family: Cornaceae
          - Genus: *Cornus*
            - Species: *C. florida*
              - Variety: *C. florida* var. *rubra*

The two **classes** of primary concern in the woody ornamental plants are gymnosperms and angiosperms. The gymnosperms, numbering less than 700 species, are primarily the evergreen species of the temperate zones. They are readily identifiable because of their naked seeds which are usually borne in cones, in contrast to the seeds of angiosperms which are fully enclosed in a fruit. Gymnosperms generally also have narrow or needlelike leaves, while angiosperms usually have broad leaves. There are over 250,000 species of angiosperms distributed all over the world.

Angiosperms are first subdivided into two major **subclasses**: the Dicotyledoneae (dicots) and the Monocotyledoneae (monocots). The dicots, numbering about 200,000 species, include most of the broadleaf herbs, shrubs, and trees. Monocots, numbering about 50,000 species, include such orders as lilies, palms, and grasses.

The next lower grouping, called the **family**, has very specific distinguishing characteristics that can be used for identification purposes. This is particularly true of reproductive (flower) parts, but frequently holds true for non-reproductive structural features such as leaf and bud arrangements. There are also definite cultural similarities that remain constant within families, such as the acid-soil requirement of the heath family (Ericaceae).

Below family, plants are grouped in a particular **genus** and these plants are very similar morphologically. Members of the same genus usually can cross pollinate among themselves but almost as a rule not with members of other genera (plural of genus).

Below genus the basic unit of this taxonomy system is the **species**. When two species interbreed, this can result in a plant that is considered a **hybrid**. Distinct and repeated variation within a species is often observed. This results in the naming of a **subspecies** or **variety** (note above the flowering dogwood with the varietal name rubra as it is the pink-flowering variety). The following discussion will help you understand the **binomial system of nomenclature**. Note that the species and variety names always include the genus name.

Plant Names Can Make Sense

Phaseolus vulgaris is a Latin term, but for what? Some may recognize it as the scientific name for the plant we know as the kidney bean or, more appropriately, the common bean.

Scientific names are used throughout biology for all plants, animals, bacteria, fungi, and so forth. Credit for this goes to Carolus Linnaeus.

Two names used together identify a particular plant in the same way as we use a person's first name and surname. Just as you have a first name and a last name, so does every plant. Your last name identifies you **generically** as being part of a particular group -- Smith, Jones, or Mentha. Your first name identifies you, **specifically** -- Sally, George, or Piperata (Pip for short). When writing your name to be classified, as on a government form, you put your generic name first, followed by your specific name -- Smith, Sally; Jones, George; *Mentha piperata* (the species name is not capitalized in scientific names). So peppermint, *Mentha piperata*, is identified as being a mint by the generic, or genus, name *Mentha*, then is given individuality by the specific name *piperata*.

The **genus** (or general) name for a plant places it in a particular group, as in *Rosa* for the rose group. Knowing the genus still does not tell us the particular plant among the many relatives in the group. For that we need the **species** (specific) name, as in rugosa of the *Rosa* genus. By convention, the genus is given first and is capitalized, the species is second and not capitalized, and both are in italics if in print or underlined if written by hand. The proper scientific name for this example is then *Rosa rugosa*, the Rugosa Rose by its common name.

It may appear complicated to end up with virtually the same scientific and common names. In this case, the common name came from the scientific name, but having the same common and scientific names is most often the exception. We like common names because they are in English and are often colorful or descriptive, which may help us remember the plant. They may also confuse us. There are problems when a plant has no common name, when two plants have the same common name, or one plant has different common names among different people. Also, common names for plants will often change from one region to the next. Scientific names are the same world-wide.

One such problem is the popular Kalanchoe (*Kalanchoe blossfeldiana*) which is also called Bryophyllum, Devil's Backbone, Air Leaf, Good Luck Plant, and Mother of Thousands. Adding to this confusion, Mother of Thousands also is recognized as a common name for the

Strawberry Begonia or Strawberry Geranium, a plant that is unrelated to the kalanchoes, begonias, geraniums, or even strawberries! Similarly, in America, an important food crop is corn, which in Britain is called maize. The term corn in Britain applies to the grain used for making bread, the grain called wheat in America. These examples can go on and on.

There was an effort to reduce this confusion in 1923 with *Standardized Plant Names*, but the results were very limited. Common names cannot be successfully legislated in public usage. Scientific names continue as the only reliable means to communicate one and only one plant across different languages, locations, and backgrounds.

A scientific name and a common name may be learned with equal ease. We just need to make the association with the plant. Most people never really take a close look at the scientific name because it appears so foreign, hard to remember, impossible to pronounce, and of no help at all in remembering the plant. In fact, the Latin genus and species may be quite familiar to us and help more than we may think in making the plant-to-name association. Pronunciation does not need to be an undue burden either (see following discussion of pronunciation).

Many Latin genus names have been adopted into our common name vocabularies, such as Aucuba, Begonia, Dieffenbachia, Draceana, Forsythia, Gladiolus, Petunia, and Philodendron. (They are not italicized or underlined when used as English common names, but still must be when including the Latin species.) Other times, the common name is a direct English version of the Latin genus, as in juniper from *Juniperus*, lily from *Lilium*, pine from *Pinus*, rose from *Rosa*, and spirea from *Spiraea*. For other genera, the name derivation is not as direct, but with repetition, it is equally easy to relate *Acer* as maples, *Dianthus* as pinks, *Ilex* as hollies, *Ligustrum* as privets, or *Taxus* as yews.

The species name is generally selected to be somehow descriptive of the plant within the genus. This was how some earlier naming systems were set up, using a group name followed by one to several descriptive adjectives. (And students think learning two Latin names is a burden today!) Linnaeus simplified this for us with a genus name that is always a noun and a single species name that is either an adjective or another supporting noun. These relate such things as plant attributes, the place it was originally found, or the discoverer. (In this last case, we may see the older practice of capitalizing the species name as a proper noun, as in *Berberis Thunbergii*, named after Thunberg. This is out of favor today.)

Looking at these Latin words may offer instant recognition or severely challenge the high school memory. The short list provided here is just a beginning. Further help could really benefit our learning effort. An English dictionary may offer some clues if we look up origins of root words in the name. This involves more effort than we may wish, while a full compendium, such as *Botanical Latin* (W.T. Stearn, 2004, Hafner Publishing Co., New York) is more for the taxonomist than the gardener. A similar but simpler reference is *A Dictionary of Botanical Terms* (F.A. Swink, 1990, American Nurseryman Publishing Co., 800-621-5727). A favorite is the soft-bound, pocket-size *The Pronouncing Dictionary of Plant Names* (rev. 2006). As the title says, both pronunciations and translations are provided for a wide array of genus and species names. It also may be obtained from American Nurseryman Publishing.

But what happens when several related people, with the same generic name, are also given the same specific name? Margaret, for example -- they all look different, but how do we differentiate among them in conversation, when we cannot point to them and say "that Margaret, not the other one"? We use nicknames, Meg, Margie, Maggie, Peggy.

These are like names of plant varieties. The **variety** is a subgroup name in which the plant differs only slightly from the species. This further delineates a specific plant. It is shown in Latin notation following the genus and species with the abbreviation var., as in *Mentha piperata* var. *variegata*, the peppermint with the white-variegated leaves. So with plants, the genus is the general plant group, and the species is used with the genus to designate a distinct plant type in the group. Species retain their distinguishing characteristics as they reproduce sexually in nature. Individual plants will exhibit some differences due to natural variation, but they still fit the species characteristics. Sometimes, there may be a characteristic that differs enough from the true species to justify a different name, but not a different species. In these cases, then a subgroup of the species may be designated, usually as a variety (var.) but sometimes as a subspecies (subsp.) or form (f.).

Another naming distinction often is needed in these species subgroups. A botanical variety will sexually breed true to its type in nature. Another type, the

cultivated variety or cultivar, is known only in cultivation because the unique characteristics would be lost without controlled sexual or asexual propagation. Cultivar names are either English or Latinized words and are set off either in boldface type, with the abbreviation cv., or most often with single quotation marks. While often proper names, cultivar names will usually offer some descriptive information that may help us remember the plant's special characteristics.

Let's try a few example names to pick out what they tell us. We started with *Phaseolus vulgaris*, or "bean, common" by literal translation. A popular garden type is *P. vulgaris* 'Kentucky Wonder', a selected pole snap cultivar (Kentucky Wonder) of the common bean. Another type is *P. vulgaris* var. *humilus* 'Tendercrop'. This time our snap bean cultivar (Tendercrop) is of a low or bush form (var. *humilus*) of the species. In contrast, we recognize that *P. coccineus* is another bean, but its name notes the scarlet (*coccineus*) flowers which are unique in this genus to the Scarlet Runner Bean. (Note that after its first use in a written form, the genus *Phaseolus* is abbreviated as *P.* for future uses.)

Similar examples may be drawn with ornamental plants. Virginia's state tree is *Cornus florida*, the Flowering Dogwood (a direct translation), with its wonderful display of white floral bracts. A tree was found and named *C. florida* var. *rubrum*. We can conclude from this that the tree's bracts are red (*rubrum*) and it breeds true from seed in the wild (botanical variety). Another type, *C. florida* var. *rubrum* 'Cherokee Chief' also has red bracts, but the unique characteristic (deeper red than usual) of this cultivar must be maintained through asexual propagation.

Now test yourself. What is a distinguishing feature of *Viburnum acerifolium* and of *Magnolia grandiflora*? Here each species combines a descriptive prefix and root word. (Did you get maple-like leaf for the viburnum and large flower for the magnolia?) This also happens in the cultivar portion of *Juniperus chinensis* var. *procumbens* 'Aureo-variegata' which may literally translate into "the golden-variegated, trailing variety of juniper first collected in the region of China."

The next time you see a new plant name, look closely at the Latin words. Are the words and their meanings familiar? If not, look them up -- this information will help you remember the name and match it with the plant. Then try to pronounce the name. Don't worry if it sounds funny the first few times. As you repeat and use the name, you will be surprised by how easy it is to remember.

Guide for Pronouncing Latin Names

Latin pronunciations of plant names have evolved from the classical form of the language classroom to a more-comfortable, modernized form. The rules are still rather complicated, but the following guide may help in understanding and using the pronunciations.

Consonants		
Letter	**Sound**	**Example**
C-	soft (as in city) when followed by E, I, Y, AE, or OE	Cycas = SIGH-kus
	hard (as in call) when followed by A, O, U, AU, OI, or a consonant	Coccinea - kok-SIN-ee-uh
G-	soft (as in gem) when followed by E, I, Y, AE, or OE	Ginkgo = JINK-go
	hard (as in go) when followed by A, O, U, AU, or OI	
CH-	always as K (as in chemist) unless part of a proper name	Chamaedorea = kam-ee-DOR-ee-uh
		Pachysandra = pak-ih-SAN-druh
		Veitchia = VEETCH-ee-uh (for English Nursery)

Vowels	
Letter	**Sound**
A-	long as in fate (sometimes fat), short as in idea
E-	long as in be; short as in bell
I-	long as in pine (sometimes machine); short as in pin. Species names ending in -ii have the first pronounced as machine and the second as in side (-ii = ee-eye)
O-	long as in note; short as in not
U-	long as in rule; short as in up
Y-	long as in type; short as in symbol
Use long vowel sounds:	
1.	If the vowel ends the name (unless it is "a").
2.	If the vowel is followed by another vowel.
3.	If a single consonant follows the vowel in the next to last syllable.
4.	If a single consonant follows the vowel in any unaccented syllable. This does not apply to the last syllable unless it is -des (= deez). Note: This rule is often modified in common usage, particularly with first syllables, for easier speaking.
Use short vowel sounds:	
1.	If the vowel is in a final syllable ending with a consonant.
2.	If the vowel is followed by an "x" or any two consonants.
3.	If the vowel is followed by one or more consonants in an accented syllable which is not the next to last syllable.

Diphthongs

ae-	as in Caeser	*dracaena* = dra-SEE-nuh
oe-	as in oenology	*amoena* - a-MEE-nuh
au-	as in author	*centaurea* = cen-TAU-ree-uh
eu-	as in neuter	*leucothoe* = loo-KOTH-oh-ee
oi-	as in coin	*deltoides* = del-TOY-deez

Accents

Final syllables are never accented. When the name has three or more syllables, the next to last is generally accented. If that syllable is very short (especially if a single vowel), the accent is commonly placed on the preceding syllable. Note: Common usage sometimes interferes with these rules, and some plant dictionaries may even disagree.

Gypsophila = jip-so-PHIL-uh rather than jip-SOPH-il-uh
Pittosporum = pit-oh-SPOR-um rather than pit-TOSS-pore-um
Araucaria = ar-au-CARE-ee-uh rather than ar-au-care-EE-uh

Some Examples for Study

Cordyline terminalis	kor-dih-LYE-nee	ter-mih-NAY-lis
Crassula argentea	kra-SOO-luh	ar-JEN-tee-uh
Gerbera jamesonii	jer-BEE-ruh	jame-eh-SO-nee-eye
Kalachoe blossfeldiana	kal-an-KOH-ee	bloss-fel-dee-AYN-uh
Liriope muscari	lih-RYE-oh-pee	muss-CARE-eye
Pachystachys lutea	pack-ih-STAY-kiss	loo-TEE-uh
Phoenix roebelenii	FEE-nix	roh-bel-EH-nee-eye
Sedum acre	SEE-dum	AY-kree
Senecio mikanioides	seh-NEE-see-oh	my-kan-ee-OY-deez

These examples include some common usage variations from the rules. This should suggest that the rules are an important starting guide, but using the names in a comfortable pronunciation should be your goal. Gardeners are generally forgiving and will not correct another's mispronunciation. However, using the guide or other references in the future will make saying new names much easier. Also recognize and practice that *Kalanchoe* is kal-an-KOH-ee, not ka-LAN-cho, and *Liriope* is lih-RYE-oh-pee, not LEER-ee-ohp or any of its other common names, and proper pronunciations will become second nature.

What Do Those Words Mean?

This short list of Latin words used in plant names offers a glimpse of the information they provide. Adjectives here are presented in the masculine form to go with a masculine noun (genus). The endings would differ for a feminine or neuter genus, but the root portion would stay the same.

Designating Plant Habitat

aquaticus = in water	*arvensis* = in fields
maritimus = by the sea	*palustris* = in swamps
pratensis = in meadows	*sativus* = cultivated
sylvestris, sylvaticus = in woods	

Designating Plant Geography

americanus = Americas	*australis* = southern
borealis = northern	*canadensis* = Canada (N. US)
carolinianus = Carolinas	*chinensis, sinensis* = China
occidentalis = western (New World)	*virginianus* = Virginias
orientalis = eastern (Old World)	

Designating Plant Attributes

annus = annual	*officianales* = medicinal
communis, *vulgaris* = common	*parennes* = perennial
pulchellus = beautiful	*rugosus* = wrinkled
setaceus = bristle-like	*spectabilis* = handsome, showy
vernus = spring flowering	

Designating Plant Appearance

gracilis = graceful, slender	*humilus* = low
procumbens = trailing	*pubescens* = downy hair surface
pumilus, *nanus* = dwarf	*repans, reptans* = creeping
scandens = climbing	*tuberosus* = forming tubers

Designating Plant Parts

carpus = fruit	*caulis* = stem
florus, anthos = flower	*folium, phyllon* = leaf

Designating Color

albus = white	*atropurpureus* = dark purple
aureus = golden	*bicolor* = of two colors
coccineus = scarlet	*concolor* = same color both sides
discolor = different color each side	*flavus, luteus* = yellow
glaucus = whitish with a bloom	*niger* = black
ruber = red	*sanguineus* = blood-red
variegatus = variegated	*viridis* = green

Designating the Collector

(occasionally capitalized)

fortunei = from Fortune	*halliana* = from Hall
sargentii = from Sargent	*thunbergii* = from Thunberg

Numerical Prefixes

uni-, mono- = one	*bi-, di-* = two
tri- = three	*quadri-, tetra-* = four
quinque-, penta- = five	*multi-* = many
a- = without, lacking	

Descriptive Prefixes

albi-, leuco- = white	*alterni-* = alternate
angusti- = narrow	*brevi-* = short
grandi- = large	*hetero-* = differing
lati- = broad	*longi-* = long
micro- = small	*macro-* = large, long
rotundi- = round	*semper-* = always

Identification With an Analytical Key

The ability to identify plants is something like learning people's names. When you are introduced to someone by name, you may concentrate on associating the name with particular features of that person, whether they are facial or other physical features. If you meet a person only once, you will probably soon forget who the person is. However, after you have been associated with a person for a long time and have called him or her by name a number of times, you will then be able to identify that person when you see him/her anywhere. If you do not see him/her for a few years, you may find that you have forgotten the name, but it will only take a short reminder to re-familiarize yourself with that person. The same process is involved in identifying plants. The significant difference between identifying plants and identifying people is that plants can't tell you who they are. Consequently, various guides have been prepared to assist in determining the identity of various plants. The bibliography at the end of this section lists several of these manuals.

The actual identification of an unknown plant usually requires an analytical key, which is a part of most identification manuals. These keys list plant features, such as leaf arrangement, leaf shape, leaf color and hairiness, various twig features, and many other identifying characteristics that are evident at various times of the year. Usually the keys are based on vegetative features, even though the first separation of plants by species was based on differences in sexual structures. Unfortunately, the flowering stages do not last long enough to use this as a general means of identifying plants.

The use of a key is a step-by-step process of elimination, beginning with the most general characteristics (for example, evergreen vs. deciduous) and progressing to the most specific characteristics. Most manuals will begin with instructions for their use, as well as definitions of the various characteristics. The terms used in the definitions can differ slightly between manuals, so review of this section is important.

Study Questions

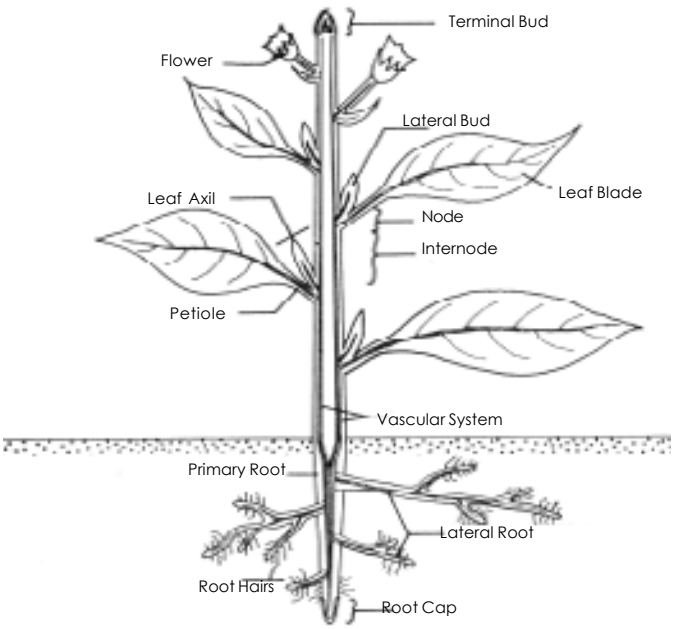
1. The science of the classification of plants and animals is called _____.
2. Hybrids are crosses of plants within the same: a) class; b) family; c) genus; d) species
3. The correct way to type the scientific name of the kidney bean is: a) Phaseolus vulgaris; b) *Phaseolus vulgaris*; c) Phaseolus Vulgaris; d) phaseolus vulgaris
4. A plant with characteristics that do not self-propagate in the wild is known as a: a) cultivar; b) variety; c) subspecies; d) form
5. The correct pronunciation of leucothoe is: a) loo-KOTH-oh-ee; b) loo-CHOCH-oh-ee; c) loo-koth-OH-ee; d) LOO-koth-oh
6. The *Juniperus chinensis* 'Columnaris Glauca' would be described as: a) a columnar, white yew; b) a columnar, red Juniper found in China; c) a blue-variegated prostrate Juniper; d) a blue/whitish bloom, columnar Juniper found in China

Answers: 1 - taxonomy; 2 - c and d; 3 - b; 4 - a; 5 - a; 6 - d

Anatomy: Plant Parts and Functions

The parts of a plant can be divided into two groups: sexual reproductive parts and vegetative parts. Sexual reproductive parts are those involved in the production of seed. They include flower buds, flowers, fruit, and seeds. The vegetative parts include leaves, roots, leaf buds, and stems. Although the vegetative parts are not directly involved in sexual reproduction, they are often used in asexual or vegetative forms of reproduction, such as for cuttings.

Principle Parts of a Vascular Plant

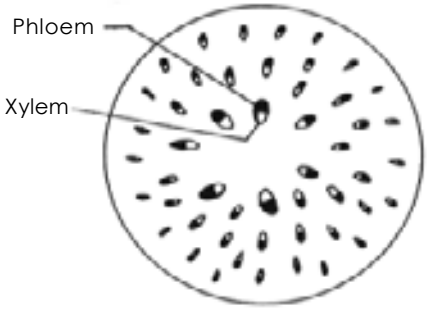


Stems

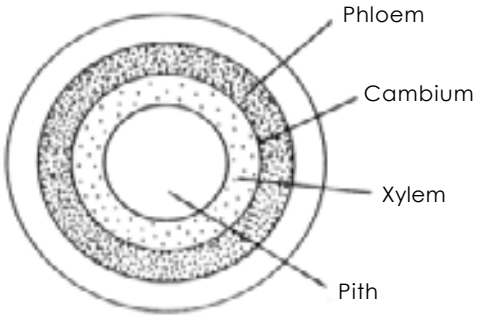
Stems are structures that support buds and leaves and serve as conduits for water, minerals, and sugars. The three major internal parts of a stem are the xylem, phloem, and cambium. The xylem and phloem are the major components of a plant's vascular system. The vascular system transports food, water, and minerals and offers support for the plant. Xylem tubes conduct water and minerals to the leaves, while phloem tubes conduct food away from the leaves.

The vascular systems of monocots and dicots differ. While both contain xylem and phloem, they are arranged differently. In the stem of a monocot, the xylem and phloem are paired into bundles; these **bundles** are dispersed throughout the stem. But in the stem of a dicot, the vascular system forms **rings** inside the stem. The ring of phloem is near the bark or external cover of the stem and is a component of the bark in mature stems. The xylem forms the inner ring; it is the sapwood and heartwood in woody plants. The difference in the vascular system of the two groups is of practical interest to the horticulturist because certain herbicides are specific to either monocots or dicots. An example is 2,4-D, which only kills dicots. In contrast, dicots may be more readily grafted as it is easier to align the vascular rings of the two stem pieces compared to the scattered bundles in monocots.

Cross-Sections of Stems



Bundle system of a monocotyledonous stem



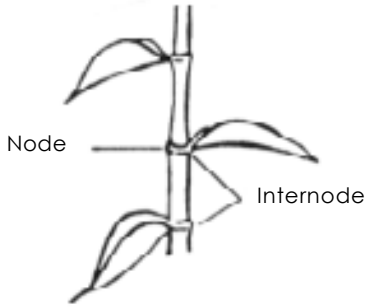
Ring system of a dicotyledonous stem

The cambium is a **meristem**, which is a site of cell division and active growth located between the xylem and phloem. This tissue is responsible for a stem's increase in girth as it produces both the xylem and phloem tissues.

A distinct part of a stem is called a **node**. This is where leaves are attached to the stem, and buds are located in these leaf axils (angle between stem and bud/leaf). Nodes are often larger than adjacent stem segments because of branching of the stem vascular system into the buds and leaves.

The stem section between nodes is called the **internode**. The length of an internode may depend on many factors. Internode length varies with the season. Growth produced early in the season has the greatest internode length; length decreases as the growing season nears its end. Decreasing

fertility will decrease internode length. Too little light will result in a long internode, causing a spindly stem. This situation is known as stretch or etiolation. Vigorously growing plants tend to have greater internode lengths than less vigorous plants. Internode length will also vary with competition from surrounding stems or developing fruit. If the energy for a stem has to be divided between three or four stems, or if the energy is diverted into fruit growth, internode length will be shortened.



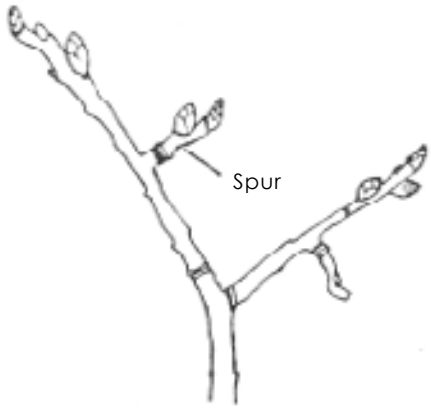
Modified Stems

The presence of leaves (regular or modified) or buds distinguishes a stem. Although typical stems are above-ground trunks and branches with great distances between leaves and buds, there are modified stems that can be found above ground and below ground. The above-ground modified stems are crowns, stolons, and spurs; and the below-ground stems are bulbs, corms, rhizomes, and tubers.

Above-ground stems:

Spurs are short, stubby, side stems that arise from the main stem. They are common on such fruit trees as pears, apples, and cherries, and are capable of bearing fruit. If severe pruning is done close to fruit-bearing spurs, the spurs can revert to a long, nonfruiting stem.

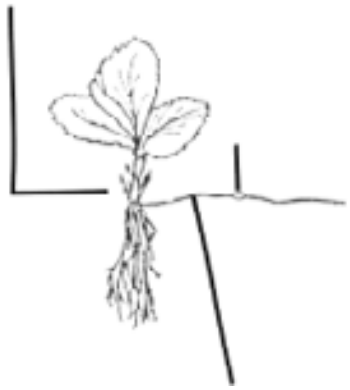
Crowns (seen in strawberries, dandelions, and African violets) are another type of compressed stem having leaves and flowers on short internodes. Crowns are located at soil level so that roots support them upright and the central growing point is never covered with soil. Many herbaceous perennials, such as Shasta daisy, also develop crowns that enlarge with branching over successive years. These crowns persist over winter with buds that develop into elongated aerial stems during the growing season.



A **spur** is a compressed fruiting branch.

A **stolon** is a horizontal stem that is fleshy or semi-woody and lies along the top of the ground. The spider plant has stolons. Strawberry runners are examples of stolons. Remember, all stems have nodes and buds or leaves. The leaves on strawberry runners are small, but are located at the nodes, which are easy to see. The nodes on the runner are the points where roots begin to form.

A **crown** is a region of compressed stem tissue from which new shoots are produced, generally found near the surface of the soil.



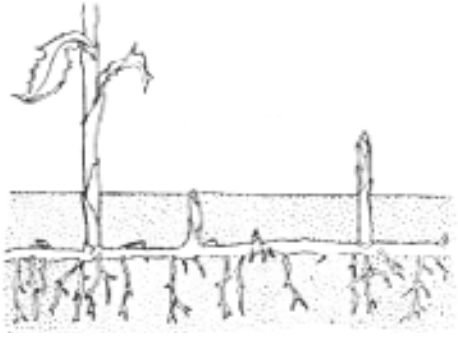
A **runner** is a type of stolon. It is a specialized stem that grows on the soil surface and forms a new plant at one or more of its nodes.

Below-ground stems, such as the potato tuber, the tulip bulb, gladiolus corm, and the iris rhizome, are underground stems that store food for the plant.

Rhizomes are similar to stolons but grow underground. Some rhizomes are compressed and fleshy, such as those of iris; they can also be slender with elongated internodes, such as bentgrass. Bermudagrass is both an effective lawn grass and a hated weed principally because of the spreading capability of its rhizomes.

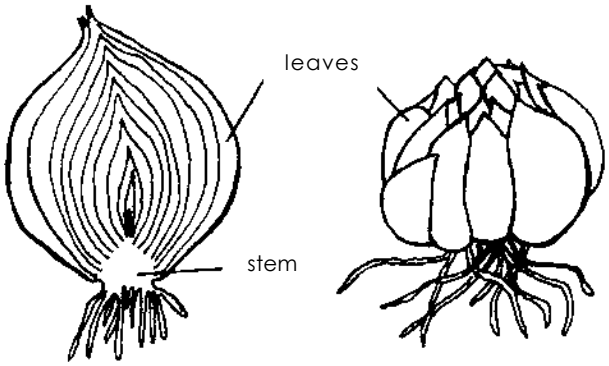
Stolon

Rhizome



Tulips, lilies, daffodils, and onions are plants that produce **bulbs** -- shortened, compressed, underground stems surrounded by fleshy scales (leaves) that envelop a central bud located at the tip of the stem. If you cut through the center of a tulip or daffodil bulb in November, you can see all the flower parts in miniature within the bulb. Many bulbs require a period of low-temperature exposure before they begin to send up the new plant. Both the temperature and length of this treatment are of critical importance to commercial growers who force bulbs for holidays.

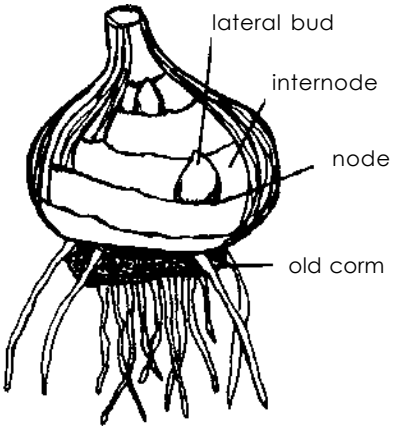
Bulb



Corms are not the same as bulbs. They have shapes similar to bulbs, but do not contain fleshy scales. A corm is a solid, swollen stem whose scales have been reduced to a dry, leaf-like covering.

A **tuber** is an enlarged portion of an underground stem. The tuber, like any other stem, has nodes that produce buds. The eyes of a potato are actually the nodes on the stem. Each eye contains a cluster of buds.

Corm



Some plants produce a modified stem referred to as a **tuberous stem**. Examples are tuberous begonia and cyclamen. The stem is shortened, flattened, enlarged, and underground. Buds and shoots arise from the crown, and fibrous roots are found on the bottom of the tuberous stem.

In addition, some plants, such as dahlia and sweet potato, produce an underground storage organ called a **tuberous root**, which is often confused with a bulb or tuber. However, these are roots, not stems, and have neither nodes nor internodes.

Tuberous Stem Tuberous Root

It may sometimes be difficult to distinguish between roots and stems, but one sure way is to look for the presence of nodes with their leaves and buds. Stems have nodes; roots do not.

Propagation

Stems are commonly used for plant propagation. Above-

ground stems can be divided into sections that contain internodes and nodes. They are referred to as cuttings and will produce roots to form a new plant. Below-ground stems are also good propagative tissues: rhizomes can be divided into pieces, bulbs form small bulblets at the base of the parent bulb, cormels are miniature corms that form under the parent corm, and tubers can be cut into pieces containing eyes and nodes. All of these will produce new plants.

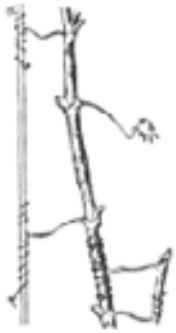
Types of Stems

A **shoot** is a young stem with leaves present. A **twig** is a stem that is less than one year old and has no leaves since it is still in the winter-dormant stage. A **branch** is a stem that is more than one year old and, typically, has lateral stems. A **trunk** is a main stem of a woody plant. Most trees have a single trunk.

Trees are perennial woody plants, usually with one main trunk, and usually more than 12 feet tall at maturity.

Shrubs are perennial woody plants that have one or several main stems, and usually are less than 12 feet tall at maturity. The distinction between a small tree and large shrub is blurry and often botanists will describe these plants as small trees or large shrubs.

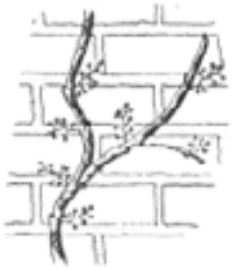
Types of Vines



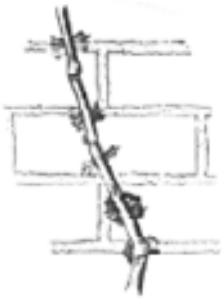
Some vines have tendrils that wrap around any type of support.

The twining vines climb by winding their stems around any available support.

A **vine** is a plant that develops long, trailing stems that grow along the ground unless they are supported by another plant or structure. Some twining vines circle their support clockwise (hops or honeysuckle), while others circle counter-clockwise (pole beans or Dutchman's pipe vine). Clinging vines are supported by aerial roots (English ivy or poison ivy), which are slender tendrils that encircle the supporting object (cucumber, gourds, grapes, and passionflowers), or tendrils with adhesive tips (Virginia creeper and Japanese creeper).



Some clinging vines climb by means of tendrils with disk-like adhesive tips that attach to any surface.



Other clinging vines attach themselves to surfaces with small aerial rootlets along the stem.

Texture and Growth of Stems

Woody stems contain relatively large amounts of hardened xylem tissue in the central core and are typical of most tree fruits, ornamental trees, and shrubs.

A **cane** is a stem that has a relatively large pith (the central, strength-giving tissue of stem) and usually lives only one or two years. Examples of plants with canes include rose, grape, blackberry, and raspberry.

Herbaceous or **succulent stems** contain only small amounts of xylem tissue and usually live for only one growing season. If the plant is perennial, it will develop new shoots from a crown or underground part.

Plants are classified by the number of growing seasons required to complete a life cycle. **Annuals** pass through their entire life cycle from seed germination to seed production in one growing season, then die.

Biennials are plants that start from seeds and produce vegetative structures and food storage organs the first season. In most biennials, during the first winter a hardy evergreen rosette of basal leaves persists. During the second season, flowers, fruit, and seeds develop to complete the life cycle. The plant then dies. Carrot, beet, cabbage, and celery are biennial plants. Hollyhock, Canterbury Bells, and Sweet William are biennials commonly grown for their attractive flowers.

Plants that typically develop as biennials may, in some cases, complete the cycle of growth from seed germination to seed production in only one growing season. This situation occurs when drought, variations in temperature, or other climatic conditions cause the plant to physiologically pass through the equivalent of two

growing seasons in a single season.

Perennial plants live for many years, and after reaching maturity, may produce flowers and seeds each year though many only flower every few years. Perennials are classified as herbaceous if the top dies back to the ground each winter and new stems grow from the roots each spring. If significant xylem develops in the stem and the top persists, as in shrubs or trees, then they are classified as woody plants.

Stems as Food

The edible portion of cultivated plants such as asparagus and kohlrabi is an enlarged succulent stem. The edible parts of broccoli are composed of stem tissue, flower buds, and a few small leaves. The edible part of potato is a fleshy, underground stem called a tuber. Although the name suggests otherwise, the edible part of the cauliflower is proliferated stem tissue.

Study Questions

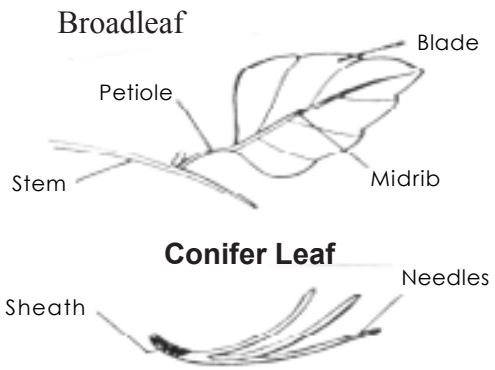
7. The _____ is the site of cell division and active growth located between the phloem and xylem.
8. A plant that has its vascular system arranged in rings would be: a) a monocot; b) a dicot; c) deciduous; d) evergreen
9. An above ground stem that has compressed leaves or flowers on short internodes at soil level is a: a) crown; b) stolon; c) runner; d) spur
10. A tuberous root and a tuberous stem can be differentiated by the presence of: a) root hairs; b) nodes; c) green tissue; d) there is no difference!
11. A _____ is a stem that has a large pith and usually lives only one or two years (i.e., grape, raspberry)
12. Plants that complete their life cycle in two growing seasons are called: a) tender; b) perennial; c) biennial; d) poor choices

Answers: 7 - cambium; 8 - b; 9 - a; 10 - b; 11 - cane; 12 - c

Leaves

Parts of a Leaf

The **blade** of a leaf is the expanded, thin structure on either side of the midrib. The blade is usually the largest and most conspicuous part of a leaf. Conifers (gymnosperm class) have a different structure in that the leaf blade is a narrow angle needle. These needles occur singly or in clusters of two or more with their bases enclosed in a sheath. The **petiole** is the stalk that supports the leaf blade; it varies in length and may be lacking entirely in some cases where the leaf blade is described as sessile or stalkless (as in conifers).

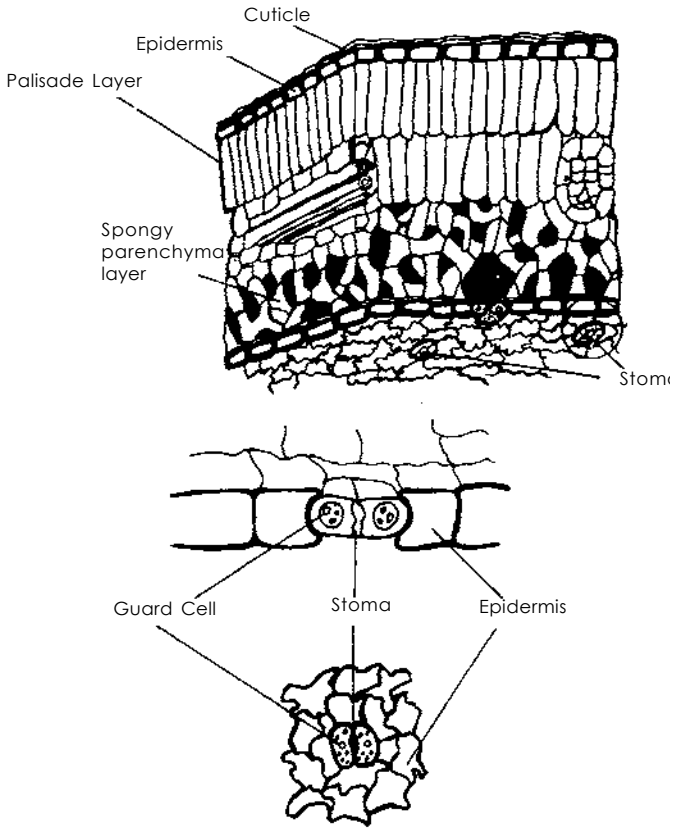


Leaves are the principal site of photosynthesis (food manufacturing) in plants. This process requires light, water from the plant's vascular system, and carbon dioxide from the air. The petiole and leaf blade provide good exposure to sunlight and air. Other structures are involved in accomplishing photosynthesis and in protecting the soft leaf tissues from desiccation.

The leaf blade is composed of several layers. On both the top and bottom is a layer of thickened, tough cells called the epidermis. The primary function of the epidermis is protection of leaf tissue. The way the cells in the epidermis are arranged determines the texture of the leaf surface. Some leaves have hairs that are an extension of certain cells of the epidermis. The African violet has so many hairs that the leaf feels like velvet.

Part of the epidermis is the **cuticle**, which is composed of a waxy substance called **cutin** that protects the leaf from dehydration and prevents penetration of some diseases. The amount of cutin is a direct response to sunlight, increasing with increasing light intensity. For this reason, plants grown in the shade should be moved into full sunlight gradually over a period of a few weeks to allow the cutin layer to build and to protect the leaves from the shock of rapid water loss or sunscald. The waxy cutin also repels water and can shed pesticides if spreader-sticker agents or soaps are not used. This is the reason many pesticide manufacturers include some sort of spray additive to adhere to or penetrate the cutin layer.

Leaf Parts



On the underside of leaves, some epidermal cells are capable of opening and closing. These cells guard the interior of the leaf and regulate the passage of water, oxygen, and carbon dioxide through the leaf. These regulatory cells are called **guard cells**. They protect openings in the leaf surface called **stomata**. The opening and closing of the cells is determined by the weather. Conditions that would cause large water losses from plants (high temperature, low humidity) stimulate guard cells to close. Mild weather conditions leave guard cells in an open condition. Guard cells will close in the absence of light.

The middle layer of the leaf is the mesophyll and is located between the upper and lower epidermis. This is the layer where photosynthesis occurs. The mesophyll is divided into a dense upper layer called the palisade, and a spongy lower layer that contains a great deal of air space, called the parenchyma layer. The cells in these two layers contain chloroplasts which are the actual site of the photosynthetic process.

Types of Leaves

A number of rather distinct types of leaves occur on plants. Leaves commonly referred to as **foliage** are the most common and conspicuous and, as previously stated, serve as the manufacturing centers where the photosynthetic activity of the plant occurs. **Scale leaves**, or cataphylls, are found on rhizomes and are the small, leathery, protective leaves that enclose and protect buds. **Seed leaves**, or cotyledons, are modified leaves that are found on the embryonic plant and commonly serve as storage organs. **Spines and tendrils**, as found on barberry and pea, are specialized modified leaves that protect the plant or assist in supporting the stems. **Storage leaves**, as found on bulbous plants and succulents, serve as food storage organs. Other specialized leaves include **bracts**, which are often brightly colored. The showy structures on dogwoods and poinsettias are bracts, not petals.

Leaves as a Means of Identifying Plants

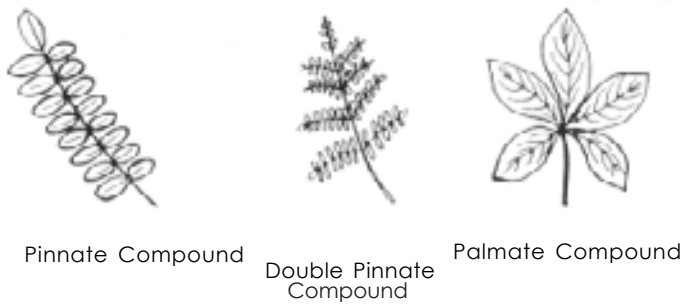
Leaves are useful in identifying species and varieties of horticultural plants. Characteristics of leaf composition, arrangement, and venation pattern should be readily recognized. Plant keys also use extensive terminology to distinguish leaf shapes, tips, bases, and margins. These terms and illustrations are provided for familiarity and future reference in efforts to identify unknown plants.

Composition: **Simple** leaves are those with a leaf blade that is a single continuous unit.

Simple Leaf

A **compound** leaf is composed of several separate leaflets arising from the same petiole. Some leaves may be doubly compound, having divisions of the leaflets. Compound leaves are further described by the palmate (as in palm of the hand) or pinnate (like a feather) arrangement of the leaflets.

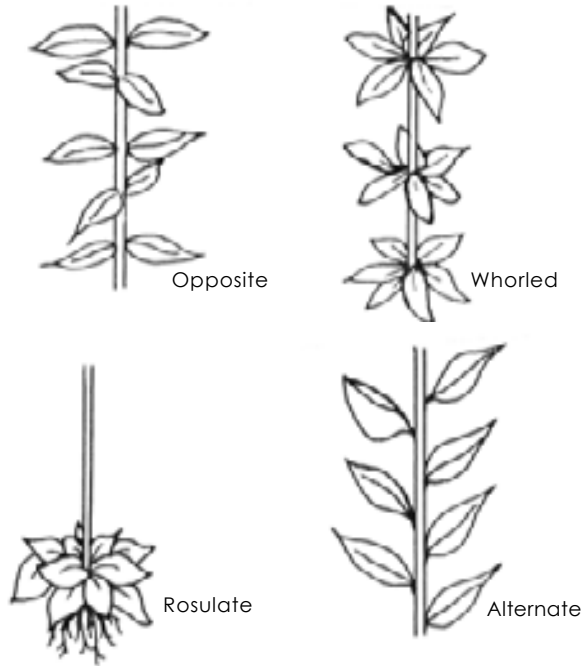
Compound Leaves



Deciding if a specimen is a compound leaf or a branch with several simple leaves can be difficult because petioles and young stems appear similar. However, remember that leaves attach to stems at a node, and there is a bud only at the node. **The presence of a bud identifies where the leaf begins.**

Leaf arrangement along a stem: In a **rosulate** leaf arrangement, the basal leaves form a rosette around the stem with extremely short nodes. **Opposite** leaves are positioned across the stem from each other, two leaves at each node. **Alternate** or spiral leaves are arranged in alternate steps along the stem with only one leaf at each node. **Whorled** leaves are arranged in circles along the stem.

Types of Leaf Arrangements



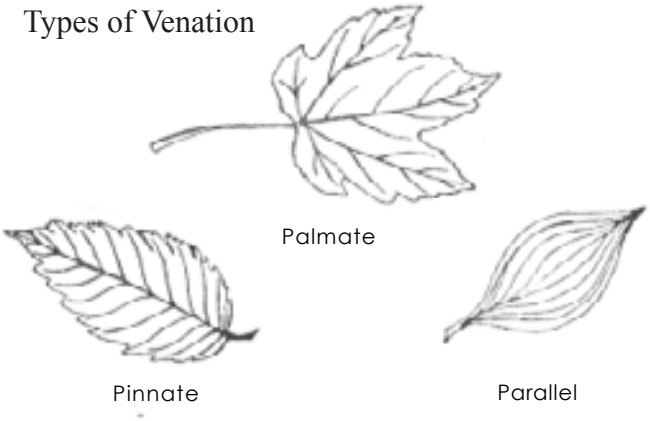
Venation of Leaves

The vascular tissues from the stem extend as bundles through the petiole and spread out into the blade. The term venation refers to the pattern of vein distribution in the blade. Two principal types of venation are parallel-veined and net-veined.

Parallel-veined leaves are those with numerous veins that run essentially parallel to each other and are connected laterally by minute, straight veinlets. Possibly the most common type of parallel veining is that found in plants of the grass family, where the veins run from the base to the apex of the leaf. Another type of parallel venation is found in plants such as banana, calla, and pickerel-weed, where the parallel veins run laterally from the midrib. Parallel-veined leaves mainly occur on plants that are part of the monocotyledon group.

Net-veined leaves, also called reticulate-veined, have veins that branch from the main rib(s), then subdivide into finer veinlets which then unite in a complicated network. This system of enmeshed veins gives the leaf more resistance to tearing than most parallel-veined leaves. Net venation may be either pinnate or palmate. In **pinnate** venation, the veins extend laterally at an angle from the midrib to the edge, as in apple, cherry, and peach. **Palmate** venation occurs in grape and maple leaves where the principal veins extend outward, like the ribs of a fan, from the petiole near the base of the leaf blade. Net-veined leaves occur on plants that are part of the dicotyledon group.

Types of Venation



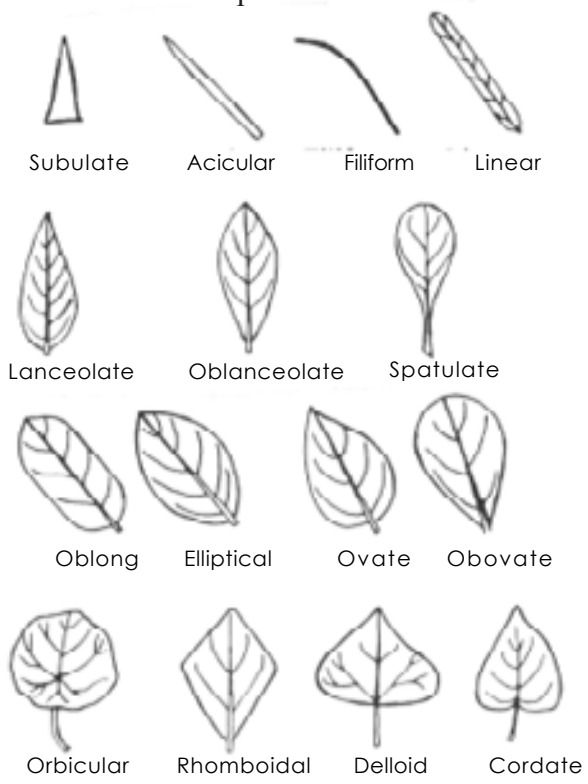
Leaf Shape

Shape of the leaf blade: The following are some common shapes that are found in leaves and leaflets.

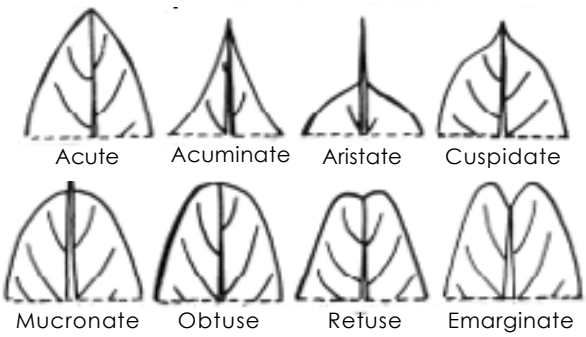
Linear: Narrow, several times longer than wide; approximately the same width throughout

Lanceolate: Longer than wide; tapering toward the apex and base
Elliptical: Two or three times longer than wide; tapering to an acute or rounded apex and base
Ovate: Egg-shaped, basal portion wide; tapering toward the apex
Cordate: Heart-shaped, broadly ovate; tapering to an acute apex, with the base turning in and forming a notch where the petiole is attached

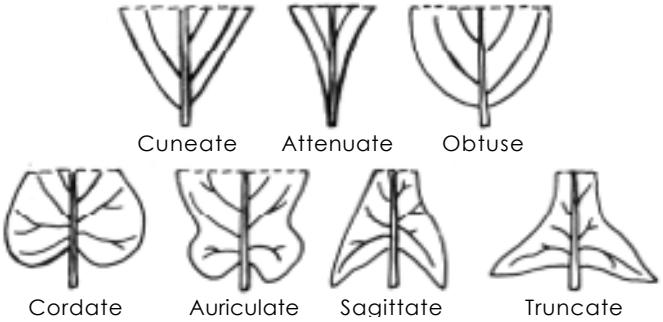
Leaf Blade Shapes



Leaf Apex Shapes



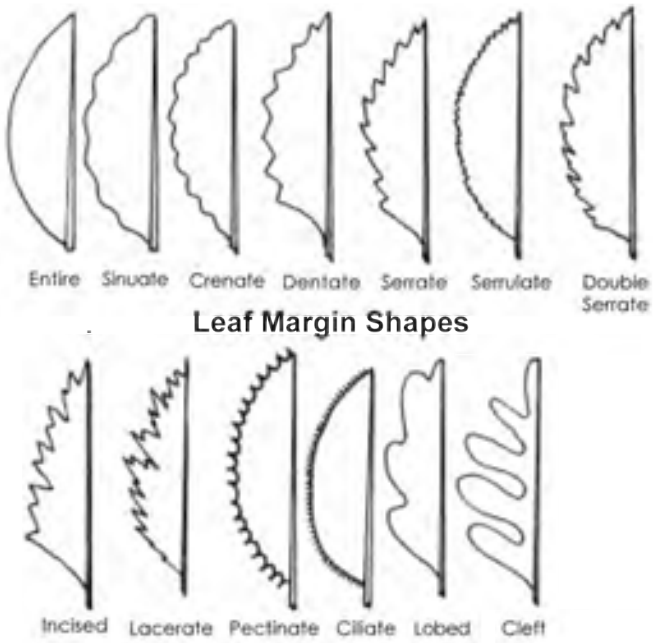
Leaf Base Shapes



Shape of the leaf apex and base: The following are common shapes found in leaves.
Acuminate: Tapering to a long, narrow point
Acute: Ending in an acute angle with a sharp, but not acuminate, point
Obtuse: Tapering to a rounded edge
Sagittate: Arrowhead-shaped, with two pointed lower lobes
Truncate: Having a relatively square end

Leaf margins: Studying leaf margins is especially useful in the identification of certain varieties of fruit plants.

Entire: A smooth edge with no teeth or notches
Serrate: Having small, sharp teeth pointing toward the apex
Dentate: Having teeth ending in an acute angle, pointing outward
Crenate: Having rounded teeth
Sinuate: Having a pronounced sinuous or wavy margin
Incised: Margin cut into sharp, deep, irregular teeth or incisions
Lobed: Incisions extend less than halfway to the midrib
Cleft: Incisions extend more than halfway to the midrib



Leaves as Food

The leaf blade is the principal edible part of several horticultural crops, including chive, collard, dandelion, endive, kale, leaf lettuce, mustard, parsley, spinach, and Swiss chard. The edible part of leek, onion, and Florence fennel is a cluster of fleshy leaf bases. The petiole of the leaf is the edible product in celery and rhubarb. In Brussels sprout, cabbage, and head lettuce, the leaves -- in the form of a large, naked bud -- are the edible product.

Buds

A bud is an undeveloped shoot from which embryonic leaves or flower parts arise. The buds of trees and shrubs of the temperate zone typically develop a protective outer layer of small, leathery bud scales. Annual plants and herbaceous perennials have naked buds with outer leaves that are green and somewhat succulent.

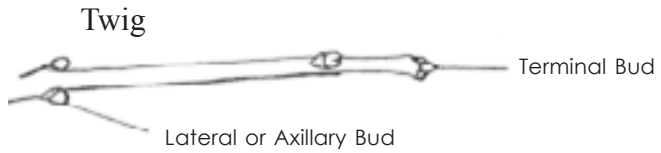
Buds of many plants require exposure to a certain number of days below a critical temperature (a period of rest) before they will resume growth in the spring. This time period varies for different plants. The flower buds of forsythia require a relatively short rest period and will grow at the first sign of warm weather. Many peach varieties require from 700 to 1000 hours of temperatures below 45°F (7°C) before they will resume growth. During rest, dormant buds can withstand very low temperatures, but after the rest period is satisfied, buds become more susceptible to weather conditions and can be damaged easily by cold temperatures or frost.

A **leaf bud** is composed of a short stem with embryonic leaves, with bud primordia (early bud embryo) in the axils and at the apex. Such buds develop into leafy shoots. Leaf buds are often less plump and more pointed than flower buds.

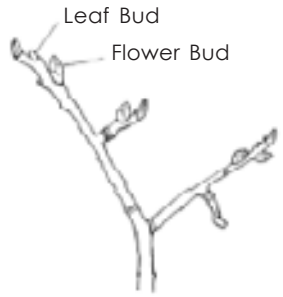
A **flower bud** is composed of a short stem with embryonic flower parts. In some cases, the flower buds of plants that produce fruit crops of economic importance are called fruit buds. This terminology is objectionable because, although flowers have the potential for developing into fruit, this development may never occur because of adverse weather conditions, lack of pollination, or other unfavorable circumstances. The structure is a flower bud and should be so designated since it may never set fruit.

Types of Buds

Buds are named for their location on the stem. **Terminal buds** are located at the apex of a stem. **Lateral buds** are borne on the sides of the stem. Most lateral buds arise in the leaf axils and are called **axillary buds**. In some instances, more than one bud is formed. **Adventitious buds** are those arising at sites other than in the terminal or axillary position. Adventitious buds may develop from the internode of the stem, at the edge of a leaf blade, from callus tissue at the cut end of a stem or root, or laterally from the roots of a plant.



Leaf & Flower Buds of Elm



Buds as Food

Enlarged buds or parts of buds form the edible portion of some horticultural crops. Cabbage and head lettuce are examples of unusually large terminal buds. Succulent axillary buds of Brussels sprouts become the edible part

of this plant. In the case of globe artichoke, the fleshy basal portion of the bracts of the flower bud are eaten along with the solid stem portion of the bud. Broccoli is the most important horticultural plant having edible flower buds that are consumed. In this case, portions of the stem as well as small leaves associated with the flower buds are eaten.

Study Questions

13. A leaf without a petiole is called _____.
14. The pores on a leaf surface that allow for gaseous exchange with the atmosphere are called _____.
15. Photosynthesis occurs in cells that contain _____.
16. Modified leaves that are found on embryonic plants are called _____.
17. Most monocot leaves are:
    a) net-veined; b) pinnately compound; c) parallel-veined; d) palmately compound
18. A leaf that is arrow-head shaped with two pointed lower lobes would be called:
    a) sagittate; b) cordate; c) truncate; d) cuspidate
19. Flower buds on fruit trees should not be called fruit buds because: a) flowers and fruit form on different buds; b) the flower may not develop into fruit; c) they might actually be lateral buds; d) spur buds aren't capable of producing fruit
20. Buds arising from a site other than the terminal or axillary position are called _____ buds.

Answers:
13 - sessile or stalkless; 14 - stomata; 15 - chloroplasts; 16 - cotyledons; 17 - c; 18 - a; 19 - b; 20 - adventitious

Roots

A thorough knowledge of the root system of plants is essential if their growth, flowering, and fruiting responses are to be understood. The structure and growth habits of roots have a pronounced effect on the size and vigor of the plant, method of propagation, adaptation to certain soil types, and response to cultural practices and irrigation. The roots of certain vegetable crops are important as food.

Roots typically originate from the lower portion of a plant or cutting. They possess a root cap, have no nodes, and never bear leaves or flowers directly. The principal functions of roots are to absorb nutrients and moisture, to anchor the plant in the soil, to furnish physical support for the stem, and to serve as food storage organs. In some plants, they may be used as a means of propagation.

Types of Roots

A **primary** (radicle) root originates at the lower end of the embryo of a seedling plant. A **taproot** is formed when the primary root continues to elongate downward into the soil and becomes the central and most important feature of the root system, with a somewhat limited amount of secondary branching. Some trees, especially nut trees like pecan, have a long taproot with very few lateral or fibrous roots. This makes them difficult to transplant and necessitates planting only in deep, well-drained soil. The taproots of carrot, parsnip, and salsify are the principal edible parts of these crops.

Fibrous Roots of Grass

Taproot of Carrot

A **lateral**, or secondary, root is a side or branch root that arises from another root.

A **fibrous** root system is one where the primary root ceases to elongate, leading to the development of numerous lateral roots which branch repeatedly and form the feeding root system of the plant. A fibrous root remains small in diameter because of a lack of significant cambial activity. One factor that causes shrubs and dwarf trees to remain smaller than standard trees is the inactivity of the cambium tissue in the roots.

If plants that normally develop a taproot are undercut so that the taproot is severed early in the plant's life, the root will lose its taproot characteristic and develop a fibrous root system. This is done commercially in nurseries so trees, which naturally have tap roots, will develop a compact, fibrous root system. This allows a higher rate of transplanting success.

The quantity and distribution of plant roots are very

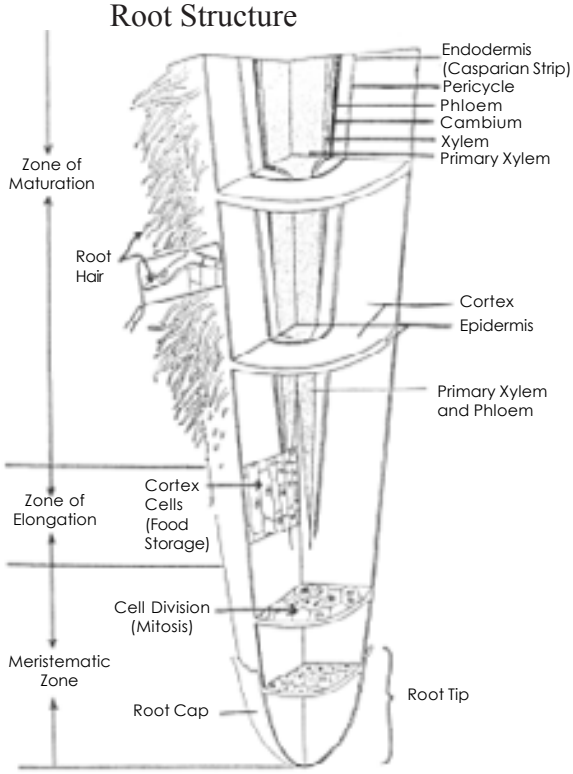
important because these two factors have a major influence on the absorption of moisture and nutrients. The depth and spread of the roots are dependent on the inherent growth characteristics of the plant and the texture and structure of the soil. Roots will penetrate much deeper in a loose, well-drained soil than in a heavy, poorly drained soil. A dense, compacted layer in the soil will restrict or stop root growth.

During early development, a seedling plant absorbs nutrients and moisture from the few inches of soil surrounding it. Therefore, the early growth of most horticultural crops that are seeded in rows benefits from band applications of fertilizer, placed several inches to each side and slightly below the seeds.

As plants become well established, the root system develops laterally and usually extends far beyond the spread of the branches. For most cultivated crops, roots meet and overlap between the rows. The greatest concentration of fibrous roots occurs in the top foot of soil, but significant numbers of laterals may grow downward from these roots to provide an effective absorption system several feet deep.

Parts of a Root

Root Structure



Internally, there are three major parts of a root. The **meristem** is at the tip and manufactures new cells; it is an area of cell division and growth. Behind it is the **zone of elongation**, where cells increase in size through food and water absorption. These cells, by increasing in size, push the root tip through the soil. The third major root part is the **maturation zone**, where cells undergo changes to become specific tissues, such as epidermis, cortex, or vascular tissue. The epidermis is the outermost layer of cells surrounding the root. These cells are responsible for the absorption of water and minerals dissolved in water. Cortex cells are involved in the movement of water from the epidermis and in food storage. Vascular tissue is located in the center of the root and conducts food and water.

Externally, there are two areas of importance; **root hairs** are found along the main root and perform much of the actual work of water/nutrient absorption. The **root cap** is the outermost tip of the root and consists of cells that are sloughed off as the root grows through the soil. The root cap covers and protects the meristem.

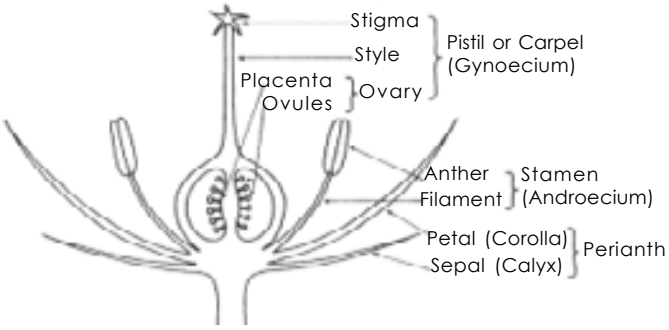
Roots as Food

The enlarged root is the edible portion of several vegetable crops. The sweet potato is a swollen root, called a tuberous root, which serves as a food storage area for the plant. Carrot, parsnip, salsify, and radish are elongated taproots.

Flowers

The sole function of the flower, which is generally the showiest part of the plant, is sexual reproduction. Its attractiveness and fragrance have not evolved to please humans but to ensure the continuance of the plant species. Fragrance and color are devices to attract pollinators -- insects that play an important role in the reproductive process.

Parts of a Flower



Parts of a Flower

As the reproductive part of the plant, the flower contains the male pollen and/or the female ovule plus accessory parts such as petals, sepals, and nectar glands.

Sepals are small, green, leaf-like structures on the base of the flower that protect the flower bud. The sepals collectively are called the calyx.

Petals are highly colored portions of the flower. They may contain perfume as well as nectar glands. The number of petals on a flower is often used in the identification of plant families and genera. The petals collectively are called the corolla. Flowers of dicots typically have sepals and/or petals in multiples of four or five. Monocots typically have these floral parts in multiples of three.

The **pistil** is the female part of the plant. It is generally shaped like a bowling pin and located in the center of the flower. It consists of the stigma, style, and ovary. The stigma is located at the top and is connected to the ovary by the style. The ovary contains the eggs, which reside in the ovules. After the egg is fertilized, the ovule develops into a seed.

The **stamen** is the male reproductive organ. It consists of a pollen sac (anther) and a long, supporting filament. This filament holds the anther in position so the pollen it contains may be dispersed by wind or carried to the stigma by insects or birds.

Types of Flowers

If a flower has a stamen, pistils, petals, and sepals, it is called a **complete** flower. If one of these parts is missing, the flower is designated **incomplete**.

If a flower contains functional stamens and pistils, it is called a **perfect** flower. (Stamens and pistils are considered the essential parts of a flower.) If either of the essential parts is lacking, the flower is **imperfect**.

Pistillate (female) flowers are those that possess a functional pistil(s), but lack stamens. **Staminate** (male) flowers contain stamens, but no pistils.

Because cross fertilization combines different genetic material and produces stronger seed, cross-pollinated plants are usually more successful than self-pollinated plants. Consequently, more plants reproduce by cross pollination than by self pollination.

As previously mentioned, there are plants that bear only male flowers (staminate plants) or only female flowers (pistillate plants). Species in which the sexes are separated into staminate and pistillate plants are called dioecious. Most holly trees are **dioecious**; therefore, to obtain berries it is necessary to have a female tree. **Monoecious** plants are those with separate male and female flowers on the same plant. Corn plants and pecan trees are examples. Some plants bear only male flowers at the beginning of the growing season, but later develop flowers of both sexes; examples are cucumbers and squash.

How Seeds Form

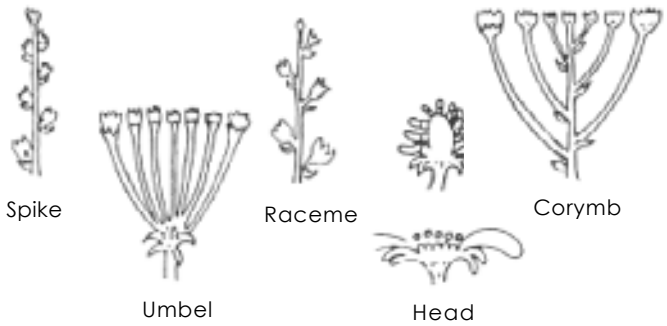
Pollination is the transfer of pollen from an anther to a stigma. This may occur by wind or by pollinators. Wind-pollinated flowers lack showy floral parts and nectar since they don't need to attract a pollinator. Flowers are brightly colored or patterned and contain a fragrance or nectar when they must attract insects, animals, or birds. In the process of searching for nectar, these pollinators will transfer pollen from flower to flower.

The stigma contains a chemical that stimulates activity of pollen from the same type of plant, causing it to grow a long tube down the inside of the style to the ovules inside the ovary. The sperm from the pollen grain moves down the tube, and fertilization typically occurs. Fertilization is the union of the male sperm nucleus (from the pollen grain) and the female egg (in the ovule). If fertilization is successful, the ovule will develop into a seed.

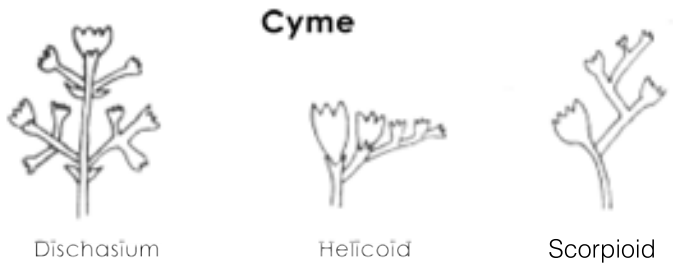
Types of Inflorescences

Some plants bear only one flower per stem and are called solitary flowers. Other plants produce an **inflorescence**, a term that refers to a cluster of flowers and how they are arranged on a floral stem. Most inflorescences may be classified into two groups -- racemes and cymes.

Racemose



In the **racemose** group, the florets, which are individual flowers in an inflorescence, bloom from the bottom of the stem and progress toward the top. Some examples of racemose inflorescence include spike, raceme, corymb, umbel, and head. A spike is an inflorescence where many stemless florets are attached to an elongated flower stem, or peduncle, an example being gladiolus. A raceme is similar to a spike, except the florets are borne on small stems attached to the peduncle. An example of a raceme inflorescence is the snapdragon. A corymb is made up of florets with stalks, or pedicels, that are arranged at random along the peduncle in such a way that the florets create a flat, round top. Yarrow has a corymb inflorescence. An umbel is similar, except that the pedicels all arise from one point on the peduncle. Dill has an umbel inflorescence. A head, or composite, inflorescence is made up of numerous stemless florets and is characteristic of daisy inflorescence.



In the **cyme** group, the top floret opens first and blooms downward along the peduncle. A dichasium cyme has florets opposite each other along the peduncle. Baby's breath inflorescence is an example. A helicoid cyme is one where the lower florets are all on the same side of the peduncle, examples being freesia and statice inflorescences. A scorpioid cyme is one where the florets are alternate to each other along the peduncle; examples are tomato and potato inflorescences.

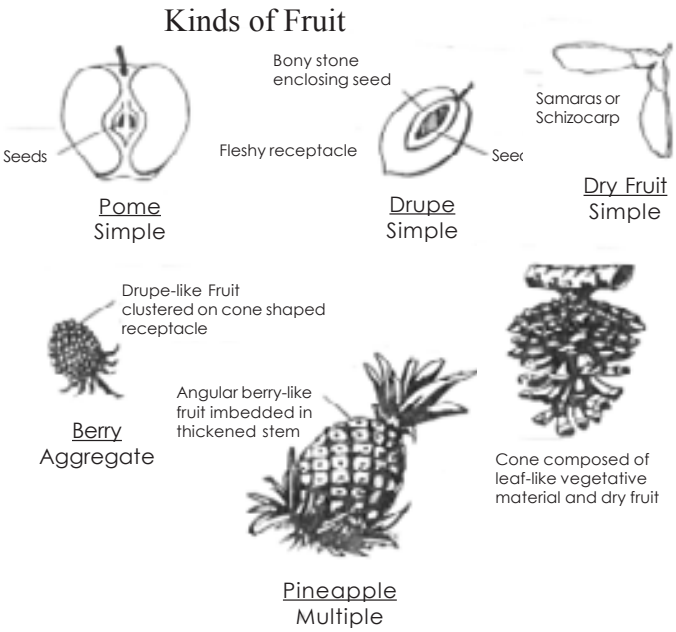
Fruit

Parts of Fruit

A fruit is defined as a ripened ovary. Fruit consists of the fertilized and mature ovules (called seeds) and the ovary wall, which may be fleshy (as in melons), or dry and hard (as in a pecan nut). The only parts of the fruit that are genetically representative of both the male and female flowers are the seeds (mature ovules). The rest of the fruit arises from the maternal plant, and is therefore genetically identical to that parent. Many fruits have additional maternal tissues develop along with the ovary; for example, the core of an apple is the ovary containing the seeds, while the part consumed develops from the receptacle that supported the ovary in the flower.

Types of Fruit

Fruits can be classified as simple fruits, aggregate fruits, or multiple fruits. **Simple** fruits develop from a single ovary. These include cherries and peaches (drupes), pears and apples (pomes), and tomatoes (berries). Tomatoes are a botanical fruit since they develop from the flower, as do squash, cucumber, and eggplant. All of these fruits develop from a single ovary. Other types of simple fruit are dry -- the fruit wall becomes papery or leathery and hard. Examples are peanut (legume), poppy (capsule), maple (samara), and walnut (nut).



Aggregate fruits, such as raspberries, come from a single flower with many ovaries. The flower appears as a simple flower with one corolla, one calyx, and one stem, but with many pistils or ovaries. The ovaries are fertilized separately and independently. If ovules are not pollinated successfully, the fruit will be misshapen and imperfect. Strawberry and blackberry are also aggregate fruits with the addition of an edible, enlarged receptacle. For this reason, they are sometimes termed aggregate-accessory fruits.

Multiple fruits are derived from a tight cluster of separate, independent flowers borne on a single structure. Each flower has its own calyx and corolla. Examples

of multiple fruits are pineapple, fig, and the beet seed. Multiple fruits are not common in Virginia.

Special note about gymnosperms: While gymnosperms are also vascular plants with many of the same basic plant structures as angiosperms, there are important differences. One is the leaf form, the needle previously discussed, with the one significant landscape exception of the ginkgo which is a broadleaf gymnosperm. Another distinction is that all gymnosperms are woody perennials; no herbaceous forms exist. But the main difference is in the reproductive structures. One structure produces pollen while another produces eggs and nourishes the developing seed. This means that gymnosperms are either monoecious or dioecious. The reproductive structures generally are the familiar cones of pine, hemlock, and spruce. Some others may appear like berries (i.e., juniper, yew, and ginkgo), but **since there is no ovary present**, none of these is a fruit.

Aggregate Fruit

Actual fruits are achenes imbedded in the fleshy receptacle.

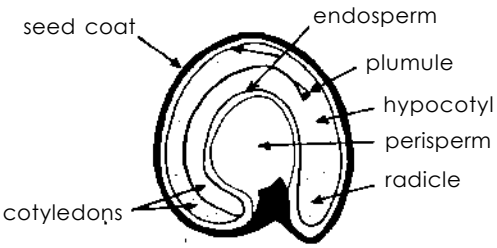
Multiple Fruit

Numerous achene-like fruits develop from flowers that bloom within fleshy covering.

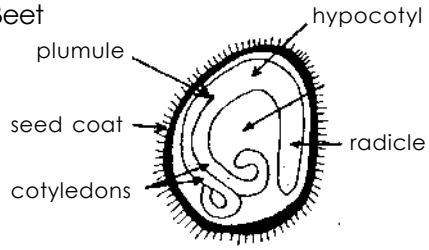
Seeds

The seed, or matured **ovule**, is made up of three parts. The **embryo** is a miniature plant in an arrested state of development. Most seeds contain a built-in food supply called the **endosperm** which can be made up of proteins, carbohydrates, or fats. (Orchid is an exception in producing no endosperm, while in some other mature seeds, the endosperm has been absorbed and stored within the embryo.) The third part is the hard outer covering, called a **seed coat**, which protects the seed from disease and insects and prevents water from entering the seed (this would initiate the germination process before the proper time).

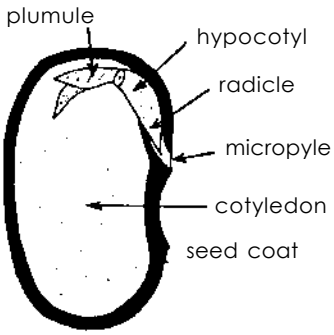
Parts of a Seed



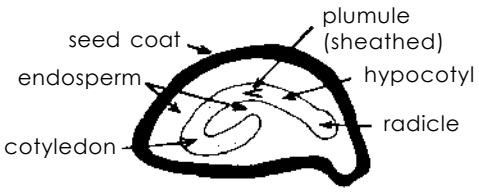
Beta vulgaris
Beet



Lycopersicon esculentum
Tomato



Phaseolus vulgaris
(one cotyledon removed)
Bean



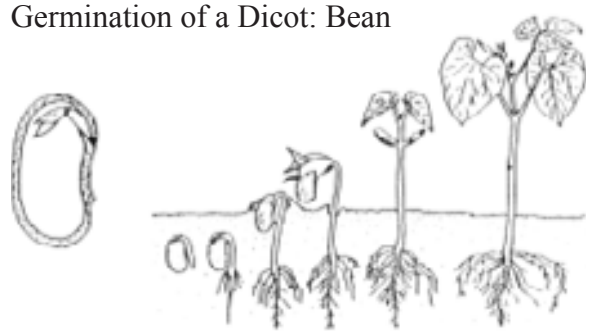
Allium cepa
Onion

Seedlings

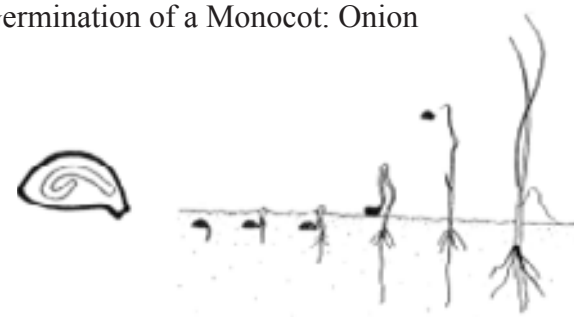
Germination is the resumption of active embryo growth. Prior to any visual signs of growth, the seed must absorb water through the seed coat. In addition, the seed must be in the proper environmental conditions; that is, exposed

to oxygen, favorable temperatures, and for some, correct light. The **radicle** is the first part of the seedling to emerge from the seed. It will develop into the primary root from which root hairs and lateral roots develop. The portion of the seedling between the radicle and the first leaf-like structure is called the **hypocotyl**. The seed leaves, or **cotyledons**, encase the embryo and are usually different in shape from the leaves that the mature plant will produce. Plants producing one cotyledon fall into the group of monocotyledons or **monocots**. Plants producing two seed leaves are called dicotyledons or **dicots**.

Germination of a Dicot: Bean



Germination of a Monocot: Onion



Study Questions

21. A plant will be difficult to successfully transplant if it has: a) a long taproot; b) many fibrous roots; c) many lateral roots; d) pruned roots

22. Most of the mineral and water absorption is done by: a) the root meristem; b) the root cap; c) the root hairs; d) the root tip

23. The male parts of a flower are the:
a) petals and sepals; b) anther and filament;
c) stigma and style; d) pistils and ovules

24. Most holly trees are _____, so in order to get berries both a male and female must be planted.

25. A cluster of flowers arranged on a stem are called an _____.

26. Fruit that comes from a single flower with many ovaries is called: a) simple; b) aggregate;
c) multiple; d) pine cones

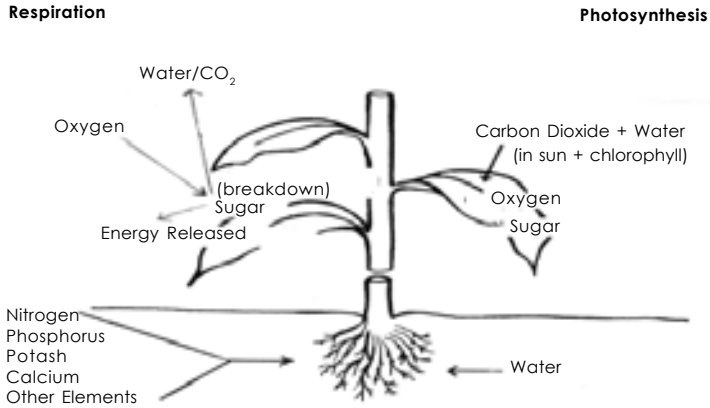
27. The first part of a seedling to emerge from a seed during germination is the:
a) radicle; b) endosperm; c) embryo; d) hypocotyl

Answers:
21 - a; 22 - c; 23 - b; 24 - dioecious; 25 - inflorescence; 26 - b; 27 - a.

Physiology: Plant Growth and Development

The five major plant functions that are the basics for plant growth and development are photosynthesis, respiration, transpiration, absorption, and translocation.

How a Plant Grows



Photosynthesis

One of the major differences between plants and animals is the ability of plants to internally manufacture their own food. To produce food for itself, a plant requires energy from sunlight, carbon dioxide from the air, and water from the soil. If any of these ingredients is lacking, photosynthesis, or food production, will stop. If any factor is removed for a long period of time, the plant will die. Photosynthesis literally means "to put together with light."

carbon dioxide + water ----------> sugar + oxygen
(chlorophyll + light)

$$6CO_2 + 6H_2O \text{ ----------> } C_6H_{12}O_6 + 6O_2$$

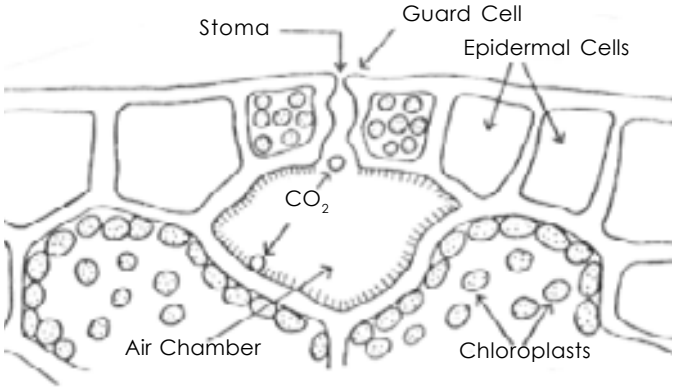
Plants first store the energy from light in simple sugars, such as glucose ($C_6H_{12}O_6$). This food may be converted back to water and carbon dioxide, releasing the stored

energy through the process called respiration. This energy is required for all living processes and growth. Simple sugars are also converted to other sugars and starches (carbohydrates) which may be transported to the stems and roots for use or storage, or may be used as building blocks for more complex structures (e.g., oils, pigments, proteins, cell walls).

Any green plant tissue is capable of photosynthesis. Chloroplasts in these cells contain the green pigment chlorophyll which traps the light energy. However, leaves are generally the site of most food production due to their special structure. The internal tissue (mesophyll) contains cells with abundant chloroplasts in an arrangement that allows easy movement of water and air. The protective upper and lower epidermis (skin) layers of the leaf include many stomata that regulate movement of the gases involved in photosynthesis into and out of the leaf.

Photosynthesis is dependent on the availability of **light**. Generally speaking, as sunlight increases in intensity, photosynthesis increases. This results in greater food production. Many garden crops, such as tomatoes, respond best to maximum sunlight. Tomato production is cut drastically as light intensities drop. Only two or three varieties of "greenhouse" tomatoes will produce any fruit when sunlight is minimal in late fall and early spring.

Leaf Section



Water (H_2O) plays an important role in photosynthesis in several ways. First, it maintains a plant's turgor, the firmness or fullness of plant tissue. Turgor pressure in a cell can be compared to air in an inflated balloon. Water pressure or turgor is needed in plant cells to maintain shape and ensure cell growth. Second, water is split into hydrogen and oxygen by the energy of the sun that has been absorbed by the chlorophyll in the plant leaves. The oxygen (O_2) is released into the atmosphere, and the hydrogen is used in manufacturing carbohydrates. Third, water dissolves minerals from the soil and transports them up from the roots and throughout the plant where they serve as raw materials in the growth of new plant tissues. The soil surrounding a plant should be moist, not too wet or too dry. Water is pulled through the plant by evaporation of water through the leaves (transpiration).

Photosynthesis also requires **carbon dioxide** (CO_2) which enters the plant through the stomata. Carbon and oxygen are used in the manufacturing of carbohydrates. Carbon dioxide in the air is plentiful enough so that it is not a limiting factor in plant growth. However, since carbon dioxide is consumed in making sugars and is not replenished by plants at a rapid rate, a tightly closed greenhouse in midwinter may not let in enough outside air to maintain an adequate carbon dioxide level. Under these conditions, improved crops of roses, carnations, tomatoes, and certain other crops can be produced if the carbon dioxide level is raised with CO_2 generators or, in small greenhouses, with dry ice.

Although not a direct component in photosynthesis, temperature is an important factor. Photosynthesis occurs at its highest rate in the temperature range 65 to 85°F (18 to 27°C) and decreases when temperatures are above or below this range.

Respiration

Carbohydrates made during photosynthesis are of value to the plant when they are converted into energy. This energy is used in the process of building new tissues (plant growth). The chemical process by which sugars and starches produced by photosynthesis are converted into energy is called respiration. It is similar to the burning of wood or coal to produce heat (energy). This process in cells is shown most simply as:

sugar + oxygen ----------> carbon dioxide + water + energy

$$C_6H_{12}O_6 + 6O_2 \text{ ----------> } 6CO_2 + 6H_2O$$

This equation is precisely the opposite of that used to illustrate photosynthesis, although more is involved than just reversing the reaction. However, it is appropriate to relate photosynthesis to a building process, while respiration is a breaking-down process.

Photosynthesis	Respiration
Produces food	Uses food for plant energy
Stores energy	Releases energy

Photosynthesis	Respiration
Occurs in cells containing chloroplasts	Occurs in all cells
Releases oxygen	Uses oxygen
Uses water	Produces water
Uses carbon dioxide	Produces carbon dioxide
Occurs in sunlight	Occurs in darkness and light

By now, it should be clear that respiration is the reverse of photosynthesis. Unlike photosynthesis, respiration occurs at night as well as during the day. Respiration occurs in all life forms and in all cells. The release of accumulated carbon dioxide and the uptake of oxygen occurs at the cell level. In animals, blood carries both carbon dioxide and oxygen to and from the atmosphere by means of the lungs or gills. In plants, there is simple diffusion into the open spaces around the cells, and exchange occurs through the leaf stomata or stem or root surfaces.

Transpiration

Transpiration is the process by which a plant loses water, primarily from leaf stomata. Transpiration is a necessary process that involves the use of about 90% of the water that enters the plant through the roots. The other 10% of the water is used in chemical reactions and in plant tissues. Transpiration is involved in water absorption by roots, mineral transport from the roots to the upper plant parts, movement of sugars and plant chemicals, and maintenance of cell turgor pressure.

The amount of water lost from the plant depends on several environmental factors such as temperature, humidity, and wind or air movement. An increase in temperature or air movement decreases humidity outside the leaf and increases the rate of transpiration. This presents a continuing danger to plants as the rate of water loss may not be matched by the rate of water absorption from dry soil into the roots. A water deficit in the plant may only lead to temporary wilting from which the plant may rapidly recover when the transpiration rate decreases later in the day or stops overnight. The guard cells respond to the loss of turgor by shrinking and closing the stomata. While this significantly reduces further damaging water loss, it also impedes carbon dioxide entry for photosynthesis. Repeated temporary wilting can lead to stunted plants due to reduction of the food supply and other metabolic changes, especially in cell division and enlargement.

Absorption

Absorption is the process by which substances, particularly water and minerals, are moved into the plant. This occurs mainly through the roots in the tip region where root hairs are present, but it may also occur through leaf surfaces. Water absorption into roots may be a passive process due to a "pulling" action, drawing water through the xylem tubes to replace water lost from the leaves through transpiration. Other water absorption is an active process linked to active absorption of mineral nutrients. This is discussed later in the section on plant nutrition.

Translocation

Water, minerals, and foods are moved through a plant's vascular system. All such movement is referred to as translocation, although the substances moved and tissues involved may be differentiated. Water and simple mineral nutrients move from the roots to upper plant parts in the transpiration stream -- the upward water flow due to transpiration. This occurs in the dead cells of the xylem. Sugars and other plant chemicals into which minerals have been combined follow a different path through the living phloem cells. This translocation is often an active process requiring respiration energy as the substances are moved upward and downward in the plants to growing areas or storage.

Study Questions

28. Photosynthesis uses ____ and ____ to produce carbohydrates: a) sugar, water; b) carbon dioxide, sugar; c) carbon dioxide, water; d) nutrients, water

29. The green pigments in cells that trap light energy for photosynthesis are called _____.

30. Respiration does NOT:
    a) occur at all times; b) occur in all cells;
    c) produce energy; d) release oxygen

31. Transpiration is involved in:
    a) water absorption by the roots; b) respiration;
    c) food storage in the roots; d) ozone depletion

32. Translocation of water occurs in the:
    a) phloem; b) cambium; c) xylem; d) stomata

Answers:
28 - c; 29 - chlorophyll; 30 - d; 31 - a; 32 - c

Environmental Factors Affecting Plant Growth

Plant growth and distribution are limited by the environment. If any one environmental factor is less than ideal, it will become a limiting factor in plant growth. Limiting factors are also responsible for the geography of plant distribution. For example, only plants adapted to limited amounts of water can live in deserts. Most plant problems are caused by environmental stress, either directly or indirectly. Therefore, it is important to understand the environmental aspects that affect plant growth. These factors are light, temperature, water, humidity, and nutrition.

Light

Light has three principal characteristics that affect plant growth: quantity, quality, and duration.

Light **quantity** refers to the intensity or concentration of sunlight and varies with the season of the year. The maximum is present in the summer and the minimum in winter. The more sunlight a plant receives (up to a point), the better capacity it has to produce plant food through photosynthesis. As the sunlight quantity decreases, the photosynthetic process decreases. Light quantity can be decreased in a garden or greenhouse by using cheesecloth shading above the plants. It can be increased by surrounding plants with white or reflective material, or supplemental lights.

Light **quality** refers to the color or wavelength reaching the plant surface. Sunlight can be broken up by a prism into respective colors of red, orange, yellow, green, blue, indigo, and violet. On a rainy day, raindrops act as tiny prisms and break the sunlight into these colors, producing a rainbow. Red and blue light have the greatest effect on plant growth. Green light is least effective to plants as they reflect green light and absorb none. It is this reflected light that makes them appear green to us. Blue light is primarily responsible for vegetative growth or leaf growth. Red light, when combined with blue light, encourages flowering in plants. Fluorescent, or cool-white, light is high in the blue range of light quality and is used to encourage leafy growth. Such light would be excellent for starting seedlings. Incandescent light is high in the red or orange range, but generally produces too much heat to be a valuable light source. Fluorescent "grow" lights have a mixture of red and blue colors that attempts to imitate sunlight as closely as possible, but they are costly and generally not of any greater value than regular fluorescent lights.

Light **duration**, or photoperiod, refers to the amount of time that a plant is exposed to sunlight. When the concept of photoperiod was first recognized, it was thought that the length of periods of light triggered flowering. The various categories of response were named according to the light length (i.e., short-day and long-day). It was then discovered that it is not the length of the light period, but the length of uninterrupted dark periods that is critical to floral development. The ability of many plants to flower is controlled by photoperiod. Plants can be classified into three categories depending upon their flowering response to the duration of darkness. These are short-day, long-day, or day-neutral plants.

Short-day plants form their flowers only when the day length is less than about 12 hours in duration. Short-day plants include many spring- and fall-flowering plants, such as chrysanthemum and poinsettia. **Long-day** plants form flowers only when day lengths exceed 12 hours (short nights). They include almost all of the summer-flowering plants, such as rudbeckia and California poppy, as well as many vegetables, including beet, radish, lettuce, spinach, and potato. **Dayneutral** plants form flowers regardless of day length. Some plants do not really fit into any category, but may be responsive to combinations of day lengths. The petunia will flower regardless of day length, but flowers earlier and more profusely under long daylight. Since chrysanthemums flower under the short-day conditions of spring or fall, the method for manipulating the plant into experiencing short days is very simple. If long days are predominant, a shade cloth is drawn over the chrysanthemum for 12 hours daily to block out light until flower buds are initiated. To bring a long-day plant into flower when sunlight is not present longer than 12 hours, artificial light is added until flower buds are initiated.

Temperature

Temperature affects the productivity and growth of a plant, depending on whether the plant variety is a warm- or cool-season crop. If temperatures are high and day length is long, a cool-season crop such as spinach will bolt rather than produce the desired flower. Temperatures that are too low for a warm-season crop such as tomato will prevent fruit set. Adverse temperatures also cause stunted growth and poor quality, for example, the bitterness in lettuce is caused by high temperatures.

Sometimes temperatures are used in connection with day length to manipulate the flowering of plants. Chrysanthemums will flower for a longer period of time if daylight temperatures are 59°F (15°C). The Christmas cactus forms flowers as a result of short days and low temperatures. Temperatures alone also influence flowering. Daffodils are forced to flower by putting the bulbs in cold storage in October at 35 to 40°F (2 to 4°C). The cold temperatures allow the bulb to mature. The bulbs are transferred to the greenhouse in midwinter where growth begins. The flowers are then ready for cutting in three to four weeks.

Thermoperiod refers to the difference in temperature between night and day. Plants produce maximum growth when exposed to a day temperature that is about 10 to 15° higher than the night temperature. This allows the plant to photosynthesize (build up) and respire (break down) during an optimum daytime temperature and to curtail the rate of respiration during a cooler night. High temperatures cause increased respiration, sometimes above the rate of photosynthesis. This means that the products of photosynthesis are being used more rapidly than they are being produced. For growth to occur, photosynthesis must be greater than respiration.

Low temperatures can result in poor growth. Photosynthesis is slowed down at low temperatures. Since photosynthesis is slowed, growth is slowed, and this results in lower yields. Not all plants grow best in the same temperature range. For example, snapdragons grow best when night temperatures are 55°F (12°C); the poinsettia prefers 62°F (17°C). Florist cyclamen does well under very cool conditions, while many bedding plants prefer a higher temperature. Recently, it has been found that roses can tolerate much lower night temperatures than previously believed. This has meant a conservation in energy for greenhouse growers.

However, in some cases, a certain number of days of low temperatures are needed by plants to grow properly. This is true of crops growing in cold regions of the country. Peaches are a prime example; most varieties require 700 to 1000 hours below 45°F (7°C) and above 32°F (0°C) before they break their rest period and begin growth. Lilies need 6 weeks at 33°F (1°C) before blooming.

Plants can be classified as either hardy or nonhardy (tender), depending on their ability to withstand cold temperatures. Winter injury can occur to nonhardy plants if temperatures are too low or if unseasonably low temperatures occur early in the fall or late in the spring. Winter injury may also occur because of desiccation (drying out) -- plants need water during the winter. When the soil is frozen, the movement of water into the plant is severely restricted. On a windy winter day, broadleaved evergreens can become water-deficient in a few minutes; the leaves or needles then turn brown. Wide variations in winter temperatures can cause premature bud break in some plants and consequent bud-freezing damage. Late spring frosts can ruin entire peach crops. If temperatures drop too low during the winter, entire trees of some species are killed by the freezing and splitting of plant cells and tissue.

Review of Temperature Effects on Plant Growth:

Photosynthesis: Increases with temperature to a point
Respiration: Rapidly increases with temperature
Transpiration: Increases with temperature
Flowering: May be partially triggered by temperature
Sugar storage: Low temperatures reduce energy use and increase sugar storage
Dormancy: Warmth after a period of low temperature will break dormancy, and the plant will resume active growth

Water

As mentioned earlier, water is a primary component of photosynthesis. It maintains the turgor pressure or firmness of tissue and transports nutrients throughout the plant. In maintaining turgor pressure, water is the major constituent of the protoplasm (living material) of a cell. By means of turgor pressure and other changes in the cell, water regulates the opening and closing of the stomates, thus regulating transpiration. Water also provides the pressure to move a root through the soil. Among water's most critical roles is that of the solvent for minerals moving into the plant and for carbohydrates moving to their site of use or storage.

Relative Humidity is the ratio of water vapor in the air to the amount of water the air could hold at a given temperature and pressure, expressed as a percent. For example, if a pound of air at 75°F could hold 4 grams of water vapor and there are only 3 grams of water in the air, then the relative humidity (RH) is:

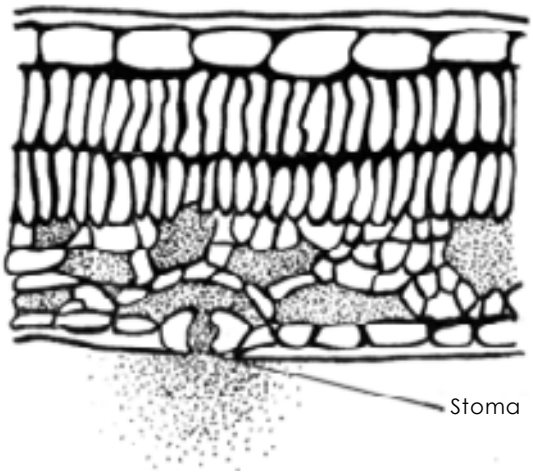
$$RH = \frac{\text{water in the air}}{\text{water the air could hold (at constant temperature and pressure)}}$$

so, RH = 3/4 = 0.75. Expressed as a percent = 75%

Warm air can hold more water vapor than cold air; therefore, if the amount of water in the air stays the same and the temperature increases, the relative humidity decreases.

Water vapor will move from an area of high RH to one of low RH. The greater the difference in humidity, the faster water will move.

Cross Section of Leaf
(Dots Represent Relative Humidity)



The relative humidity in the air space between the cells within the leaf approaches 100%; therefore, when the stomate is open, water vapor rushes out. As the vapor moves out, a cloud of high humidity is formed around the stomate. This cloud of humidity helps slow down transpiration and cool the leaf. If air movement blows the humid cloud away, transpiration will increase.

Nutrition

Many people confuse plant nutrition with plant fertilization. Plant nutrition refers to the needs and uses of the basic chemical elements in the plant. Fertilization is the term used when these materials are supplied to the environment around the plant. A lot must happen before a chemical element supplied in a fertilizer can be taken up and used by the plant.

Plants need 16 elements for normal growth. Carbon, hydrogen, and oxygen are found in air and water. Nitrogen, potassium, magnesium, calcium, phosphorous, and sulfur are found in the soil. The latter six elements are used in relatively large amounts by the plant and are called macronutrients. There are seven other elements that are used in much smaller amounts; these are called micronutrients or trace elements. The micronutrients, which are found in the soil, are iron, zinc, molybdenum, manganese, boron, copper, chlorine, and cobalt. All 16 elements, both macronutrients and micronutrients, are essential for plant growth.

Most of the nutrients that a plant needs are dissolved in water and then absorbed by the roots. Many nutrient combinations in fertilizers dissolve easily, and those nutrients can be readily absorbed. Sometimes two dissolved nutrients will combine into a product that has very low solubility. Availability of both nutrients to the plant is then severely reduced. This can occur with calcium and phosphorus and the micronutrients. Nutrient solubility is also affected by soil pH. High (alkaline) pH levels drastically reduce the solubility and availability of micronutrients (a factor in iron deficiency in azaleas and other ericaceous plants), while low (very acidic) pH levels make some micronutrients (and non-nutrient minerals such as aluminum) so highly available as to injure the plant. Another consideration is the nutrient balance in the soil. For example, calcium and magnesium are absorbed similarly, but magnesium is absorbed more readily. The root does not select the nutrient to be absorbed; if both are present at the absorption site, the magnesium will be absorbed. This is why a soil test may indicate that, while there is sufficient calcium in the soil, a plant can suffer calcium deficiency because of an excess of magnesium competing for absorption.

The process whereby nutrients are absorbed varies. Water and nutrients can move between the outer cells of the root, but eventually they must cross a membrane to enter a cell. Water and some nutrients can do this easily (a passive process) while other nutrients are too large for the ‘holes’ in the membrane, and energy is needed to move these nutrients into the cell (an active process). Absorption is generally a combination of these processes; certain nutrients are actively absorbed, others enter passively to maintain a chemical balance, and water moves in because of the concentration of nutrients inside the root.

Active absorption is an important part of nutrient and water absorption. The energy needed for this active process is provided by respiration in the root cell. This requires sugar transported from the leaves and oxygen that must be available in the soil and not transported within the plant. Without adequate soil oxygen, there is no energy for nutrient absorption, and without the accumulation of nutrients in the root, there is no concentration difference

for passive water absorption.

Anything that lowers or prevents the production of sugars in the leaves can lower nutrient absorption. If the plant is under stress due to low light or extremes in temperature, nutrient deficiency problems may develop. The stage of growth or rate of growth may also affect the amount of nutrients absorbed. Many plants go into a rest period, or dormancy, during part of the year. During this dormancy, few nutrients are absorbed. Plants may also absorb different nutrients just as flower buds begin to develop.

Foliar Absorption: A Special Case

Under normal growing conditions, plants absorb most nutrients except carbon, hydrogen, and oxygen from the soil. However, some nutrients can also be absorbed by the leaves if they are sprayed with a dilute solution. The factors that affect absorption by the cell are still important because the nutrient must enter the cell to be used by the plant. Care must be taken that the concentration of the nutrient is not too high or the leaf will be injured. Also, the leaf is covered by a thin layer of wax called the cuticle that the nutrient must get around or through before it can enter the cell.

Study Questions

33. Characteristics of light that affect plant growth include: a) intensity; b) photoperiod; c) wavelength; d) any of the above

34. A light source that is good for leafy, green indoor plants would be: a) fluorescent; b) incandescent; c) warm-white; d) lava lamps and black lights

35. Plants that can withstand cold temperatures are called _____.

36. High temperatures do NOT affect plant growth by: a) increasing photosynthesis; b) increasing respiration; c) increasing transpiration; d) increasing sugar storage

37. Relative humidity increases as: a) temperature increases; b) temperature decreases; c) humidity decreases; d) humidity increases

38. Compared to macronutrients, micronutrients are: a) less important for plants; b) smaller molecules; c) used in smaller quantities; d) only used by small plants

39. Nutrient solubility is affected by: a) soil pH; b) nematodes; c) temperature; d) oxygen in the soil

40. _____ requires energy provided by respiration for uptake of nutrients that are too large to pass through the cell membranes passively.

Answers:
33 - d; 34 - a; 35 - hardy; 36 - d; 37 - b; 38 - c; 39 - a; 40 - active absorption

Macronutrient Outline

Nitrogen (N)

Leaches from soil

Mobile in plant

Nitrogen Excess:

Succulent growth, dark green color, weak spindly growth, few fruits, may cause brittle growth especially under high temperatures

Nitrogen deficiency:

Reduced growth, yellowing (chlorosis), reds and purples may intensify with some plants, reduced lateral branching; symptoms appear first on older growth

Action notes:

Uptake of N is inhibited by high P levels. Indoors, the best N/K ration is 1/1 unless light is extremely high. In soils with a high C:N ratio, more N should be supplied

Phosphorus (P)

Does not leach from soil readily

Mobile in plant

Phosphorus excess:

Shows up as micronutrient deficiency of Zn, Fe, or Co

Phosphorus deficiency:

Reduced growth, color may intensify, browning or purpling in foliage of some plants, thin stems, reduced lateral breaks, loss of lower leaves, reduced flowering

Action notes:

Rapidly “fixed” on soil particles when applied. Under acid conditions fixed with Fe, Mg, and Al. Under alkaline conditions fixed with Ca. Important for young plants and seedling growth. High P interferes with micronutrient absorption and N absorption. Used in relatively small amounts when compared to N and K. May leach from soil high in bark or peat

Potassium (K)

Leaches from soil

Mobile in plant

Potassium excess:

Causes N deficiency in plants and may affect the uptake of other positive ions

Potassium deficiency:

Reduced growth, shortened internodes, marginal burn or scorch (brown leaf edges), necrotic (dead) spots in the leaf, reduction of lateral branching and tendency to wilt readily

Action notes:

N/K balance is important; high N/low K favors vegetative growth; low N/high K promotes reproductive growth (flower, fruit)

Magnesium (Mg)

Leaches in soil

Mobile in plant

Magnesium (Mg)

Magnesium excess:

Interferes with Ca uptake

Magnesium deficiency:

Symptoms are reduction in growth, marginal chlorosis or interveinal chlorosis (yellow between the veins) of the older leaves in some species, reduction in seed production, and cupped leaves

Action notes:

Mg is commonly deficient in foliage plants because it is leached and not replaced. Epsom salts at a low rate of 1 teaspoon per gallon may be used two times a year. Mg can also be absorbed by leaves if sprayed with a weak solution. Dolomitic limestone can be applied in outdoor situations to rectify a deficiency

Calcium (Ca)

Moderately leachable from soil

Not mobile in plant

Calcium excess:

Interferes with Mg absorption. High Ca usually causes high pH which then precipitates many of the micronutrients so that they become unavailable to the plant

Calcium deficiency:

Inhibition of bud growth, death of root tips, cupping of mature leaves, weak growth, blossom end rot of many fruits, pits on root vegetables

Action notes:

Ca is important to pH control and is rarely deficient if the correct pH is maintained. Water stress (too much or too little) can affect Ca relationships within the plant causing deficiency in the location where Ca was needed at the time of stress

Sulphur (S)

Leaches from soil

Not mobile in plant

Sulfur excess:

Sulfur excess is usually in the form of air pollution

Sulfur deficiency:

Sulfur is often a carrier or impurity in fertilizers and is rarely deficient. It may also be absorbed from the air and is a by-product of combustion. Symptoms are a general yellowing of affected leaves or entire plant

Action notes:

Sulfur excess is difficult to control

Micronutrient Outline

The majority of the micronutrients are not mobile; thus, deficiency symptoms are usually found on new growth. Their availability in the soil is highly dependent upon the pH and the presence of other ions. The proper balance between the ions present is important, as many micronutrients are antagonistic to each other. This is especially true of the heavy metals where an excess of one element may show up as a deficiency of another. If the pH is maintained at the proper level and a fertilizer which contains micronutrients is used once a year, deficiency symptoms (with the exception of iron deficiency symptoms) are rarely found on indoor plants. Many of the micronutrients are enzyme activators.

Iron (Fe)

Iron excess:

Rare except on flooded soils

Iron deficiency:

Interveinal chlorosis primarily on young tissue, which may become white. Fe deficiency may be found under the following conditions even if Fe is in the soil: soil high in Ca, poorly drained soil, soil high in Mn, high pH, high P, soil high in heavy metals (Cu, Zn), oxygen deficient soils or when nematodes attack the roots. Fe should be added in the chelate form; the type of chelate needed depends upon the soil pH.

Boron (B)

Boron excess:

Blackening or death of tissue between veins

Boron deficiency:

Failure to set seed, internal breakdown, death of apical buds

Zinc (Zn)

Zinc excess:

Appears as Fe deficiency. Interferes with MG

Zinc deficiency:

“Little leaf,” reduction is leaf size, short internodes, distorted or puckered leaf margins, interveinal chlorosis

Copper (Cu)

Copper excess:

Can occur at low pH; shows up as Fe deficiency

Copper deficiency:

Copper (Cu)

New growth small, misshapen, wilted; may be found in soil peat soils

Manganese (Mn)

Manganese excess:

Reduction in growth, brown spotting on leaves; shows up as Fe deficiency found under acid conditions

Manganese deficiency:

Interveinal chlorosis of leaves followed by brown spots producing a checkered red effect

Molybdenum (Mo)

Molybdenum deficiency:

Interveinal chlorosis on older or midstem leaves, twisted leaves (whiptail)

Chlorine (Cl)

Chlorine excess:

Salt injury, leaf burn, may increase succulence

Chlorine deficiency:

Wilted leaves which become bronze then chlorotic and may die; club roots

Cobalt (Co)

Necessary to recently established plants

Essential for nitrogen fixation

Little is known about its deficiency or excess (toxicity) symptoms

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Chapter 3
Soils

Soils

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Soils

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Revised by *Dan Nortman, Extension Agent, Agriculture and Natural Resources (2015)*
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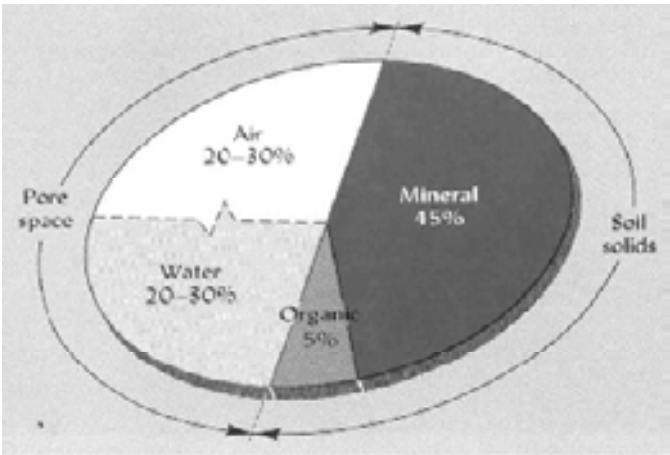
Soil is formed when rock (parent material) is broken down by climate and vegetation over a period of time. Soil is weathered rock fragments and decaying remains of plants and animals (organic matter). It also contains varying amounts of air, water, and microorganisms. It furnishes mechanical support and nutrients for growing plants.

Contents

Introduction

A desirable surface soil in good condition for plant growth contains approximately 50% solid material and 50% open pore space. Most of the soil solids are a mineral component which is usually made up of many different kinds and sizes of particles, ranging from those visible to the unaided eye to particles so small that they can only be seen with the aid of a very powerful (electron) microscope. This mineral material comprises about 45% to 48% of the total volume. Organic material makes up about 2% to 5% of the volume and may contain both plant and animal material in varying stages of decomposition. Under ideal or near-ideal moisture conditions for growing plants, soil pore spaces contain about 25% air and 25% water based on the total volume of soil.



Although most Virginia soils developed under forest vegetation, variables such as climate, elevation, and parent material have provided a diversity of soil conditions.

The percentage of mineral matter and organic matter in a cubic foot of surface soil varies from one soil to another, and within the same soil, depending on the kinds of crops grown, frequency of tillage, and wetness or drainage of the soil. Content of organic matter will usually be high in soils that have not been cultivated over long periods of time. Soils that are tilled frequently and have relatively small amounts of plant residues worked into the soil are usually low in organic matter. Plowing and tilling the soil increases the amount of air in the soil, which increases the rate of organic matter decomposition. Soils with poor drainage or high water tables usually have a higher organic matter content than those that are well drained, because water excludes air from the soil mass.

Since either air or water fills pore spaces, the amount of air in a soil at a particular time depends on the amount of water present in the pore spaces. Immediately after a rain, there is more water and less air in the pore spaces. Conversely, in dry periods, a soil contains more air and less water. Increasing organic matter content usually increases water-holding capacity, but adding large amounts of undecomposed organic material reduces water-holding capacity until the material has partially decomposed.

Soil Profile

O	Leaf litter
A	Mineral horizon at the surface showing organic matter enrichment; topsoil
E	Subsurface horizon showing depletion of organic matter, clay, iron, and aluminum compounds
B	Subsoil horizon showing enrichment of clay material, iron, aluminum, or organic compounds
C	Horizon of loosened or unconsolidated parent material
R	Hard bedrock

Soil Horizons or Layers

Most soils have four distinct principal layers or horizons. Each layer can have two or more sub-horizons. The principal horizons (collectively called the soil profile) are: O, leaf litter; A, surface soil or topsoil; E, the subsurface; and B, the subsoil. Beneath the soil profile lies: C, the parent material; and R, rock, similar to that from which the soil developed. Horizons usually differ in color, texture, consistency, and structure. In addition, there are usually considerable differences in chemical characteristics or composition.

The **surface** and **subsurface** are usually the coarsest layers. The surface soil contains more organic matter than the other soil layers. Organic matter gives a gray, dark-brown, or black color to the surface horizon, the color imparted depending largely upon the amount of organic matter present. Soils that are highest in organic matter

usually have the darkest surface colors. The surface layer is usually most fertile and has the greatest concentration of plant roots; plants obtain much of their nutrients and water from the surface soil.

The **subsoil** layer is usually finer and firmer than the surface soil. Organic matter content of the subsoil is usually much lower than that of the surface layer. Subsoil colors are strong and bright; shades of red, brown, and yellow are frequently observed. The subsoil supports the surface soil and may be considered the soil reservoir, providing storage space for water and nutrients for plants, aiding in temperature regulation of the soil, and supplying air for the roots of plants.

The bottom horizon, or **parent material**, is decomposed rock that has acquired some characteristics of the subsoil and retained some characteristics of the rock from which it weathered. It is not hard, like rock, but may show the form or structure of the original rocks or layering if it is in a water-laid deposit. The parent material influences soil texture, natural fertility, rate of decomposition (and thus rate of soil formation), acidity, depth, and in some cases, topography (or lay of the land) on which the soil is formed.

Physical Properties of Soils

The physical properties of a soil are those characteristics which can be seen with the eye or felt between the thumb and fingers. They are the result of soil parent materials being acted upon by climatic factors (such as rainfall and temperature), and affected by topography (slope and direction, or aspect) and vegetation (kind and amount, such as forest or grass) over a period of time. A change in any one of these influences usually results in a difference in the type of soil formed. Important physical properties of a soil are color, texture, structure, drainage, depth, and surface features (stoniness, slope, and erosion).

The physical properties and chemical composition largely determine the suitability of a soil for its planned use and the management requirements to keep it most productive. To a limited extent, the fertility of a soil determines its possible uses, and to a larger extent, its yields. However, fertility level alone is not indicative of its productive capacity, since soil physical properties usually control the suitability of the soil as growth medium. Fertility is more easily changed than soil physical properties.

Color

When soil is examined, color is one of the first things noticed. It indicates extremely important soil conditions. In general, color is determined by: (1) organic matter content, (2) drainage conditions, and (3) degree of oxidation (extent of weathering).

Surface soil colors vary from almost white, through shades of brown and gray, to black. Light colors indicate a low organic matter content and dark colors can indicate a high content. Light or pale colors in the surface soil are frequently associated with relatively coarse texture, highly leached conditions, and high annual temperatures. Dark colors may result from high water table conditions (poor drainage), low annual temperatures, or other influences that induce high organic matter content and, at the same time, slow the oxidation of organic materials. However, soil coloration may be due to the colors imparted by the parent material. Shades of red or yellow, particularly where associated with relatively fine textures, usually indicate that subsoil material has been incorporated in the surface layer.

Subsoil colors, in general, are indications of air, water, and soil relationships and the degree of oxidation of certain minerals in the soil. Red and brown subsoil colors indicate relatively free movement of air and water allowed by the soil. If these or other bright colors persist throughout the subsoil, aeration is favorable. Some well-aerated subsoils will appear mottled (have mixed colors), in shades of red and brown.

Yellow-colored subsoils usually indicate some drainage impediment. Most mottled subsoils, especially those where gray predominates, have too much water and too little air (oxygen) much of the time. The red-to-brown color of subsoils comes from iron coatings under well-aerated conditions. In wet soils with low oxygen levels, the iron coatings are chemically and biologically removed, and the gray color of background soil minerals shows.

Texture

Texture refers to the relative amounts of differently sized soil particles (i.e., percent sand, silt, and clay), or the fineness/coarseness of the mineral particles in the soil. In each texture class, there is a range in the amount of sand, silt, and clay that class contains.

The coarser mineral particles of the soil are **sand**. These particles vary in size. Most sand particles can be seen

without a magnifying glass. All feel rough when rubbed between the thumb and fingers.

Relatively fine soil particles that feel smooth and floury are called **silt**. When wet, silt feels smooth but is not slick or sticky. When dry, it is smooth, and if pressed between the thumb and finger, will retain the imprint. Silt particles are so fine that they cannot usually be seen by the unaided eye and are best seen with a microscope.

Clays are the finest soil particles. Clay particles can be seen only with the aid of a very powerful (electron) microscope. They feel extremely smooth when dry, and become slick and sticky when wet. Clay will hold the form into which it is molded.

Loam is a textural class of soil that has moderate amounts of sand, silt, and clay. Loam contains approximately 7% to 27% clay, 28% to 50% silt, and 23% to 50% sand. Loams are desirable for plant growth.

Determining Soil Texture

Soil texture (the proportions of sand, silt, and clay particles) can be accurately determined by a lab. A fairly good estimate can be made at home, however, using the texture-by-feel method. The first part of this test determines the amount of clay in your soil. Take a small amount of soil from your representative sample, moisten it, and knead it into a smooth, walnut-sized ball in your hand; if it is impossible to form a ball, it is a sand soil. Using your thumb, gently push a ribbon of soil of even thickness out between your thumb and crooked forefinger. A loamy sand soil will form no ribbon at all. A ribbon less than 1 inch indicates a loam; 1 to 2 inches, a clay loam; and more than 2 inches, a clay soil.

The second part of the test will further qualify the soil texture as sandy or silty, if necessary. Take a pinch of soil, place it in your palm, and thoroughly wet it. Rub your finger in the soil and note if it feels very smooth and floury (silty), very gritty (sandy), or equally smooth and gritty (no further qualification of the texture you determined in the first part of the test is needed). For example, if your soil forms a 1.5 inch ribbon (a clay loam), and feels very smooth and floury in the second part of the test (silty), then your soil texture is a silty clay loam.

Although there are approximately 20 classes of soil texture, most surface soils in Virginia fall into five general textural classes. Each class name indicates the size of the mineral particles that are dominant in the soil. Texture is determined in the field by rubbing moist-to-wet soil between the thumb and fingers. These observations can be checked in the laboratory by mechanical analysis or by separation into clay, silt, and various sized sand groups. Regardless of textural class, all soils in Virginia contain sand, silt, and clay, although the amount of a particular particle class may be small.

Principal Surface Soil Classes Found in Virginia:

* Loam - When rubbed between the thumb and fingers, approximately equal influence of sand, silt, and clay is felt.
* Sandy loam - Varies from very fine loam to very coarse. Feels quite sandy or rough, but contains some silt and a small amount of clay. The amount of silt and clay is sufficient to hold the soil together when moist.
* Silt loam - Silt is the dominant particle in silt loam, which feels quite smooth or floury when rubbed between the thumb and fingers.
* Silty clay loam - Noticeable amounts of both silt and clay are present in silty clay loam, but silt is a dominant part of the soil. It is smooth to the touch when dry, but when moist, it becomes somewhat slick/sticky.
* Clay loam - Clay dominates a clay loam, which is smooth when dry and slick/sticky when wet. Silt and sand are usually present in noticeable amounts in this texture of soil, but are overshadowed by clay.

Specific soil attributes can be found in the online soil survey: http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm

Other textural designations of surface soils are sands, loamy sands, sandy clay loams, and clays. In each textural class there is a range in the amount of sand, silt, or clay that class may contain. The composition of each textural class does not allow for overlap from one class to another.

Texture of soil influences many different characteristics. A brief comparison between sandy and clay soils will highlight these points. Coarse-textured or sandy soils allow water to enter at a faster rate and to move more freely than in a clay. In addition, the relatively low water-holding capacity and the large amount of air present in sandy soils allows them to warm up faster than fine-textured soils. Sandy soils are also more easily tilled. They are well-suited for the production of special crops such as vegetables, flue-cured tobacco, peanuts, and certain fruits.

Structure

Soil particles are grouped together to form structural pieces called peds or aggregates. In surface soil, the structure will usually be granular unless it is disrupted. The soil aggregates will be rounded and vary in size from that of a very small shot pellet to that of a large pea. If organic matter content is low and the soil has been under continuous cultivation, the soil structure may be quite indistinct. If the soil is fine-textured, it may have a blocky subsoil structure.

Air and water movement within the soil is closely related to its structure. Good structure allows rapid movement of air and water, while poor structure slows down this movement. Water can enter a surface soil that has granular structure more rapidly than one that has little structure. Since plant roots move through the same channels in the soil as air and water, good structure allows extensive root development while poor structure discourages it. Water, air, and plant roots move more freely through subsoils that have blocky structure than those with a platy horizontal structure. Good structure of the surface soil is promoted by an adequate supply of organic matter, and by working the soil only when moisture conditions are correct.

Plant root growth also changes the soil structure, sending roots into the soil for mechanical support and to gather water and nutrients. As they grow, the roots of plants tend to enlarge the openings in the soil. When they die and decay, they leave channels for movement of air and water. In addition to the plants that we see, there are bacteria, molds, and other very small plants growing in the soil which can be seen only with the aid of a microscope. Even these plants enrich the soil as they die.

Drainage

Soil drainage is defined as the rate and extent of water movement in the soil, including movement across the surface as well as downward through the soil. Slope is a very important factor in soil drainage. Other factors include texture, structure, and physical condition of surface and subsoil layers. Soil drainage is indicated by soil color.

Clear, bright subsoil colors indicate well-drained soils. Mixed, drab, and dominantly gray colors indicate imperfection in drainage. Low-lying areas within the landscape receive run-off water. Frequently, the water

Examples of Soil Structure

Name	*Shape*	*Description*	*Where commonly found in soils*
Single Grain		Usually individual sand grains not held together	Sandy or loamy textures
Granular		Porous granules held together by organic matter and some clay	“A” horizons with some organic matter
Platy		Aggregates that have a thin vertical dimension with respect to lateral dimensions	Compacted layers and sometimes “E” horizons
Blocky		Roughly equidimensional peds usually higher in clay that other structural aggregates	“B” horizons with clay
Prismatic		Structural aggregates that have a much greater vertical than lateral dimension	In some “B” horizons
Massive		No definite structure or shape; usually hard	“C” horizons or compact transported material

from these areas must escape by lateral movement through the soil or by evaporation from the surface, as poor structure and other physical influences do not allow drainage.

Too much or too little water in the soil is equally undesirable. With too much water, most plants will suffocate. Where there is too little water, plants will wilt and eventually die. The most desirable soil moisture situation is one in which approximately $^1/_2$ of the pore space of the surface soil is occupied by water.

Depth

The effective depth of a soil for plant growth is the vertical distance into the soil from the surface to a layer that essentially stops the downward growth of plant roots. The barrier layer may be rock, sand, gravel, heavy clay, or a partially cemented layer.

Terms that are used to express effective depth of soil are:	
Very shallow	Soil surface is less than 10 inches from a layer that retards root development
Shallow	Soil surface is 10 to 20 inches from a layer that retards root development
Moderately deep	Soil surface is 20 to 36 inches from a layer that retards root development
Deep	Soil surface is 36 to 60 inches from a layer that retards root development
Very deep	Soil surface is more than 60 inches from a layer that retards root development

Soils that are deep, well drained, and have desirable texture and structure are suitable for the production of most crops. Deep soils can hold more plant nutrients and water than can shallow soils with similar textures. The depth of a soil and its capacity for nutrients and water frequently determine the yield from a crop, particularly annual crops grown through the summer months.

Plants growing on shallow soils also have less mechanical support than those growing in deep soils. Trees growing in shallow soils are more frequently blown over by wind than are those growing in deep soils.

Erosion

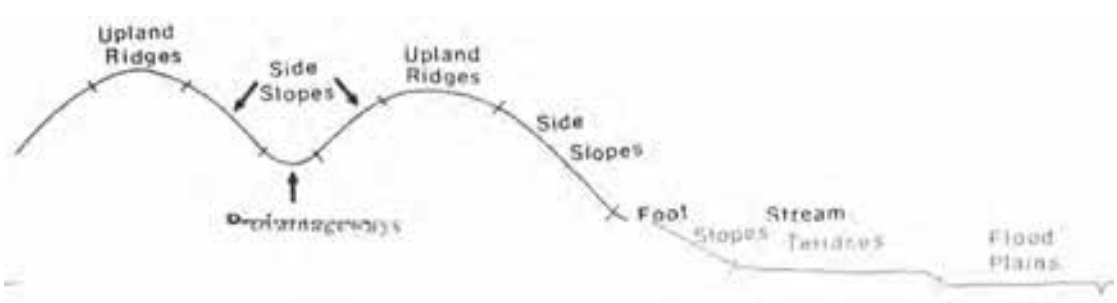
Soils that have lost part or all of their surface are usually harder to till and have lower productivity than those that have desirable thickness of surface soil. To compensate for surface soil loss, better fertilization, liming, and other management practices should be used. Increasing the organic matter content of an eroded soil often improves its tillage characteristics, as well as its water and nutrient holding capacity.

The principal reasons for soil erosion in Virginia are:

* Insufficient vegetative cover
* Overexposure through the use of cultivated crops on soils not suited to cultivation
* Improper equipment and methods used in preparation and tillage of the soil.

Soil erosion can be held to a minimum by:

* Producing crops to which the soil is suited
* Mulching
* Thorough soil preparation
* Proper tillage methods



* Adequate fertilization and liming to promote vigorous growth of plants

Study Questions

1. Under ideal moisture conditions, soil pore spaces contain _____% air and _____% water based on total volume of soil.

2. Adding large amounts of UNDECOMPOSED organic material temporarily _____ a soil's water holding capacity.

3. The soil layer that is most fertile and contains the greatest concentration of plant roots is:
a) leaf litter; b) surface layer; c) subsoil layer; d) unconsolidated parent material

4. Physical properties of a soil are affected by:
a) climatic factors; b) vegetation; c) topography; d) all of the above

5. The color of a soil is NOT determined by:
a) soil texture; b) organic matter content; c) drainage; d) degree of oxidation

6. _____ is a textural class of soil that has moderate amounts of sand, silt, and clay.

7. The soil that has the lowest water holding capacity, allowing water to enter a fast rate and move freely would be: a) clay; b) silt; c) sand; d) loam

8. Water, air, and plant roots most freely move through subsoils that have: a) a blocky structure; b) a platy structure; c) no structure; d) no organic matter

9. A _____ soil color indicates imperfection in drainage.

10. Soil erosion is worsened by:
a) mulching; b) soil preparation; c) proper tilling methods; d) reducing vegetative cover

Answers:
1 - 25; 2 - reduces; 3 - b; 4 - d; 5 - a; 6 - loam; 7 - c; 8 - a; 9 - gray; 10 - d

Components of Soil

Organic Matter

Organic matter in soil consists of the remains of plants and animals. When temperature and moisture conditions are favorable in the soil, earthworms, insects, bacteria, fungi, and other types of plants and animals use the organic matter as food, breaking it down into humus (the portion of organic matter that remains after most decomposition has taken place) and soil nutrients. Through this process, materials are made available for use by growing plants.

The digested and decomposing organic material also helps develop good air-water relationships. In very sandy soil, organic material occupies some of the space between the sand grains, binding them together, and increasing water-holding capacity. In a finely textured soil (e.g., loam, clay loam), organic material creates aggregates of the fine soil particles, allowing water to move more rapidly around these larger particles. This grouping of the soil particles into aggregates or peds makes it easier to work.

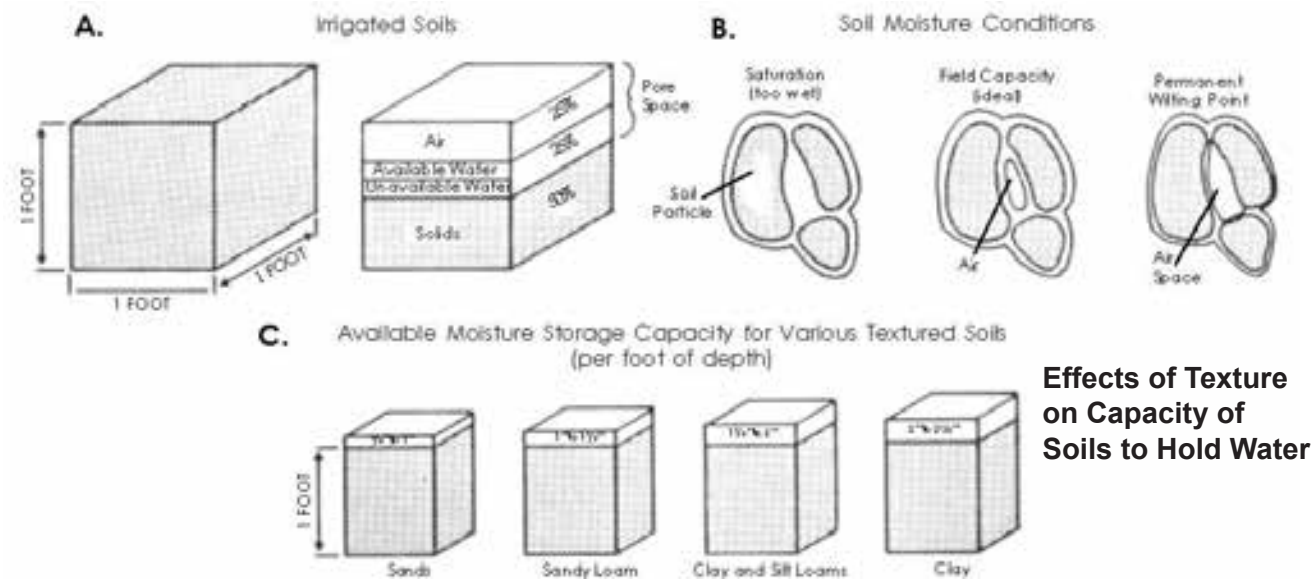
Organic matter content depends primarily on the kinds of plants that have been growing in a soil, the long-term management practices, temperature, and drainage. Soils that have native grass cover for long periods usually have a relatively high organic matter content in the surface area. Those that have native forest cover usually have relatively low organic matter content. In either case, if the plants are grown on a soil that is poorly drained, the organic matter content is usually higher than where the same plants are grown on a well-drained soil. This is due to differences in available oxygen and other substances needed by the organisms that attack and decompose the organic material. Soils in a cool climate have more organic matter than those in a warm climate.

Water and Air

All water in the soil ultimately comes from precipitation (rain, snow, hail, or sleet), entering the soil through cracks, holes, and openings between the soil particles. As the water enters, it pushes the air out. Oxygen is taken up by roots for respiration. If air is unavailable for too long, the roots will die.

Some water is used by plants, some is lost by evaporation, and some moves so deep into the soil that plant roots cannot reach it. If it rains very hard or for a long time, some of the water is lost through run-off.

When organic matter decomposes in the soil, it gives off carbon dioxide. This carbon dioxide replaces some of the oxygen in the soil pores. As a result, soil air contains less oxygen and more carbon dioxide than the air above the soil surface.



Effects of Texture on Capacity of Soils to Hold Water

Carbon dioxide is dissolved by water in the soil to form a weak acid. This solution reacts with the minerals in the soil to form compounds that can be taken up and used as foods by the plants.

Plant Nutrients

Plants need 16 elements for normal growth. Carbon, hydrogen, and oxygen (which come from air and water) and nitrogen (which is in the soil) make up 95% of plant solids. Although the atmosphere is 78% nitrogen, it is unavailable for plant use. However, certain bacteria that live in nodules on the roots of legumes are able to fix nitrogen from the air into a form available to plants.

The other 12 essential elements are phosphorus, potassium, calcium, magnesium, sulphur, iron, copper, manganese, zinc, boron, chlorine, and molybdenum. These elements come from the soil. With the exception of phosphorus, potassium, calcium, and magnesium, there is usually a large enough quantity of each of these elements in the soil for cultivation of crops.

Soil pH

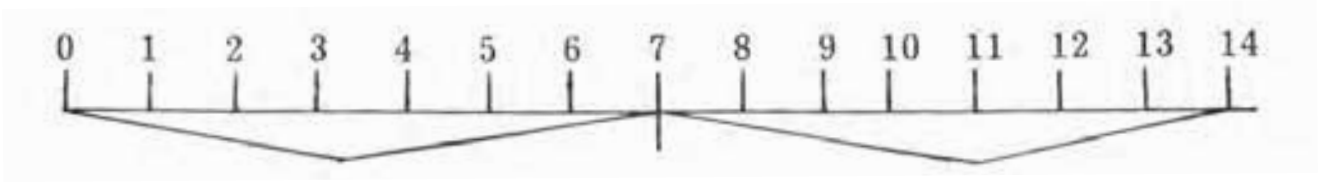
A pH is a reading taken from a scale that measures the hydrogen (acid-forming) ion activity of soil or growth media. The reading expresses the degree of acidity or alkalinity in terms of pH values. The scale of measuring acidity or alkalinity contains 14 divisions known as pH units. It is centered around pH 7 which is neutral. Values below 7 constitute the acid range of the scale and values above 7 make up the alkaline range.

The measurement scale is not a linear scale but a logarithmic scale. That is, a soil with a pH of 8.5 is ten times more alkaline than a soil with a pH of 7.5, and a soil with a pH of 4.5 is ten times more acid than a soil with a pH of 5.5.

The pH condition of soil is one of a number of environmental conditions that affect the quality of plant growth. A near-neutral or slightly acidic soil is generally considered ideal for most plants. Some types of plant growth can occur anywhere in a 3.5 to 10.0 range. With some notable exceptions, a soil pH of 6.0 to 7.0 requires no special cultural practices to improve plant growth.

The major impact that pH extremes have on plant growth is the availability of plant nutrients and concentration of the plant-toxic minerals. In highly acidic soils, calcium, phosphorous, and magnesium become tied up and unavailable, and manganese can be concentrated in toxic levels. At pH values of 7 and above, phosphorus, iron, copper, zinc, boron, and manganese become less available.

The following tables present some approximate amounts of ground limestone needed to increase the pH of five soil types. These values are only representative and should not be taken as recommendations. To avoid under or over applying liming material, applications should be



pH Range

based on a soil test. In order to ascertain a more precise lime requirement recommendation, the Virginia Tech Soil Testing Laboratory not only performs a soil pH using distilled water, but it also determines a pH using a buffered solution to measure the total (active plus reserve) acidity and buffering capacity for a particular soil sample. Preferably, any applied lime should be thoroughly tilled into the soil prior to planting. As with soil testing for fertilizer needs, amendments to improve aeration and/or drainage should be applied prior to testing soil pH.

Approximate amount of ground limestone needed to increase the pH of the upper 7 inches of soil to 6.5

	pH range			
	4.5 to 4.9	*5.0 to 5.4*	*5.5 to 5.9*	*6.0 to 6.4*
Soil texture (Upper 7 inches)	*Lime to apply lbs./1000 square feet*			
Sand	115	92	69	23
Loamy sand	138	115	92	46
Sandy loam	184	138	115	69
Clay and silty clay	270	230	184	92
Clay loam and loam	230	184	138	92

Lime recommendations are based on using a ground limestone with a neutralizing value of 90%

Approximate amount of ground sulfur needed to decrease the pH of the soil to 6.5

	pH range			
	7.0 to 7.5	*7.6 to 8.0*	*8.1 to 8.5*	*8.6 to 9.0*
Soil Texture	*Sulfur to apply (lbs./1000 square feet)*			
Sandy soils	9-13	22-34	34-45	45-68
Clay soils	18-22	34-45	34-45	----

Sulfur recommendations are based on using a ground sulfur material containing 95% S.
This information was provided by D.A. Bailey, Department of Horticulture Science, NCSU

Wood ashes are often used as a soil amendment. They contain appreciable amounts of potash (potassium), with lower amounts of phosphate, boron, and other elements. Wood ashes can be used to raise soil pH with twice the weight of ash applied as limestone for the same effect. Ashes should not come into contact with germinating seedlings or plant roots as they may cause root damage. Spread on a thin layer during the winter, and incorporate into the soil in the spring. Check pH yearly if you use wood ashes. Never use coal ashes or large amounts of wood ash (no more than 20 lbs. per 1000 square feet), as toxicity problems may occur.

If the soil pH is too high and must be lowered, elemental sulfur or aluminum sulfate can be incorporated into the soil to reduce alkalinity. If only a small decrease in pH is required, acid-forming fertilizer such as ammonium nitrate can be used as a nitrogen source. Most ornamental plants require slightly to strongly acidic soil. These species develop iron chlorosis (starting with the new leaves) when grown in soils in the alkaline range. Iron chlorosis is often confused with nitrogen deficiency since the symptoms (a definite yellowing of the leaves) are similar. This problem can be corrected by applying chelated iron or iron sulfate to the soil to reduce the alkalinity and add iron.

The term **chelate** comes from the Greek word for claw. Chelates are chemical claws that help hold metal ions, such as iron, in solution, so that the plant can absorb them. Different chemicals can act as chelates, from relatively simple natural chelates like citrate to more complex, manufactured chemicals. When a chelated metal is added to the soil, the nutrient held by the chelate will remain available to the plant for a longer period of time than if added as a salt form such as iron sulfate.

Most nutrients do not require the addition of a chelate to help absorption. Only a few of the metals, such as iron,

benefit from the addition of chelates. The types of chelate used will depend on the nutrient needed and the soil pH.

Study Questions

11. Organic matter content depends on:
    a) temperature; b) drainage; c) vegetation; d) all of the above

12. Because of the presence of organic matter, soil contains more _____ than the surrounding air.

13. The essential elements that are from air and water do NOT include: a) carbon; b) nitrogen; c) oxygen; d) hydrogen

14. Plants that prefer acidic soils develop _____ when pH is too high.

15. _____ are chemical compounds that hold metal ions in solution so that plants can absorb them.

Answers:
11 - d; 12 - carbon dioxide; 13 - b; 14 - iron chlorosis; 15 - chelates

A Guide for Estimating Moisture Content of Soil

% of Field Capacity	*Adequacy of Soil Moisture for Plant Growth*	*Response to Physical Manipulation*		
		Loamy sand, sandy loam	*Silt loam, loam*	*Silty clay loam*
100 plus	Saturated soil - too much moisture and too little air in the soil; can damage plants if this condition persists	Free water appears on soil when squeezed	Same as sandy loam	Same as sandy loam
100	Excess moisture has drained into subsoil after rainfall or irrigation and optimum amounts are available in the root zone for plant growth	When squeezed, no free water appears on the surface, but it leaves a wet outline on your hand	Same as sandy loam	Same as sandy loam
		Forms weak ball; usually breaks when bounced in hand, will not stick	Forms a very pliable ball; sticks readily	Ribbons out (can be formed into a thin strand when rolled between thumb and forefinger), has a slick feeling
75	Adequate moisture for plant growth	Tends to ball under pressure, but breaks easily when bounced in hand	Forms a ball, somewhat plastic, sticks slightly with pressure	Forms a ball, ribbons out between thumb and forefinger, has slick feeling
	Marginal moisture for plant growth; time to irrigate			
50	Inadequate moisture for plant growth	Appears too dry; will not form a ball with pressure	Somewhat crumbly, but holds together with pressure	Somewhat pliable, balls under pressure
25	Moisture in soil unavailable for plant growth	Dry, loose, falls through fingers	Powdery, sometimes crusty, but easily broken down into a powdery condition	Hard, cracked, difficult to break down to powdery condition

Note: soil sample was at 4 to 6 inch depth. Adapted from: Craig, C.L. 1976. *Strawberry Culture in Eastern Canada*. Agric. Canada Publication 1585:19.

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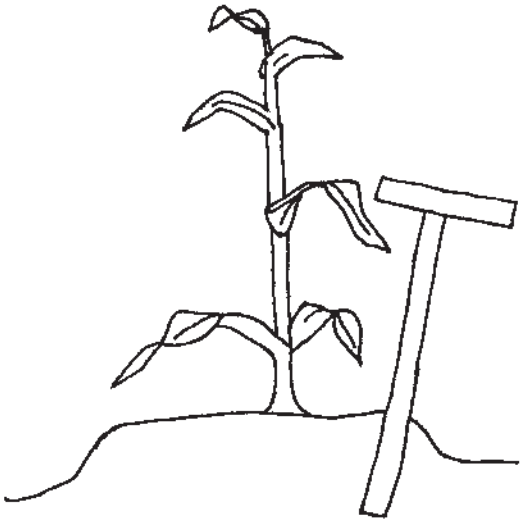
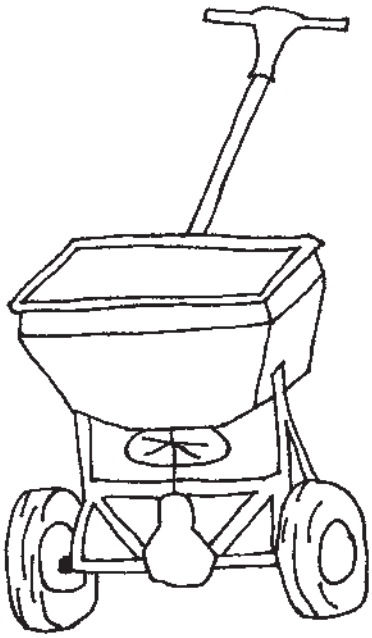
Nutrient Management & Fertilizers

Chapter 4





Nutrient Management & Fertilizers

Chapter 4

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Nutrient management is a complex science, taking into account a number of variables. A good definition is provided by Wikipedia, "Nutrient management is the science and art directed to link soil, crop, weather, and hydrologic factors with cultural, irrigation, and soil and water conservation practices to achieve the goals of optimizing nutrient use efficiency, yields, crop quality, and economic returns, while reducing off-site transport of nutrients that may impact the environment" (https://en.wikipedia.org/wiki/Nutrient_management). Environmental awareness drives our need to optimize yield or quality without degrading our environment and has led to many developments in the science of nutrient management from the agricultural to urban sectors. In this chapter you will learn about relationships between soil, nutrients, and fertilizers, and how these interact with the environment. Fertilizer types, application techniques, and timing will be discussed, as well as what factors need to be kept in mind when planning for nutrient management.

Contents

Nutrients in Soil

Plant Nutrients

Plants need 16 elements for normal growth. Carbon, hydrogen, and oxygen (which come from air and water) and nitrogen (which is in the soil) make up 95% of plant solids. Nitrogen is usually the most limiting nutrient. Although the atmosphere is 78% nitrogen, atmospheric nitrogen is unavailable for plant use. The other 12 essential elements are phosphorus, potassium, calcium, magnesium, sulfur, iron, copper, manganese, zinc, boron, chlorine, and molybdenum. These elements come from the soil. With the exception of phosphorus, potassium, calcium, and magnesium, there is usually a large enough quantity of each of these elements in the soil for cultivation of crops.

Element	*Symbol*	*Ions Most Frequently Absorbed*
	Micronutrient Elements	
Molybdenum	Mo	MoO_4
Copper	Cu	Cu^+ Cu^{++}
Zinc	Zn	Zn^{++}
Manganese	Mn	Mn^{++}
Iron	Fe	Fe^{++} Fe^{+++}
Boron	B	BO_3^- $B_4O_7^-$
Chlorine	Cl	Cl
	Macronutrient Elements	
Carbon	C	
Hydrogen	H	
Oxygen	O	O^2
Nitrogen	N	NO_3^- NO_4^-
Potassium	K	K^+
Calcium	Ca	Ca^{++}
Phosphorus	P	$H_2PO_4^-$ HPO_4^+
Magnesium	Mg	Mg^{++}
Sulfur	S	SO_4^+

Soil pH

Soil pH is a measure of the hydrogen (acid-forming) ion activity. The reading expresses the degree of acidity or alkalinity in terms of pH values. The scale of measuring acidity or alkalinity contains 14 divisions known as pH units. It is centered around pH 7 which is neutral. Values below 7 constitute the acid range of the scale and values above 7 make up the alkaline range.

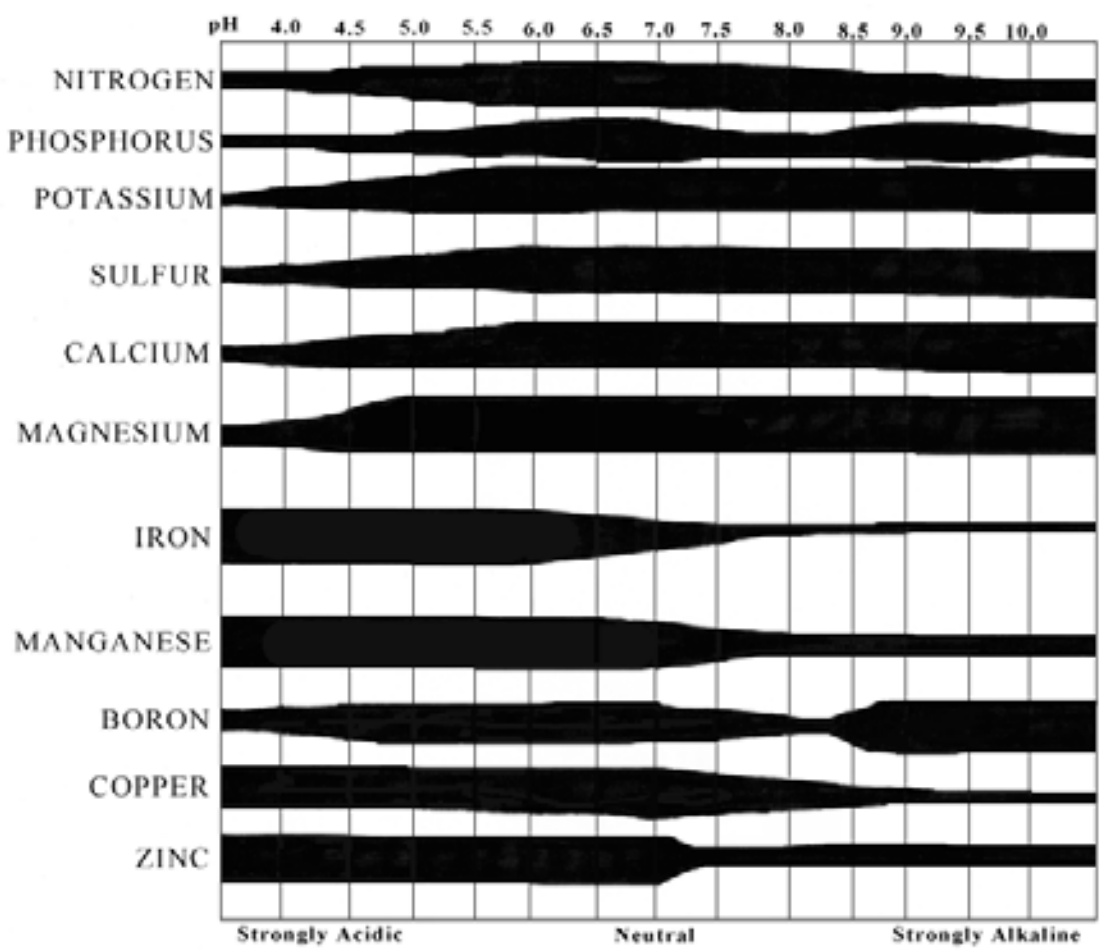
The measurement scale is not a linear scale but a logarithmic scale. That is, a soil with a pH of 8.5 is ten times more alkaline than a soil with a pH of 7.5, and a soil with a pH of 4.5 is ten times more acid than a soil with a pH of 5.5.

The pH condition of soil is one of a number of environmental conditions that affect the quality of plant growth. A near-neutral or slightly acidic soil is generally considered ideal for most plants. Some types of plant growth can occur anywhere in a 3.5 to 10.0 range. With some notable exceptions, a soil pH of 6.0 to 7.0 requires no special cultural practices to improve plant growth. Some examples of preferred pH range for landscape plants can be found at https://extension.msstate.edu/sites/default/files/publications/publications/p2571_0.pdf and https://pubs.ext.vt.edu/430/430-027/430-027_pdf.pdf.

The major impact that pH extremes have on plant growth is the availability of plant nutrients and concentration of the plant-toxic minerals. In highly acidic soils, calcium, phosphorous, and magnesium become tied up and unavailable, and manganese can be concentrated in toxic levels. At pH values of 7 and above, phosphorus, iron, copper, zinc, boron, and manganese become less available.

Ground lime stone and rarely sulfur are used to adjust pH that is not in the ideal range for plant growth. To avoid under or over applying these materials, applications should be based on a soil test. Preferably, any applied lime

Nutrient Availability by pH



should be thoroughly tilled into the soil prior to planting.

If the soil pH is too high and must be lowered, elemental sulfur or aluminum sulfate can be incorporated into the soil to reduce alkalinity. If only a small decrease in pH is required, acid-forming fertilizer such as ammonium nitrate can be used as a nitrogen source.

Most ornamental plants require slightly to strongly acidic soil. When grown in soils in the alkaline range, these species may develop trace metal deficiencies (such as iron or manganese; trace metal deficiency symptoms will first appear on new leaves). While there is likely plenty of iron in the soil, because the pH is not in a favorable range for the plant being grown, the iron is unavailable to the plant. This problem can be corrected by applying chelated iron.

The term chelate comes from the Greek word for claw. Chelates are chemical claws that help hold metal ions, such as iron, in solution, so that the plant can absorb them. Different chemicals can act as chelates, from relatively simple natural chelates like citrate to more complex, manufactured chemicals. When a chelated metal is added to the soil, the nutrient held by the chelate will remain available to the plant for a longer period of time than if added as a salt form such as iron sulfate.

Most nutrients do not require the addition of a chelate to help absorption. Only a few of the metals, such as iron, benefit from the addition of chelates.

Study Questions

1. All of the following essential elements are plant available from air and water EXCEPT: a) carbon; b) nitrogen; c) oxygen; d) hydrogen

2. The optimum soil pH for most plants is: a) 3.5-4.5; b) 4.5-5.5; c) 5.5-6.5; d) 6.0-7.0

3. Plants that prefer acidic soils develop_____ deficiencies when pH is too high.

4. _____ are chemical compounds that hold metal ions in solution so that plants can absorb them.

Answers:
1 - nitrogen; 2 - d; 3 - trace metal; 4 - chelates.

Soil Testing

The purpose of a soil test is to supply the homeowner with enough information to make wise decisions about the purchase and application of lime and fertilizer. A soil test from Virginia Tech will provide information on the soil, pH, and the plant available levels of phosphorus, potassium and seven other essential elements or nutrients. A Virginia Tech Soil Test report will also provide an estimated Cation Exchange Capacity (CEC), which gives an indication of a soil's ability to retain nutrients (Ca, Mg & K) against leaching. Soil tests should be performed if such tests have never before been conducted or is past soil test results are unavailable. A soil test need not be performed more often than every 3 to 4 years.

The accuracy of the soil test is a reflection of the sample taken. Be sure the sample is representative of the area to be treated; sampling should be specific and occur for one landscape type or use (e.g. vegetable garden, turf, landscape bed). Sample the soil from 10 or more random areas of the garden to a depth of 6 inches. Avoid sampling unusual areas such as those near gravel roads, manure or compost spots, brush piles, or under eaves. Place the samples in a clean pail or container, and mix the soil thoroughly. Contact your local Extension office for soil sampling boxes and proper sampling procedures. For more information go to www.soiltest.vt.edu.

A soil test is the only way to determine if phosphorus, potassium, calcium, or magnesium must be added or if a pH adjustment is needed. The soil test results provide recommendations on how much of each nutrient to add. Without a soil test, any application of fertilizer could be detrimental to the landscape and surrounding environment or ecosystem. Over application or application of unneeded materials could result in salt injury to plants, cause nutrient imbalances unsuitable for plant growth, and has the potential to become an environmental pollutant.

Most nutrients move very slowly through the soil profile . To be most effective, they should be incorporated into the top 4 to 6 inches. However, these elements can be surface applied ,but the nutrients will not be as readily available to the plants and will be less effective.

Magnesium may be deficient, especially in low pH soils. If magnesium levels and soil pH are low, dolomitic limestone can be used to raise the pH and supply the needed magnesium. To add magnesium without affecting the pH, Epsom salts ($MgSO_4$) can be applied, either

as a soil incorporation or as a soil drench. Potassium can be surface applied, if needed. It is possible to over apply potassium which can lead to deficiencies of other nutrients, particularly magnesium, so follow soil test recommendations closely.

Nitrogen is the nutrient that most frequently limits plant growth, and is often the only nutritional element that accelerates the growth of ornamental plants.

Unfortunately, nitrogen is also the most challenging nutrient to manage. Unlike other nutrients, it is not possible to accurately determine from a soil test how much nitrogen will be available during a plant's growth. Nitrogen moves or leaches in the soil. The challenge is to provide adequate nitrogen levels when needed to meet the plant growth requirements. A soil test will recommend the amount and time to apply nitrogen based upon established annual requirements for the specified plant to be grown.

Nitrogen can be supplied with two different approaches and both work very well. Nitrogen can be applied as (1) a water soluble form which includes liquid feed and granular fertilizers or (2) slow release forms. See chapters on specific plant groups (i.e., lawns, woody ornamentals, etc.) and the chapter on water quality for more information on fertilizer application.

Nutrients as Pollutants

Nitrogen and Phosphorus are currently major sources of pollution in our waterways. Excess nutrients come from sewage treatment plants, automobile exhaust, animal wastes, excess nutrients applied to agricultural fields, excess nutrients applied to home lawns and gardens, failing septic fields, etc. These pollutants can come from organic sources or synthetic sources. Once these nutrients are in the water, they become available for algae to use and grow. This large and quick growth of algae is referred to as an algae bloom. Once the algae has used up the available flush of nitrogen and phosphorus, the algae quickly dies and begins to be broken down by bacteria. The increasing bacterial population, which uses oxygen to help break down the algae, causes a crash in the oxygen levels in the water. When the water is low in dissolved oxygen, fish and other aquatic animals perish.

Nitrogen is mobile in the soil. It can easily leach out of the soil or run off the soil surface with the movement of water. Nitrogen easily ends up in waterways where it contributes to algae blooms. Phosphorus on the other hand is not usually mobile in the soil. Phosphorus binds with clay particles and organic matter in the soil. Plants are then able to use the phosphorus associated with organic material and soil particles. Phosphorus usually becomes a pollutant in our waterways when it is washed into streams, and creeks while attached to a soil particle. Thus it is important to limit the amount of soil erosion. Another factor that makes phosphorus toxic to our waterways is the fact that algae are much more responsive to phosphorus than to nitrogen. Thus, a small amount of phosphorus can cause the same algae bloom as a much larger amount of nitrogen. High rates of phosphorus have been seen in soils that have had repeated applications of fertilizers containing phosphorus.

Because nitrogen and phosphorus have been identified as pollutants one might expect Virginia Cooperative Extension to recommend not using fertilizers on lawns and gardens in the future. The answer is much more nuanced than this. When plants have the nutrients they need available to them, the plants are healthier; they grow thicker and denser and their roots are stronger. They hold soil better and limit erosion. Thus, these plants help to limit the amount of nitrogen and phosphorus that end up in our waterways. Conversely, if plants don't have enough nutrients to thrive and stay healthy they are often spindly and small; they may not be able to hold soils in place as well as we would like and may contribute to soil erosion. Thus, the results of a soil test are invaluable in helping to determine the need for nutrient amendments, as well as the form and amount needed. Nutrients are beneficial when applied in needed situations; misapplied nutrients become pollutants.

Our communities are making concerted efforts to help reduce the amount of phosphorus and nitrogen that ends up in our waterways. Virginia law prohibits the sale of synthetic fertilizers with phosphorus for maintenance purposes. Phosphorus fertilizers are, however, allowed to be used for establishing new plantings or for use on sites that are low in phosphorus according to a soil test.

Areas Inappropriate for Fertilizer Application

Locations may exist on residential properties where fertilizer application would not be appropriate. These locations have high potential for runoff and/or leaching, in which case the fertilizer then becomes an environmental

pollutant. Detailed information on each of these types of locations is given below.

Impervious Surfaces

Driveways, sidewalks and other paved areas should not have fertilizers applied to them. During lawn fertilization some fertilizer may spread to these areas and this fertilizer should be swept or blown back into the planting areas. Fertilizers should not be used as deicers in the winter.

Soils with high water table

Fertilizer is more likely to move into water where there are soils that do not drain well or there is a high water table. Individuals should be cautious about applying fertilizers in these areas.

Stream and pond banks

In places where a lawn goes directly to the edge of a stream or pond, a buffer should be left in place. An area of turf grass that is 20 feet from the water should not be fertilized and ideally there is an area of vegetation that is thicker and taller than a lawn that is typically mowed weekly during the growing season.

Well heads and rock outcroppings

Both of these sites have the potential to take surface water directly into local ground water. And as such a buffer or no fertilization zone should be left around these sites.

Karst bedrock

Many areas of Virginia have limestone based bedrock. This limestone dissolves over time and often there are channels or sinkholes that provide immediate movement of surface water into ground water. Use fertilizers in these areas cautiously.

Steep slopes

Steep slopes have a high potential to have fertilizers wash away. Slow release fertilizers work best in these situations.

Keeping soils covered with healthy plants is the best way to limit the amount of nutrients that end up in local waterways. But where plants are absent it is helpful to have the soil covered. Hardwood or pine bark mulch and other plant based mulches can be helpful to limit erosion and nutrients reaching water.

Study Questions

5. While it is not soluble in water, this nutrient is a much more problematic pollutant: a) Nitrogen; b) Phosphorus; c) Potassium; d) Sulfur

Answers: 5 - b.

Understanding Fertilizers

As mentioned earlier, there are 16 elements essential to plant growth. Carbon, hydrogen, and oxygen come from air and/or water. Nitrogen, phosphorous and potassium are considered fertilizer macronutrients because plants require them in a relatively large quantity for maximum growth. Calcium, magnesium, and sulfur are secondary macronutrients but usually are either present in sufficient quantities or are added coincidentally with other materials (e.g., lime). The other seven nutrients, called micronutrients, are just as important but are required in smaller amounts. To review the roles of the elements in plant growth, please see the section, "Physiological and Biochemical Functions of Essential Elements in Plants" in the Abiotic Stress Effects on Plant Growth and Development chapter.

If plants are low in any of these elements, they exhibit signs of nutrient deficiency; high levels may contribute to nutrient toxicity. Some of these symptoms are given in the discussion of nutrients in the Botany chapter.

Fertilizer Analysis

The fertilizer analysis given on the package refers to the amount of an element present in a formulation based on percentage of weight. All fertilizers are labeled with three numbers, giving the percentage by weight of nitrogen (N), phosphate (P_2O_5), and potash (K_2O) respectively.

Often, to simplify matters, these numbers are said to represent nitrogen, phosphorus, and potassium, or N-P-K. We should remember that it is not N-P-K, but N-P_2O_5-K_2O. For example, a bag of 10-10-10 fertilizer contains 10% N, 10% P_2O_5 , and 10% K_2O by weight. For example, if we have a 100-pound bag of this fertilizer labeled 10-10-10, there are 10 pounds of N, 10 pounds of P_2O_5, and 10 pounds of K_2O in that bag.

In some fertilizers, a filler may be added to bulk up the fertilizer. This is done to lower the analysis, or dilute the

concentration, allowing a more even spreading pattern as compared to trying to spread a small amount of a high analysis fertilizer over an area. A filler is generally an inert material such as sand, lime, ground corn cobs, etc. Some fillers are used to enhance the fertilizer's handling qualities.

For many years, there has been a model label law which many states have adopted for the classification of fertilizers. The law also establishes minimum levels of nutrients allowable and provides specific labeling requirements. The information contained on fertilizer labels has been well standardized, and the consumer is protected by state laws requiring manufacturers to guarantee the claimed nutrients.

The law requires that the manufacturer guarantees accuracy of what is claimed on the label. In some cases, a fertilizer will contain secondary nutrients or micronutrients not listed on the label because the manufacturer does not want to guarantee their exact amounts.

On fertilizer labels, the initials WIN and WSN stand for Water Insoluble Nitrogen and Water Soluble Nitrogen, respectively. Water soluble nitrogen (WSN) dissolves readily and is usually in a simple form, such as ammoniacal nitrogen (ammonium, NH_4^+) or nitrate (NO_3^-) nitrogen. Nitrogen, which will not dissolve readily, may exist in other forms in the fertilizer. Water insoluble nitrogen (WIN) is referred to as a slow-release nitrogen (SRN) source and delivers nitrogen at different rates according to the amount and kind of material in its composition. WIN is also sometimes referred to as slowly-available nitrogen (SAN).

The best fertilizer to use depends on many factors, such as the nutrients needed, soil structure, soil chemistry, and method of applying the fertilizer.

Complete vs. Incomplete

A fertilizer is said to be complete when it contains nitrogen, phosphorus, and potassium. Examples of commonly used complete fertilizers are 10-10-10 and 20-10-5. An incomplete fertilizer will be missing one of the major components. Examples of incomplete fertilizers are indicated on the following chart.

Common Incomplete (Agricultural) Fertilizers

	% Nitrogen	*% Phosphate (P_2O_5)*	*% Potash (K_2O)*
Ammonium nitrate	34	0	0
Ammonium sulfate	21	0	0
Mono-annomi-um phosphate	11	48	0
Muriate of potash (Potas-sium chloride)	0	0	60
Potassium sulfate	0	0	52
Superphos-phate	0	20	0
Triple super-phosphate	0	46	0
Urea	46	0	0
Ureaformal-dehyde (Urea form)	38	0	0

Using the various formulations above, manufactures are able to blend different fertilizers to create the many different fertilizer ratios found in store shelves.

The fertilizer ratio indicates the proportion of nitrogen, phosphate, and potash contained in the fertilizer. The specific fertilizer ratio you will need depends on the soil nutrient level, and the plants being grown.

Fertilizer Formulation

Fertilizers come in many shapes and sizes. Different formulations are made to facilitate types of situations in which fertilizer is needed. Packaging for all formulations must show the amount of nutrients contained, and sometimes it tells how quickly a nutrient is available. Some of the formulations available to the homeowner are: water-soluble powders, slow-release pellets, slow-release collars or spikes, liquids, tablets, and granular solids.

Liquid fertilizers come in a variety of different formulations, including complete formulas and special incomplete, and special types that offer just one or two micro-nutrients. All are made to be diluted with water; some are concentrated liquids themselves; others are powder or pellets. Growers of container plants often use liquid fertilizers (which typically contain more WSN) at half concentration twice as frequently, so that the plants receive a more continuous supply of nutrients.

Comparison of Slow-Release Fertilizers, Conventional Fertilizers, and Manure or Sludge	
Advantages	*Disadvantages*
Slow-Release Fertilizers	
Fewer applications	Unit cost is high
Low burn potential	Availability is limited
Release rate varies depending on fertilizer characteristics	
Comparatively slow release rate	
Conventional Fertilizers	
Fast-acting	Greater burn potential
Some are acid-forming	Solidifies in the bag when wet
Lower cost	Nitrogen leaches readily
Manure or Sewage Sludge	
Low burn potential	Salt could be a problem (except for fresh chicken manure)
Relatively slow release	Bulky, hard to handle
Contains micronutrients	Odor
Conditions the soil	Expensive per pound of actual nutrient
	Weed seeds are a problem
	Cannot select a needed formulation; usually low in N, high in P, and sometimes high in K. Best applied based on P needs (add additional conventional fertilizer for any remaining N needs)
	Heavy metals may be present in sewage sludge from large cities or industrial areas

Special-Purpose Fertilizers

When shopping for fertilizer, you will find fertilizers packaged for certain uses or types of plants such as Camellia Food, Rhododendron and Azalea Food, or Rose Food. The camellia and rhododendron/azalea fertilizers belong to an old established group, the acid plant fertilizers. Some of the compounds used in these fertilizers are chosen because they have an acid reaction, or provide the plant with its preferred nutrient source, such as ammoniacal N, so they are especially beneficial to acid-loving plants where soil is naturally neutral or alkaline.

A soil test should be performed before the purchase of any expensive, special-purpose fertilizers. It is not possible to make a blanket statement that one fertilizer is best for every area. It is true that different plants use different nutrients at different rates. What is unknown is the reserve of nutrients already in the soil. This will change with soil type and location.

Slow-Release Fertilizers

Plants can absorb nutrients continuously, so it is beneficial to provide them with a balance of nutrients throughout their growth. Perhaps the most efficient way to achieve this is to apply a slow-release fertilizer, which releases nutrients at a rate that makes them available to the plants over a long period. Slow-release fertilizers contain one or more essential elements.

Slow-release fertilizers can be categorized according to their release mechanism. The three major types of nutrient release mechanisms are: (1) materials that dissolve slowly, (2) materials requiring microorganisms to release nitrogen, and (3) granular materials with membranes made of resin or sulfur to control the rate of nutrient release into the soil.

Sulfur-coated urea is a slow-release fertilizer with a covering of sulfur around each urea particle. Different thicknesses of sulfur control the rate of nitrogen release. Sulfur-coated urea applied to the soil's surface releases nitrogen more slowly than if incorporated into the soil. This material generally costs less than other slow-release fertilizers, and it supplies the essential element sulfur.

When fertilizer products coated with multiple layers of resin come into contact with water, the layers swell and increase the pore size in the resin so that the dissolved

fertilizer can move into the soil. Release rate depends on the coating thickness, temperature, and water content of the soil. There is often a large release of fertilizer during the first two or three days after application. Release timing can be from 0 to 6 months, depending on the coating.

Slow-release fertilizers need not be applied as frequently as other fertilizers, and higher amounts can be applied without danger of burning. Plants may use the nitrogen in slow-release fertilizers more efficiently than nitrogen in other forms, since it is released over a longer period of time and in smaller quantity. Slow-release fertilizers are generally more expensive than other types. The real benefit, however, is the frequency of application, which is much lower than conventional fertilizers.

Urea formaldehyde and sulfur-coated urea have been used as turf fertilizer, while resin-coated fertilizers are predominantly used in container growing.

Caution should be used in applying slow-release fertilizers around trees or shrubs, as they may keep the plant in growth late in the summer. The late-season growth may not harden off completely, and excessive winter damage may occur.

Study Questions

6. A soil test does NOT provide information on: a) available potassium; b) pH; c) available nitrogen; d) available phosphorus

7. If calcium is low but a pH change is undesirable, use: a) dolomitic limestone; b) gypsum; c) calcitic limestone; d) Epsom salts

8. _____ is the nutrient that most frequently limits plant growth, yet is very difficult to manage in the soil.

9. The three numbers on a bag of fertilizer represent a)percent nitrogen, phosphate, and potash; b) percent nitrogen, calcium, and magnesium; c) amount to use per square foot, square yard, square acre; d) the dates the fertilizer should be applied

10. A _____is added to bulk up fertilizers and lower the analysis for more even application.

11. An example of an incomplete fertilizer is: a) 10-10-10; b) 34-0-0; c) 20-10-5; d) all of the above

12. Slow release fertilizers are available as: a) materials that dissolve slowly; b) materials that require microorganisms to release nitrogen; c) granular materials with membranes made of resin or sulfur; d) all of the above

13. A disadvantage to conventional fertilizers is: a) they are slow-acting; b) the odor; c) nitrogen leaches readily; d) the presence of weed seeds

Answers:
6 - c; 7 - d; 8 - nitrogen; 9 - a; 10 - filler; 11 - b; 12- d; 13 - c.

Organic Fertilizers

The word organic, applied to fertilizers, simply means that the nutrients contained in the product are derived solely from the remains or by-products of a once-living organism. Urea is a synthetic organic fertilizer, an organic substance manufactured from inorganic materials. Cottonseed meal, blood meal, bone meal, hoof and horn meal, and all manures are examples of organic fertilizers. When packaged as fertilizers, these products will have the fertilizer ratios stated on the labels. Some organic materials, particularly composted manures and sludge, are sold as soil conditioners and do not have a nutrient guarantee, although small amounts of nutrients are present. Most are high in one of the three major nutrients and low in the other two, although you may find some fortified with nitrogen, phosphorus, or potash for a higher analysis. Many are low in all three. In general, organic fertilizers release nutrients over a fairly long period; they first release quickly available nutrients and then additional mineral nutrients will become available via decomposition. The potential drawback is that they may not release enough of their principal nutrient at a time to give the plant what it needs for best growth. Because organic fertilizers depend on soil organisms to break them down to release nutrients, most of them are effective only when soil is moist and soil temperature is warm enough for the soil organisms to be active.

Cottonseed meal is a by-product of cotton manufacturing. As a fertilizer, it is somewhat acidic in reaction. Formulas vary slightly, but generally contain 6% nitrogen, 3% phosphate, and 2% potash. Cottonseed meal is readily available to plants in warm soils, and there is little danger of burn. For general garden use, apply 2 to 5 pounds per 1000 square feet. Cottonseed meal is frequently used for fertilizing acid-loving plants such as azaleas, camellias, and rhododendrons.

Blood meal is dried, powdered blood collected from beef processors. It is a rich source of nitrogen — so rich, in fact, that it may do harm if used in excess. The gardener must be careful not to use more than the amount recommended on the label. In addition to supplying nitrogen, blood meal supplies certain of the essential trace elements, including iron.

Fish emulsion, a complete fertilizer, is a partially decomposed blend of finely pulverized fish. No matter how little is used, the odor is intense — but it dissipates within a day or two. Fish emulsion is high in nitrogen and is a source of several trace elements. In the late spring, when garden plants have sprouted, an application of fish emulsion followed by a deep watering will boost the plant's early growth spurt. Contrary to popular belief, too strong a solution of fish emulsion can burn plants, particularly those in containers.

Manure is also a complete fertilizer, but low in the amounts of nutrients it can supply. Manures vary in nutrient content according to the animal source and what the animal has been eating, but a fertilizer ratio of 1-1-1 is typical. Manures are best used as soil conditioners instead of nutrient sources. Commonly available manures include horse, cow, pig, chicken, and sheep. The actual nutrient content varies widely: the highest concentration of nutrients is found when manures are fresh. As it is aged, leached, or composted, nutrient content is reduced. However, the subsequent reduction in salts will reduce

Fertilizer Application Rate Examples

Example 1

Determine the amount of ammonium sulfate needed by a 5000 square-foot lawn if 1 pound of nitrogen per 1000 square feet is recommended.

- Lawn: 5000 square feet
- Fertilizer: ammonium sulfate (21-0-0)
- Rate: 1 pound of nitrogen per 1000 square feet

- Since we need 1 pound of nitrogen for every 1000 square feet and we have 5000 square feet, we need 5 pounds of nitrogen.
- Ammonium sulfate is 21 percent nitrogen (round to 20 percent).
- 20 percent is the same as 0.20 or 1/5 . This means that we need 5 pounds of fertilizer to get 1 pound of nitrogen.
- Since we need 5 pounds of nitrogen, 5 x 5 = 25 pounds of fertilizer.

Total fertilizer needed =

$$\frac{\text{N application rate (lbs./1000 sq. ft.)}}{\text{N content of fertilizer}} \times \frac{\text{lawn size (sq. ft.)}}{1000} = \frac{1}{0.20} \times \frac{5000}{1000} = 25 \text{ lb. fertilizer expressed as a decimal}$$

Example 2

Determine how much 10-10-10 needs to be applied to ensure 2 pounds of nitrogen per thousand square feet in a garden that measures 20 x 10 feet.

- Garden: 20 x 10 = 200 square feet
- Fertilizer: 10-10-10 = 10 percent nitrogen
- Rate: 2 pounds of nitrogen per 1000 square feet

Total fertilizer needed =

$$\frac{\text{2 lb. Nitrogen}}{0.10} \times \frac{200}{1000} = \frac{2}{0.10} \times \frac{200}{1000} = \text{4 lb. fertilizer}$$

the chances of burning plants. Fresh manure should not be used where it will contact tender plant roots. Typical rates of manure applications vary from a moderate 70 pounds per 1,000 square feet to as much as half a ton per 1,000 square feet.

The following table shows the approximate nutrient content of manures and suggested yearly rates of application per 1000 square feet of garden area. Rates given are for materials used singly; if combinations of two or more materials are used, the rate should be reduced accordingly.

Approximate Nutrient Content of Manures and Suggested Yearly Rates of Application in a Garden (per 1000 sq ft)

Type of dry manure or fertilizer	*Nitrogen %*	*Phosphate %*	*Potash %*	*Suggested Annual Rate (per 1000 sq ft)*
Chicken manure	2.0-4.5	4.6-6.0	1.2-2.4	125
Steer manure	1.0-2.5	0.9-1.6	2.4-3.6	450
Dairy manure	0.6-2.1	0.7-1.1	2.4-3.6	600

Sewer sludge is a recycled product of municipal sewage treatment plants. Two forms are commonly available: activated and composted. Activated sludge has higher concentrations of nutrients (approximately 6-3-0) than composted sludge, and is usually sold in a dry, granular form for use as a general purpose, long-lasting, non-burning fertilizer. Composted sludge is used primarily as a soil amendment and has a lower nutrient content (approximately 1-2-0). There is some question about the long-term effects of using sewage sludge products in the garden, particularly around edible crops. Heavy metals, such as cadmium, are sometimes present in the sludge, and may build up in the soil. Possible negative effects vary, not only with the origin of the sludge, but also with the characteristics of the soil where it is used.

Compared to synthetic fertilizer formulations, organic fertilizers contain relatively low concentrations of actual nutrients, but they perform other important functions which the synthetic formulations do not. Some of these functions are: increasing organic content of the soil; improving physical structure of the soil; adding micronutrients; and increasing bacterial and fungal activity.

Fertilizers Combined with Pesticides

Fertilizers can be combined with pesticides by the manufacturer or the applicator. Be aware of the timing of the application of the fertilizer and the pesticide. Both need to be done at the appropriate time. Also, both a fertilizer and a pesticide also need to be applied at the appropriate rate. The fertilizer and the pesticide will have appropriate application rates. Always read the label carefully.

Applying Fertilizer

Fertilizer Application Rate

Computing the amount of fertilizer needed for a given area is rather tricky at first, but after a few times, this becomes second nature. Following are some examples of fertilizer determinations for lawns and gardens.

Recommendations for fertilizing vegetables are usually stated: “Apply 3 to 4 pounds of 5-10-10 fertilizer per 100 square feet of garden space.” This is fine, as long as you are using a 5-10-10 formula. If the fertilizer you want to use has a different formula, for example, one with a higher nitrogen content as indicated by the first number in the formula, the rate of application should be reduced to avoid nitrogen burn. A high phosphorus fertilizer such as 6-18-6 is often recommended for vegetables when transplants are set out. However, the amount of fertilizer applied is determined by the amount of nitrogen because it is the nutrient most easily lost from the soil. In the following chart, you can see how the amount to be applied decreases as the percentage of nitrogen increases.

Fertilizer Application Rates as Determined by N Content

Formula	*Lbs. Fertilizer applied per 1000 square feet*
5-10-10	3.5
6-18-6	2.9
8-12-4	2.2
10-10-10	1.8
12-6-6	1.5
16-16-16	1.1

Nitrogen fertilizers do not burn or damage plants if they are applied correctly. Fertilizers are salts, much like our

familiar table salt, except that they contain various plant nutrients. Salts in the fertilizer begin to diffuse or move away from the place where they had been applied. This dilutes the fertilizer and distributes it through a much larger area. If tender plant roots are close to the area where the fertilizer is placed, water will be drawn from these roots and from the surrounding soil. The more salt or fertilizer applied, the more water will be drawn from nearby roots. As water is drawn from the roots, plant cells begin to dehydrate and collapse, and the plant roots burn or dehydrate to a point from which they cannot recover. If soil moisture is limited, most of the water drawn towards the salt will come from plant roots and the damage will be more severe.

Two rules should be kept in mind when applying a fertilizer during hot weather when soil moisture is limited: 1) do not over-apply nitrogen fertilizers; and 2) make sure adequate moisture is present after applying fertilizers high in salts.

Soluble salts accumulate when fertilizer is applied repeatedly without sufficient water to leach or wash the old fertilizer's salts through the soil. It also occurs when water evaporates from the soil and leaves previously dissolved salts behind. Soluble salts will accumulate on top of the soil in a container and form a yellow-to-white crust. A ring of salt deposits may form around the pot at the soil line or around the drainage hole. Salts may also build up on the outside of clay pots.

As the salts in the soil become more concentrated, plants find it harder to take up water. If salts build up to an extremely high level, water can be taken out of the root tips, causing them to die.

Study Questions

14. An organic fertilizer that could potentially burn plants is: a) cottonseed meal; b) fish emulsion; c) composted manure; d) composted sewer sludge

15. The two commonly available forms of sewer sludge are _____ and _____.

16. Because of leaching, the amount of fertilizer to be applied depends on the percentage of: a) nitrogen; b) phosphorus; c) potassium; d) filler

17. Because fertilizers are_____, they can potentially burn plants by drawing water out of root cells.

Answers: 14 - b; 15 - activated and composted; 16 - a; 17- salts

Timing and Method of Application

Soil type dictates the frequency of fertilizer application. Sandy soils require more frequent applications of nitrogen and other nutrients than do clay-type soils. The type of crop, the level of crop productivity required, frequency and amount of water applied, and type of fertilizer applied and its release rate all affect the type of fertilizer application as well as the rate.

Timing

The type of crop influences timing and frequency of application since some crops are heavier feeders of particular nutrients than others. Root crops (such as carrots) require less nitrogen fertilization than do leafy crops (such as greens). Corn is a heavy feeder of nitrogen, while most trees and shrubs are generally light nitrogen-feeders. A general rule of thumb is that nitrogen is for leafy top growth; phosphorus is for root and fruit production; and potassium is for cold hardiness, disease resistance, and general durability.

Proper use of nutrients can control plant growth rate and character. Nitrogen is the most critical nutrient in this regard. If tomatoes are fertilized too heavily with a nitrogen fertilizer or sidedressed before fruit set, the plants may be all vegetative (shoot, stem, leaf) and no fruit. This is also the case with potatoes, which will show excess vining and poor tuber formation. If slow-release fertilizers or heavy amounts of manure are used on crops that form fruit or vegetables, vegetative growth will continue into late summer, and fruit and vegetable development will occur very late in the season. Late nitrogen fertilization can also prevent perennial plants from becoming cold-hardy, inducing cold weather injury.

Remember that a nitrogen application will have its greatest effect for three to four weeks after application. If tomatoes are fertilized heavily on June 1, there may be no flower production until July 1, which will, in turn, delay fruit ripening until late August. For this reason, it is important to plant crops with similar fertilizer needs close together to avoid improper rates of application.

Late fertilization (after July 1) of trees and shrubs can cause new flushes of growth to occur on woody plants that are normally adjusting themselves for the coming winter. This may delay dormancy of woody plants and cause

severe winter dieback in new growth. Gardeners should be aware that individual species within these groups vary considerably; see fertilizer recommendations for each group in its respective chapter of this handbook. Also refer to Chapter 19: Water Quality and Conservation, for information on fertilizer use and water quality.

Application Methods

There are different methods of applying fertilizer depending on its formulation and the crop needs.

Broadcasting

A recommended rate of fertilizer is spread over the entire growing area and left to filter into the soil or incorporated into the soil with a roto tiller or spade. Broadcasting is used over large garden areas or when time or labor is limited.

Banding

Narrow bands of fertilizer are applied in furrows 2 to 3 inches from the garden seeds and 1 to 2 inches deeper than the seeds or plants. Careless placement of the fertilizer band too close to the seeds will burn the roots of the seedlings. The best technique is to stretch a string where the seed row is to be planted. With a corner of a hoe, dig a furrow 3 inches deep, 3 inches to one side, and parallel with the string. Spread half the suggested rate of the fertilizer in the furrow and cover it with soil. Repeat the banding operation on the other side of the string, then sow seeds underneath the string.

For widely spaced plants, such as tomatoes, fertilizers can be placed in bands 6 inches long for each plant or in a circle around the plant. Place the bands 4 inches from the plant base. If used in the hole itself, place the fertilizer at the bottom of the hole, work it into the soil, and place a layer of soil about 2 inches deep over the fertilized soil before putting the plant in the hole.

Banding is one way to satisfy the needs of many plants (especially tomatoes) for phosphorus as the first roots develop. When fertilizers are broadcast and worked into soil, much of the phosphorus is locked up by the soil and is not immediately available to the plant. By concentrating the phosphorus in the band, the plant is given what it needs even though much of the phosphorus stays locked up.

Starter Solutions

Another way to satisfy the need for phosphorus when setting out transplants of vegetables and flowers is through the use of a liquid fertilizer high in phosphorus as a starter solution. Follow directions on the label.

Side-Dressing

Dry fertilizer is applied as a side dressing after annuals are up and growing. Scatter fertilizer on both sides of the row 6 to 8 inches from the plants. Rake it into the soil and water thoroughly.

Foliar Feeding

Foliar feeding is used when insufficient fertilizer was used before planting, when a quick growth response is wanted, when micronutrients (such as iron or zinc) are locked into the soil, or when the soil is too cold for the plants to use the fertilizer applied to the soil. Foliar-applied nutrients are absorbed and used by the plant quite rapidly. Absorption begins within minutes after application and, with most nutrients, it is completed within 1 to 2 days.

Foliar nutrition can be a supplement to soil nutrition at a critical time for the plant, but not a substitute. At transplanting time, an application of phosphorus spray will help in the establishment of the young plant in cold soils. For perennial plants, early spring growth is usually limited by cold soil, even when the air is warm. Under such conditions, soil microorganisms are not active enough to convert nutrients into forms available for roots to absorb; yet, if the nutrients were available, the plants could grow. A nutrient spray to the foliage will provide the needed nutrients immediately, allowing the plants to begin growth.

Enhancing Soil for Plant Growth

Well-formed soil structure can have a positive impact on nutrient retention. Organic matter is a great soil improver for both clay and sandy soils. Good sources of organic matter include manures, leaf mold, sawdust, and straw. These materials are decomposed by soil organisms. Various factors such as moisture, temperature, and nitrogen availability determine the rate of decomposition through their effects on these organisms. Adequate water must be present, and warm temperatures will increase the rate at which the microbes work. The proper balance of carbon and nitrogen is needed for rapid decomposition. The addition of nitrogen may be necessary if large amounts of undecomposed high-carbon substances such as dried leaves, straw, or sawdust are used. Fresh green wastes, such as grass clippings, are higher in nitrogen than dry material. In the process of breaking down the

organic matter, nitrogen is used by the microbes and, therefore, may become deficient in the plants.

Tilling/Incorporating

Tilling is a good way to loosen soil and break up soil clods in new beds as well as in the yearly preparation of annual flower and vegetable gardens. It is also a good opportunity to incorporate organic matter and nutrients into the soil. The best time to till is when soil is very slightly moist. Never till when the soil is wet as this can destroy soil structure. Tilling in the fall for spring planting helps kill insects and weeds and allows winter freezing and thawing to help build soil structure. Excessive tillage can be detrimental to soil organisms and soil structure.

Compost

Organic matter should make up 5% or more (by weight) of a healthy soil. Many Virginia soils, especially urban soils, are low in organic matter. The regular application of compost to lawns and landscape beds will add organic matter and improve the overall health of the soil.

The carbon in compost feeds a variety of beneficial bacteria, fungi and other organisms. As these organisms feed they convert nutrients into plant available forms. For example, nitrogen in ammonium (NH_4) and ammonia (NH_3) is converted to the more plant available form of nitrate (NO_3).

Some specialized fungi form symbiotic relationships with plants that provide plants with nutrients and water, essentially acting as an extension of the root system.

As compost-fed soil organisms thrive they break up compacted soil and exude natural glues that allow soil particles to form aggregates. These aggregates help preserve pore space that allows for the passage of water, gasses and roots.

The organic matter in compost can act as a reserve for food and water. This is especially important in sandy soils where high infiltration rates and low cation exchange capacities would otherwise require frequent applications of water and fertilizer.

The quality of compost is not uniform. Both home-made and commercial compost can vary in chemistry from batch to batch. While there is an effort to standardized commercial compost, it is not mandatory and does not cover home-made compost.

Compost should be dark, brown, and crumbly with an earthy odor when ready to use. It should not be moldy or have a rotten smell. Compost should be fluffy and not decomposed to a point of being powdery. Except for some woody pieces, the source materials that went into the compost should not be recognizable in finished compost. Finished compost should have a stable pH near neutral and low in soluble salts.

VCE Publications on Compost

426-703: Making Compost from Yard Waste, pubs.ext.vt.edu/426/426-703/426-703_pdf.pdf.

452-231: Compost – What Is It and What Is It to You, https://pubs.ext.vt.edu/452/452-231/452-231.html.

Cover Crops

Another source of inexpensive soil improvement that should not be underestimated is the cover crop. Cover crops, sometimes called green manures, can be used to increase organic matter, break up hard soils, suppress weeds, prevent erosion, hold soil nutrients and increase soil nutrients. Most cover crops have multiple uses. Cereal rye, for example, can absorb soil nutrients and hold them over the winter while also suppressing weeds.

The best time to seed a cover crop depends on the species being planted and when the previous crop is harvested. Often, cover crops are planted in the garden in the fall for incorporation in the spring. In a fall garden, plant cover crops between the rows and in any cleared areas. Cover crops can also be used in late spring and summer to suppress weeds or provide a nitrogen boost before the next crop is planted.

Cover cropping provides additional organic matter, holds nutrients that might have been lost over the winter, and helps reduce erosion and loss of topsoil. Legume cover crops can increase the amount of nitrogen in the soil and reduce fertilizer needs over time and extended use. A deep-rooted cover crop allowed to grow for a season in problem soil can help break up a hardpan and greatly improve soil tilth. Planting multiple species of cover crops together has shown to increase the diversity of soil organism communities.

Incorporate green manures at least two weeks before planting vegetables. In most cases, cover crops should

not be allowed to go to seed.

The regular addition of manures, compost, cover crops, and other organic materials can raise the soil nutrient and physical level to a point at which the need for additional synthetic fertilizers is greatly reduced. This highly desirable soil quality does not come about with a single or even several additions of organic material, but rather requires a serious soil-building program. For more information, see chapter on The Vegetable Garden.

Study Questions

18. In general, phosphorus is used for: a) leafy top growth; b) cold hardiness and durability; c) root and fruit production; d) pest resistance

19. A nitrogen application will have its greatest effect for: a) 2-3 hours after application; b) 1-2 weeks after application; c) 3-4 weeks after application; d) 6 months after application fertilizer application is used over large garden areas or when labor is limited.

20. Foliar feeding of nutrients should NOT be done: a) when insufficient fertilizer is used before planting; b) as a substitute for soil nutrition during a critical growth period; c) when micronutrients are locked in the soil; d) when soil is too cold for plants to use fertilizer applied to soil

21. In order to preserve soil structure, never till: a) when soil is wet; b) in fall; c) in spring; d) new garden beds

22. Compost should be _____ brown, and _____ when ready to use.

23. _____ _____are planted in the garden in fall and incorporated into the soil in spring.

Answers:
18 - c; 19 - c; 20 - b; 21 - a; 22 - dark, crumbly; 23 - cover crops.

Table of Common Cover Crops

Table of Common Cover Crops						
Type	*Legume (L)/Non-Legume (N)*	*Amount to Sow/100 ft^2 (Oz.)*	*When to Sow*	*When to Turn Under*	*Effects*	*Notes*
Alfalfa	L	0.5	Spring Late Summer	Fall Spring	Fixes 150-250 lbs. N/ac./yr; deep roots break up hard soil, trace elements to surface.	Loam, fairly fertile soil; needs warm temps. for germination. Lime if pH is low. Hardy. In mountains sow by Aug 10. Drought tolerant. Inoculate.
Barley	N	4	Fall Spring	Spring Fall	Adds organic matter; improves soil aggregation.	Prefers medium-rich, loam soil. Lime if pH is low. Not as hardy as rye. Tolerates drought.
Buckwheat	N	2.5	Spring Summer	Summer Fall	Mellows soil; rich in potassium	Must leave part of garden in cover crop during season. Grows quickly. Not hardy.
Crimson Clover	L	0.33	Spring Fall	Fall Spring	Fixes 100-150 lbs. N/ac./yr.	Not reliably hardy. Sow before mid-Sept. in Piedmont and mountains. Not drought tolerant. Lime if pH is low. White clover is a bit hardier.
Fava Beans	L	Plant 8” apart	Early Spring Late Summer	Early Summer Fall	Some types fix 70-100 lbs. N/ac./yr in as little as 6 weeks. Use small seeded rather than large seeded table types.	Will grow on many soil types. Medium drought tolerance. Likes cool growing weather. Good for mountain areas. If planted in early spring can grow late vegetables. Inoculate with same bacteria as hairy vetch.
Forage Radish	N	Plant 4” apart with 15” row spacing,	Fall, 4-10 weeks before excepted killing frost	Spring	Reduces soil compaction, suppresses weeds, increase soil infiltration, captures and holds up to 170 lb N/ac/yr	Will die off once the temperature reaches 25°F but roots will slowly decompose leaving open channels that will help infiltration
Oats	N	4	Spring Fall	Summer Spring	Adds organic matter; improves soil aggregation.	Needs adequate manganese. Not hardy; tolerates low pH
Rye, winter	N	3.5	Fall	Spring	Adds organic matter; improves soil aggregation.	Very hardy. Can plant until late October.
Vetch, hairy	L	2.5	Early Fall	Spring	Fixes 80-100 lbs. N/ac./yr.	Inoculate; slow to establish. Fairly hardy. Till under before it seeds; can become a weed.
Wheat, winter	N	4	Fall	Spring	Adds organic matter; improves soil aggregation.	Prefers medium-rich, loam soil. Lime if pH is low. Not as hardy as rye. Tolerates drought.

Source Material: Fall Vegetable Gardening, VT Pub 426-334 and SARE’s Managing Cover Crops Profitably, Third Edition.

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Chapter 5
Entomology

Basic Entomology

Chapter 5

Basic Entomology

Chapter 5

Revised by *Theresa Dellinger, Collections Manager, Virginia Tech Insect Collection, Department of Entomology (2015)*

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Insects are among the oldest, most numerous, and most successful creatures on earth. Insect fossils date back to over 350 million years. Estimates of insect diversity range from 5–80 million different species, with only about one million formally described so far. Insects can be found in nearly every ecosystem and habitat except the open ocean. In the typical backyard, there are probably hundreds of different species of insects present at any given time. The vast majority of insect species are beneficial or harmless to humans. Insects pollinate fruits and vegetables. They provide food for birds, fish, and other animals, including humans in some cultures. They have been a source of inspiration for the arts and sciences. They produce useful products such as honey, wax, shellac, and silk, as well as help degrade plant debris, dung, and animal carcasses. In addition, some insects feed on other insects that are considered pests by humans.

However, while less than 3% of all insect species are considered pests, these pests cause devastating problems for humans. They transmit diseases that cause illness and death in humans and animals. Insects annually destroy millions of dollars worth of agricultural crops, shade trees, and ornamental plants. They also ruin stored products, household items, and other materials valued by humans. Insects clearly have an enormous impact on our environment and they require attention by the Master Gardener. In this chapter you will learn some of the basic principles of insect identification, the diagnostics of insect damage, and insect pest management.

Contents

Basics of Classification

Taxonomy is the science of classifying life into a hierarchical scheme with categories of varying ranks. Identification of the hundreds of thousands of species of insects would be impossible if they were not organized around a standard classification system that groups organisms according to their shared characteristics. All life on Earth is divided into six kingdoms, the highest level of the classification system: Eubacteria, Archaeabacteria, Protista, Fungi, Animalia, and Plantae. Each kingdom is further divided into smaller phyla. For example, several of the phyla that contain agricultural and horticultural pests in the animal kingdom are:

* Arthropoda (insects, spiders, mites, crayfish, millipedes)
* Nematoda (roundworms, trichina)
* Platyhelminthes (flatworms, flukes, tapeworms)
* Mollusca (snails, slugs, clams)

Phyla are subdivided into classes, which are composed of orders. Orders are composed of families, which contain genera, in which the species are ultimately placed. High school biology students may remember the phrase "Keep Putting Coffee On For Good Students," or a similar mnemonic device to help remember the whole classification arrangement of kingdom through species.

Classification Mnemonic		
Kingdom	=	**K**eep
Phylum	=	**P**utting
Class	=	**C**offee
Order	=	**O**n
Family	=	**F**or
Genus	=	**G**ood
Species	=	**S**tudents

Phylum Arthropoda and its Classes

Insects belong to the phylum Arthropoda. Arthropods are a very important group of animals, representing more

than 80% of all described living animal species. Familiar arthropods include spiders, ticks, crabs, scorpions, shrimp, barnacles, and insects. All arthropods share some common characteristics, such as segmented bodies, paired segmented appendages, bilateral symmetry, and an exoskeleton (an outer "skin" or "shell" that serves as an external skeleton) that is periodically shed as the arthropod grows. Insects belong to the class Insecta. Some of the more commonly found classes of arthropods are listed in Table 1.

Orders of the Class Insecta

Classes are further divided into orders. Orders in the class Insecta are based on the type of metamorphosis, mouthparts, and wings an insect may have. Insect orders are further broken down into smaller groupings called the family. Each family is a more select group of very closely related insects. Family names end with "-idae." Aphidae (aphids), Muscidae (house flies), and Acrididae (grasshoppers) are examples of families of insects.

Families are divided into genera, which are finally divided into species. These are the most finite levels of our classification system. The house fly, *Musca domestica*, serves here as an example of specific classification:

* Phylum: Arthropoda
* Class: Insecta
* Order: Diptera
* Family: Muscidae
* Genus: *Musca*
* Species: *domestica*
* Common name: house fly

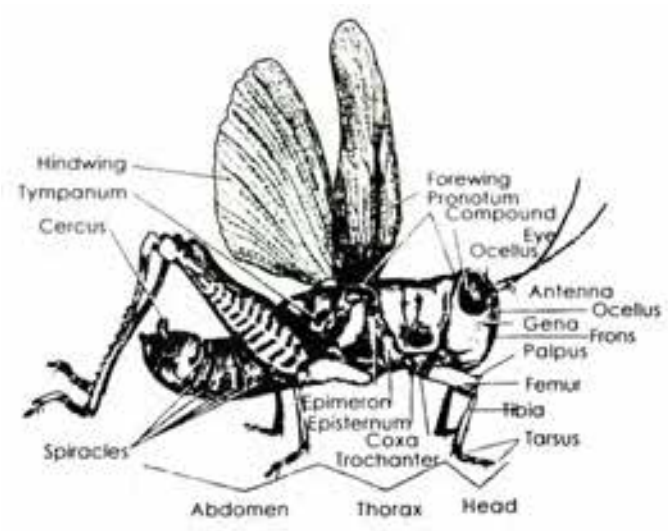
Musca domestica is the scientific name for the house fly. The scientific name of an organism includes both its genus and species names. The scientific name is always italicized and only the genus name is capitalized. Many insects, but not all, have common names; sometimes a single species will have several common names. For example, *Heliothis zea* is called the corn earworm when found on corn, but it is a tomato fruitworm when found on tomatoes. Using scientific names eliminates the confusion that can occur when an insect has several common names, or if one common name is used for more than one species. Common names can also refer to large groups of insects, such as families or orders. The entire order Coleoptera is known as the beetles. The term moth refers to thousands of species in the order Lepidoptera.

Note: Invertebrate taxonomy often changes to reflect ongoing research into the relationships among organisms. Species are moved from genus to genus, whole families can be combined with another family, and changes sometimes occur even at the level of orders. One resource that stays up-to-date on the current state of insect taxonomy is the website bugguide.net. This website has a wealth of material on insects, spiders, and related arthropods, including a fantastic gallery of photos.

Insect Form & Structure - Morphology

All adult members of class Insecta are identifiable by having three body regions, three pairs of legs, and one pair of antennae. Most adult insects have two pairs of wings, although some have only one pair and some are wingless. The legs, antennae, wings, mouthparts, and other appendages are often greatly modified to suit the habitat where the insect lives and what it eats. These appendages can be very useful in determining what order to which an insect belongs.

The three regions of the adult insect body are the head, thorax, and abdomen. Sometimes the division between two regions is not always obvious. It is helpful to remember that the eyes, mouthparts, and antennae are found on the head and the legs and wings are found on the thorax. The abdomen is primarily important for digestion and reproduction.



Insects do not have an internal bony skeleton. The insect body is supported by an exoskeleton, a tough outer body wall. The outer layer of the exoskeleton, the cuticle, is made of chitin, a strong and flexible material. However, chitin is not very hard so the body wall also includes sclerites, hardened plates that offer stronger protection. Together, this combination of hardened sclerites connected by thin, flexible cuticle is a structural feature that has helped arthropods colonize nearly every habitat on Earth. In addition, the cuticle has an outer layer of wax that limits water loss and prevents desiccation, a very important survival feature for insects. The cuticle in immature insects is often somewhat softer and not as hardened as that of the adult.

Head

The insect head is primarily involved with eating and sensory perception. The main features of the insect head are the eyes, antennae, and mouthparts. These organs may be highly specialized among orders and families.

Antennae

The antennae are a prominent and distinctive feature of many insects. Adult insects have one pair of antennae located usually between or in front of the compound eyes. Antennae are segmented and vary greatly in form and complexity. The antennae are primarily organs of smell, but may serve as organs for taste, touch, and/or hearing.

Mouthparts

Insect mouthparts are complicated structural features, and they vary greatly in form and function. Most types of insect mouthparts can be divided into two broad categories: those adapted for chewing and those adapted for sucking. There are also intermediate types of mouthparts: rasping-sucking, as found in thrips, and chewing-lapping, as found in honey bees, wasps, and bumble bees. Piercing-sucking mouthparts are typical of the Hemiptera (bugs, aphids, scales, and mealybugs), blood-sucking lice, fleas, mosquitoes, and the biting flies. Butterflies and moths have siphoning mouthparts for feeding on nectar. Houseflies and many other flies have sponging mouthparts.

The mouthparts of immature insects may differ from the adults. Larvae generally have chewing mouthparts regardless of the kind possessed by the adults. Nymphs have mouthparts similar to those of the adults. In some adult insects, the mouthparts are vestigial because the adults do not feed.

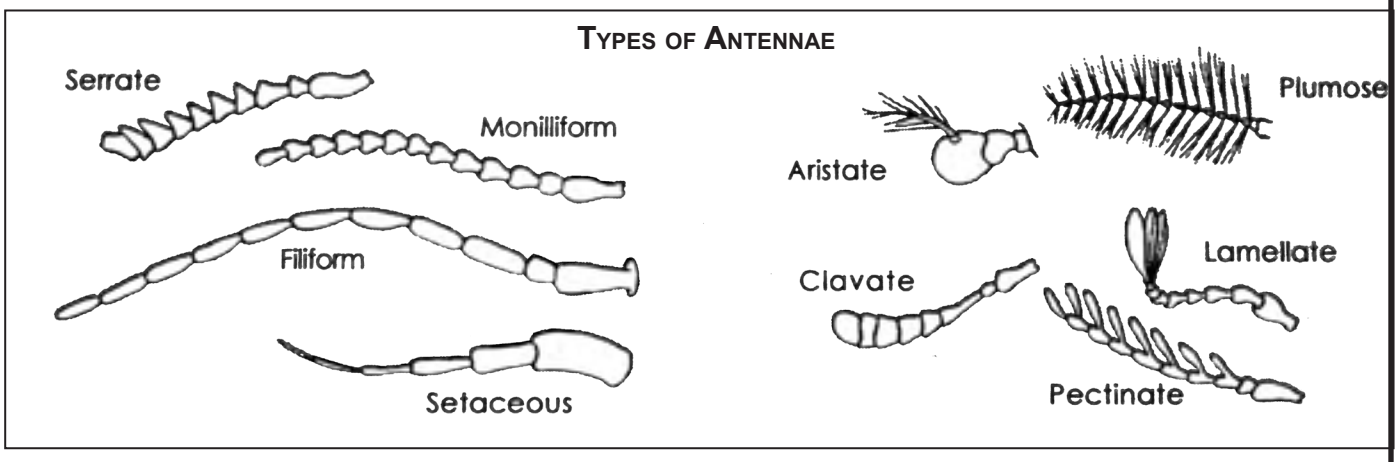
Some types of insect mouthparts are diagrammed below: a) chewing-lapping (honey bee); b) sponging (housefly); c) piercing-sucking (mosquito); d) siphoning, coiled (butterfly); e) chewing (grasshopper).

Thorax

The thorax is made up of three segments, each bearing a pair of legs. Most adult insects possess two pairs of wings that are attached to the second and third segments of the thorax.

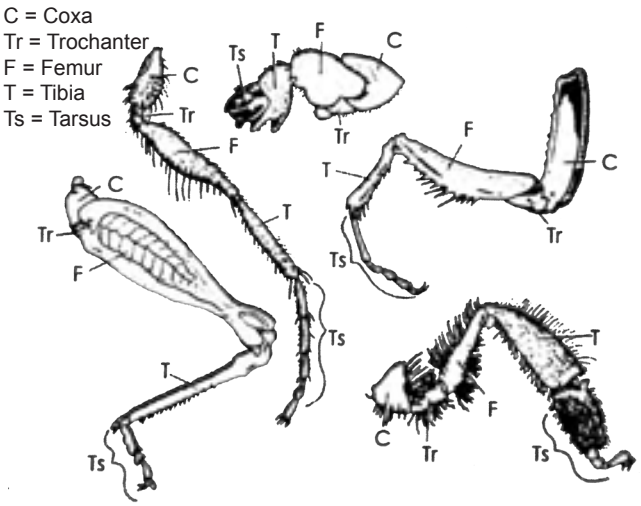
Legs

The most important characteristic for identifying something as an insect is the presence of three pairs of jointed legs. These are almost always present on adult insects and are generally present in the other stages as well. In addition to walking and jumping, insects often



use their legs for digging, grasping, feeling, swimming, carrying loads, building nests, and cleaning parts of the body. The legs of insects vary greatly in size and form and are frequently used in insect classification.

Leg adaptations of some insects are diagrammed below, (left to right): jumping (grasshopper); running (beetle); digging (mole cricket); grasping (praying mantis); swimming (diving beetle).

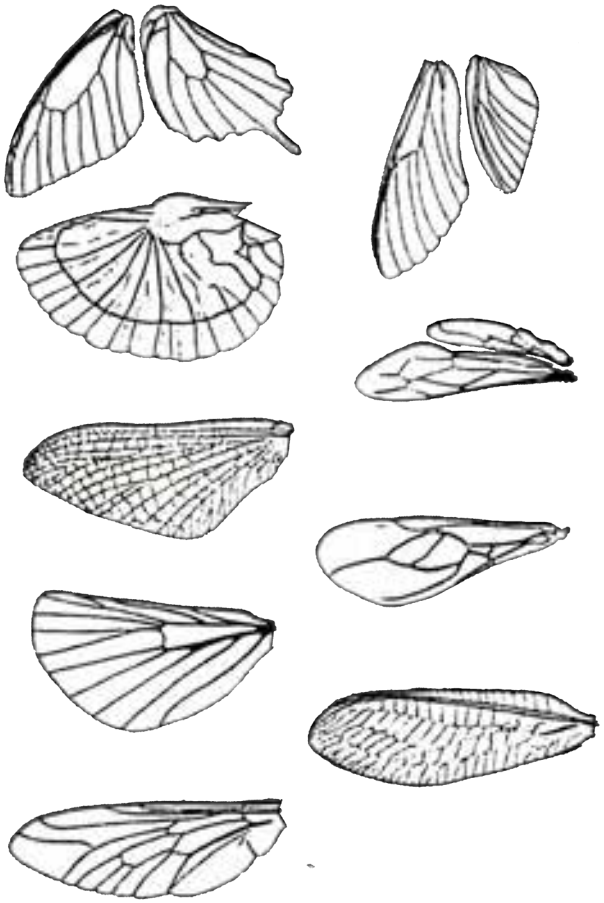


Wings

Wings are also important features of insects and the variations of wing forms can help identify insect families, genera, and even different species. Wing venation (the arrangement of veins in wings) also serves as a means of identifying insects to family or sometimes species. Wing surfaces may be covered with fine hairs or scales or they may be bare or membranous; these characteristics can be used for identification as well. Note that the names of most insect orders end in "-ptera," which comes from the Greek word meaning "with wings." Many order names describe some feature of the wings. Hemiptera means "half-winged" and refers to the appearance of the wings of true bugs, while Diptera means "two-winged" and refers to the fact that flies have only one pair of wings.

Only adult insects possess wings, although wing pads (areas where the wings are developing) are sometimes noticeable on older nymphs.

Types of Wings



Abdomen

The insect abdomen may have 11–12 segments, but in most cases they are difficult to see clearly because the segments are short or they are covered by wings. Some insects have appendages called cerci at the tip of the abdomen. Cerci can be short, as seen in grasshoppers, termites, and cockroaches; extremely long, as in mayflies; or curved, as in earwigs.

Insect Development - Metamorphosis

As immature insects feed and grow, eventually their exoskeleton gets too tight and the insect must shed the outer skeleton in a process called "molting." At various stages of growth, the immature insect will split open the exoskeleton and pull itself out of it wearing a soft, new exoskeleton it formed under the old one. The new exoskeleton will harden to protect the insect while giving it sufficient room to grow once it hardens. The stage of life between each molt is called an instar. The number

of instars, or the frequency of molts, varies with each species and to some extent with food supply, temperature, and moisture.

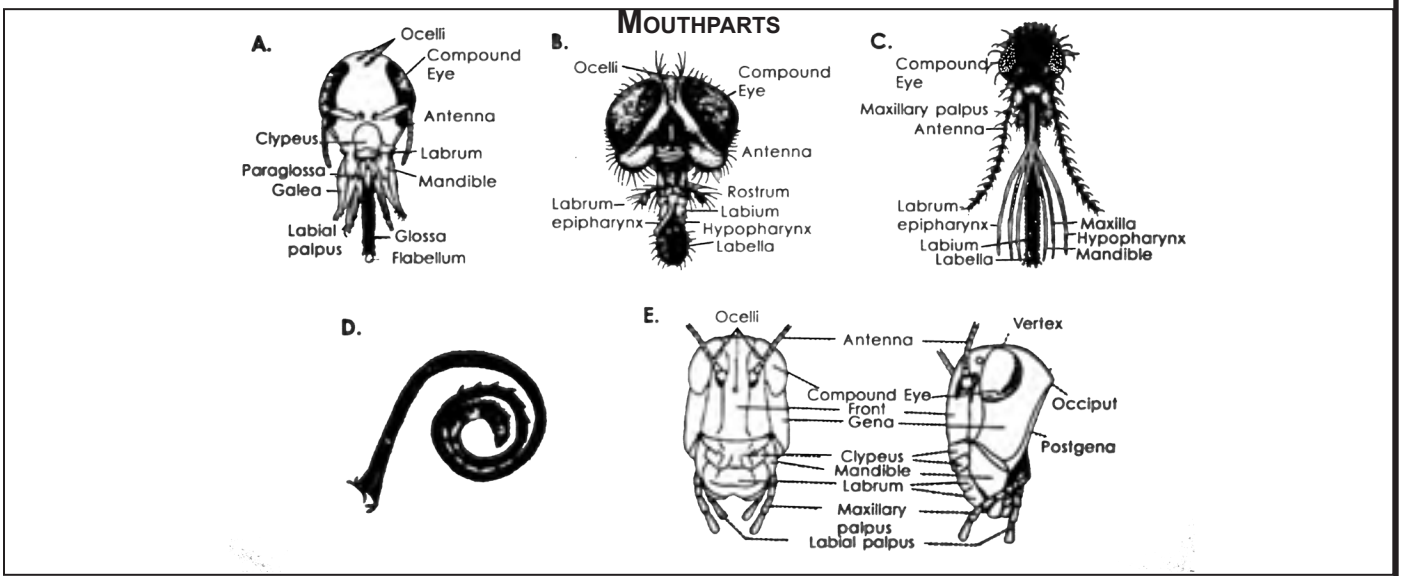
In addition to molting, insects also undergo a distinctive phenomenon called metamorphosis at certain stages of their development. The term is a combination of two Greek words: “meta”, meaning change, and “morphe”, meaning form. Metamorphosis is a biological process in which an insect undergoes an abrupt change in its form from one stage of development to the next. A familiar example of metamorphosis is the change a caterpillar undergoes when it becomes a pupa, or when the adult butterfly emerges from the pupa. There are three types of metamorphosis: ametabolous, hemimetabolous, and holometabolous.

Ametabolous insects (illustrated below as ‘Without Metamorphosis’) increase in size throughout their life cycle, but do not change basic body structure and arrangement. The adult is wingless and looks very similar to the immature form. This is considered the most evolutionarily ‘primitive’ form of metamorphosis. Silverfish are a good example of an insect with ametabolous metamorphosis.

Hemimetabolous insects (illustrated on page 111 as ‘Gradual’ or ‘Incomplete Metamorphosis’) increase in size while maintaining the same basic characteristics throughout the life of the insect. This type of metamorphosis is also called simple metamorphosis and it is the most common type of metamorphosis seen in insects. There are three stages of development in hemimetabolous insects: egg, immature, and adult. Hemimetabolous insects are usually terrestrial. The immatures, called nymphs, share similar food sources with the adult insects. Some hemimetabolous insects are aquatic, such as the dragonflies. Immature aquatic are called naiads and they have a different food source than the terrestrial adults. In both terrestrial and aquatic hemimetabolous insects, fully functioning wings are found only in the adult stage. These wings will appear as developing wing buds in the immature stage.

Holometabolous insects (illustrated below as ‘Complete Metamorphosis’) go through four distinct stages: egg, larva, pupa, and adult. The immature larvae differ greatly in appearance from their adult form. The profound change from larvae to adult takes place during the pupal stage. Many tissues and structures, such as the prolegs of caterpillars, are completely broken down and true legs, antennae, wings, and other structures of the adult are formed. The larvae of holometabolous insects often use different food sources than the adults. Orders of insects that go through complete metamorphosis include Coleoptera, Neuroptera, Hymenoptera, Trichoptera, Lepidoptera, Siphonaptera, Mecoptera, Strepsiptera, and Diptera. These are considered to be the most evolutionarily advanced and biodiverse insect orders.

Regardless of the type of metamorphosis, the adult stage of an insect focuses on reproduction rather than feeding and growth. Some adults are very short-lived and they may not feed at all.



Study Questions

1. Characteristics that place an animal in the phylum Arthropoda include: a) body segmentation and exoskeletons; b) wings; c) 3 pairs of legs; d) destruction of economic crops.
2. The adult insects' major body segments do NOT include: a) head; b) thorax; c) mandibles; d) abdomen.
3. Adult houseflies have what kind of mouthparts?
4. Caterpillars have what kind of mouthparts?
5. Aphids have what kind of mouthparts?
6. Insect legs can be adapted for: a) digging; b) self-cleaning; c) feeling; d) all of the above.
7. Holometabolous (complete) metamorphosis includes the stages: a) egg, nymph, adult; b) egg, nymph, pupa, adult; c) egg, larva, pupa, adult; d) only a gradual increase in size.

Answers:
1 - a; 2 - c; 3 - sponging; 4 - chewing; 5 - piercing-sucking; 6 - d; 7 - c

Identifying Insects

Some home gardeners recognize insects by the common name of their order, such as beetle, wasp, ant, or butterfly. Common names are sometimes regional and occasionally inaccurate. For example, a June bug in one area may be called a May beetle in another location. However, these common names can be helpful when conversing with clients who are not familiar with insects or their scientific names.

The ability to classify an insect to its correct order gives a Master Gardener access to valuable information about that insect. This information includes the type of mouthparts the insect has, which provides clues to the type of plant damage caused by members in that order and which methods may be effective in controlling those insects. Familiarity with the life cycle of an insect can help the planning for the proper use and timing of best management practices to avoid pest problems.

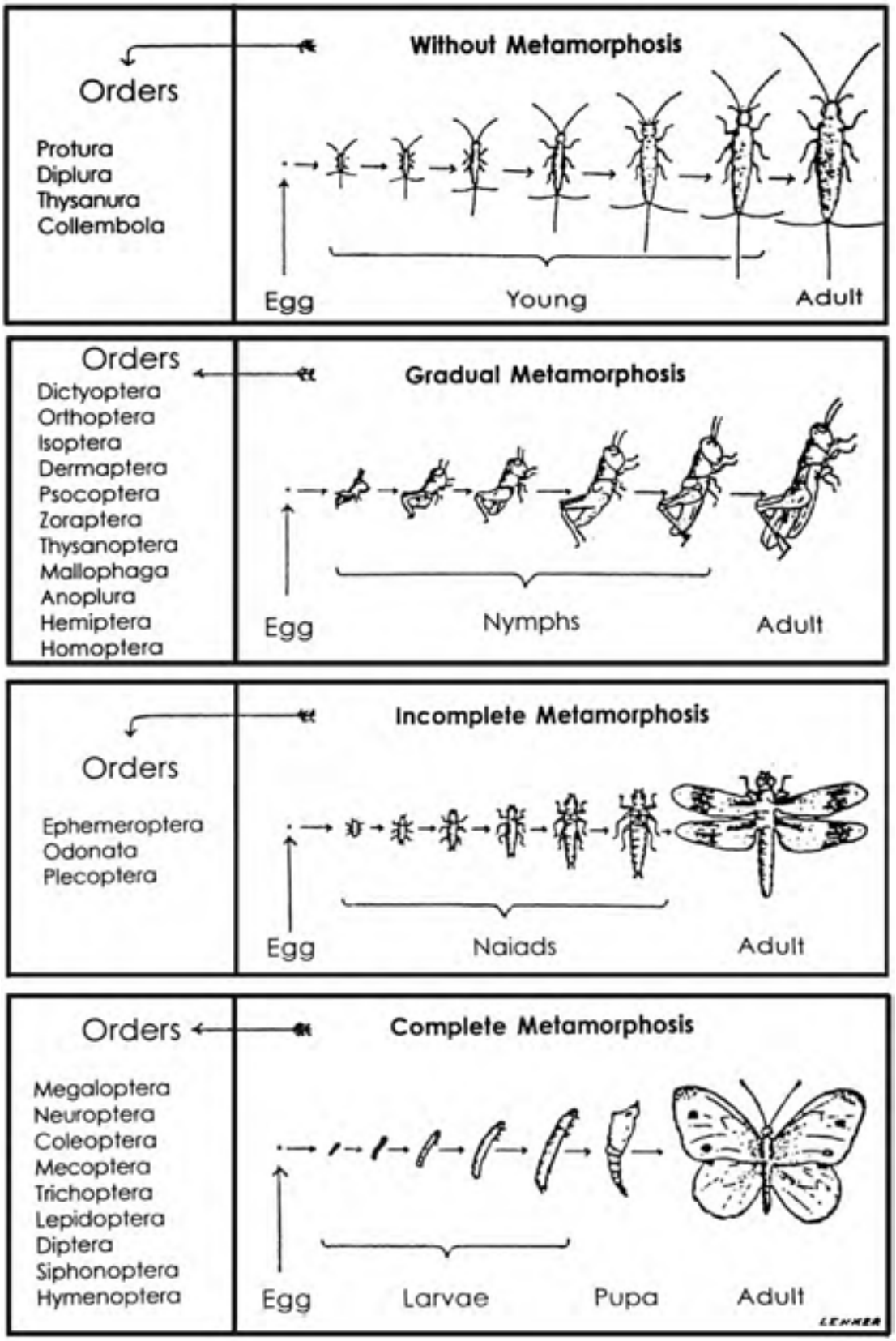
Because of the sheer number of insects, their overall diversity, and their relatively small size, identification can be difficult for the beginner. Outside of having a local expert identify them, the best way for Master Gardeners to learn insect classification is to practice using a dichotomous key. Dichotomous keys are based on an organized series of choices between mutually exclusive characteristics, arranged hierarchically from the more general to the more specific. By working through the organized set of couplets and carefully selecting answers, you can arrive at the correct identification of an organism. These keys require knowledge of insect characteristics and time spent becoming familiar with how to use the keys, but this effort will allow the Master Gardener to quickly classify insects to the order level or even higher levels. The goal of order level keys is to familiarize the user with the basic characteristics so that eventually the keys will become no longer necessary except as a reminder when memory fails. While it is tempting to simply browse pictures in an attempt to identify an insect, most photo guides are not comprehensive enough for an accurate identification and this will not help improve one's identification skills.

While the identification of adult insects can be learned with some practice, immature insects often present a greater challenge. With the exception of colorful caterpillars and some odd looking species, many immature insects are difficult to differentiate from each other and their adult counterparts. Sometimes the immature stages look nothing like the adult stage. There are some rules of thumb to describe immature insects in relation to their adult counterparts. The following table illustrates some of the main differences.

Features of Immature and Mature Insects

Immature Insects	*Adult Insects*
Sometimes worm-like or grubs	Three body regions
Number of legs can vary	Three pairs of legs
Body generally soft and/or fleshy	Usually with tough body wall
Lack wings	May have wings
Most move slowly	Most can move quickly

In some cases we are more dependent upon host and habitat information to help us identify insects in question. Some key questions can offer important clues to the identification of the immature insect. Where were the insects found? What are the insects eating? What kind of mouthparts do they have? Do they have legs? If so, how many legs? What color are the insects?



For your reference, the insect orders have been divided into three sections: those containing insects important to the gardener, those containing insects of lesser importance to the gardener, and common "noninsect" pests in Virginia. The orders containing insects of importance to home gardeners will be considered in detail.

Resources

There are many keys to the insects available in textbooks, field guides, scientific papers, and on the Internet. Start with keys that are simple, such as those for the order level, and do not rely on scientific terminology. A good key for beginners are the following books: A Field Guide to Insects North of Mexico, by Donald J. Borrer and Richard E. White; Garden Insects of North America: The Ultimate Guide, by Whitney Cranshaw: and Bugs Rule!, An Introduction to the World of Insects by Whitney Cranshaw. In addition the website bugguide.net is a fabulous resource for images of insects and other arthropods. Experts on this website may be able to assist with the identification of an arthropod if a high-quality image can be uploaded to the site. Most of the characteristics used to identify an insect to order can be seen with a 10X magnifier, although it is easier with a dissecting microscope and a good light source. Once an insect has been identified to order it can be more easily cross-referenced with other resources that narrow down possible suspects by habitat or food source.

Numerous fact sheets on insects are provided through the Virginia Cooperative Extension. To see a current listing of entomology fact sheets, see the publication index at https://pubs.ext.vt.edu/index.html.

Submitting Samples

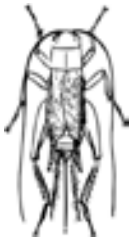
Insects can be submitted to an Entomologist at a University for identification with proper paperwork. All insect submissions must be reviewed by the local extension agent and mailed from that office. Important information that must be included is: Host plant or location found, date, description of damage, when was if first found, and if control information is required. Since an extension office is an excellent resource on local pests, identifications can often be obtained at that office without sending a sample to state identifier.

Insects of Importance to the Gardener

Orthoptera: Grasshoppers, crickets, katydids

* Adults can be moderate to large insects, often with hard bodies.
* Hind legs are modified for jumping. Antennae can be very long.
* They undergo simple metamorphosis. Nymphs resemble adults but lack wings.
* Adults have two pairs of wings. The forewings are elongated, narrow, and hardened. Hindwings are membranous with extensive folded areas. Some species have reduced wings or may be wingless.
* Many orthopterans "sing" or chirp by rubbing one part of their body against another.

Grasshopper



Cricket

Katydid

Blattodea: Cockroaches and termites

* Both cockroaches and termites have chewing mouthparts.
* Both cockroaches and termites undergo simple metamorphosis. Nymphs generally resemble the adults but without wings.
* Cockroaches have oval, flattened bodies and are usually dark brown to reddish in color. They can be small to large insects. Adults may have wings, or they may be reduced in size or absent. Cockroaches are known for being fast runners.
* Termites somewhat resemble ants in shape and size, but they lack the "waist" seen in ants. They are soft-bodied and live in colonies with a complex social system. Termites feed on cellulose and are very destructive to wood. Reproductive termites have two pairs of wings, but they may shed them quickly.

Cockroach

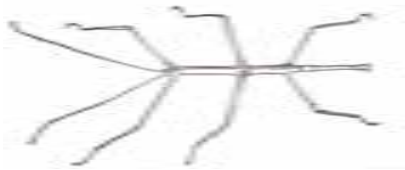
Mantodea: Praying mantises, mantids

* Adults can be moderate to large insects.
* They have elongated bodies, large eyes, and front legs modified for catching their prey.
* Adults have two pairs of wings. The forewings are elongated, narrow, and hardened. Hindwings are membranous with extensive folded areas.
* They undergo simple metamorphosis. Nymphs resemble adults but lack wings.
* Both nymphs and adults have chewing mouthparts and eat other arthropods.

Mantid

Phasmida: Walkingsticks

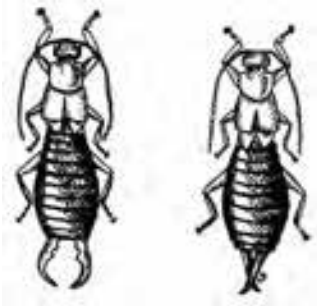
* Largely resemble brown or green twigs with long legs and antennae.
* They undergo simple metamorphosis. Nymphs resemble small adults.
* Both nymphs and adults have chewing mouthparts and feed on foliage of trees.
* Typically very slow moving and may hold themselves to look like twigs.



Walkingstick

Dermaptera: Earwigs

* Adults are moderate-sized insects.
* They undergo gradual metamorphosis with both the nymphs and adults being similar in appearance.
* They are elongated and flattened, with strong, moveable forceps at the tip of the abdomen. Some species can pinch with their forceps. The forceps in the immature is somewhat weaker.
* Adults have short, hardened outer wings that cover the folded, membranous inner wings. Some adults are wingless.
* Both adult and immature earwigs possess chewing mouthparts.



Line art by Kathy Bourne

Earwigs

Hemiptera: True bugs, cicadas, hoppers, aphids, scales, and allies

* This is a very large and diverse group of insects with considerable differences in appearances and life histories.
* Range from being generally small, soft-bodied insects to the large, hard-bodied cicadas.
* They undergo gradual metamorphosis, but some (like the aphids) have complex life cycles involving alternate plant hosts.
* Nymphs of true bugs (such as squash bug and stink bugs) generally resemble the adults.
* Adult true bugs usually have two pairs of wings. The first pair are “half-wings” with a thickened part close to the body and a membranous bottom half. The second pair of wings is fully membranous.

* Other adult hemipteran species may have both winged and wingless forms.
* Nymphs of scales, mealybugs, and whiteflies can look very different from the adults.
* All homopterans have piercing-sucking mouthparts. Most are plant feeders, but some feed on blood.
* Many plant feeders transmit plant pathogens; some blood feeders carry human and animal diseases.

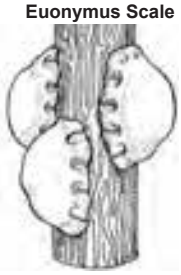
Aphids

Cicada

Euonymus Scale

Woolly Alder Aphid

Milkweed Bug



Wax Scale

Mealybug (Male)

(Female)

Above Line art by Kathy Bourne (except mealybugs)

Stink Bug

White Fly

Wheel Bug

Two-lined Spittlebug

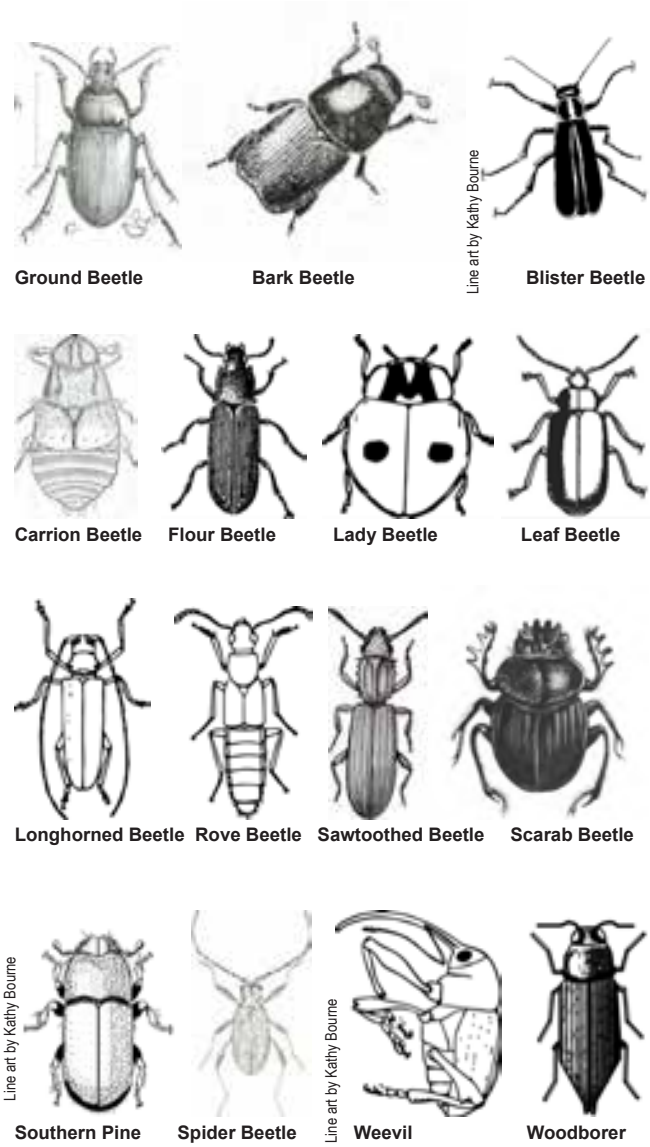
Thysanoptera: Thrips

* Called thrips whether there is one thrips or several.
* Small, soft-bodied insects.
* Metamorphosis includes a mix of gradual and complete stages.
* Mouthparts are rasping-sucking.
* Can be found on flowers or foliage of plants and may transmit plant diseases.
* Adults have two pairs of slender wings with a fringe of hairs resembling feathers.

Thrip

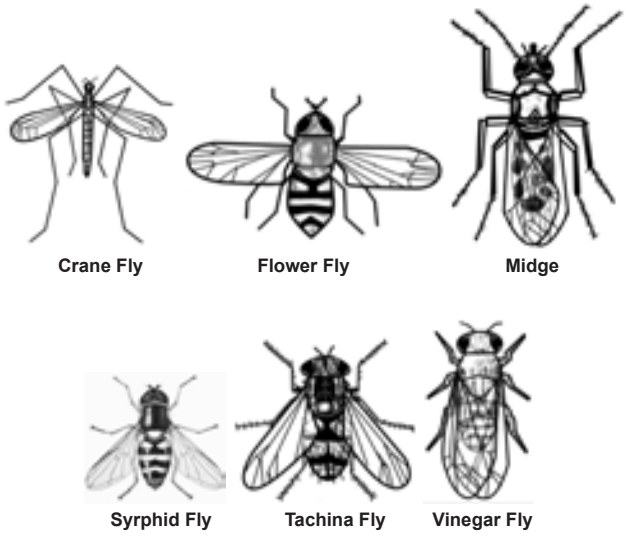
Coleoptera: Beetles, weevils, borers, white grubs

* Adults often have a hardened exoskeleton, but some species have soft bodies as adults.
* Adults usually have two pairs of wings; the outer pair (the elytra) is hard and protects the membranous inner pair. The elytra usually cover the abdomen but some species have very short elytra that do not completely cover the abdomen.
* Both adult and immature beetles possess chewing mouthparts.
* Adults usually have noticeable antennae, sometimes in very distinctive forms that can be useful in identifying them to the family level.
* Adult beetles range in size from the very tiny, approximately 1 mm long, to an inch or more in the larger species.
* They undergo complete metamorphosis. The larvae are often called grubs.
* Larvae have a head capsule, three pairs of legs on the thorax, and no legs on the abdomen. Weevil larvae, however, do not have any legs.



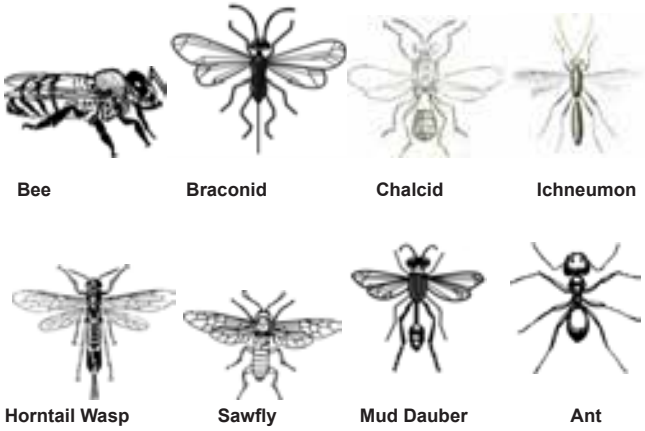
Diptera: Flies, mosquitoes, gnats, midges

* Adult flies have one pair of wings, are usually soft-bodied, and often covered with hairs or bristles.
* Flies undergo complete metamorphosis.
* Most larvae are legless with chewing mouthparts or mouth "hooks."
* Adults have sponging mouthparts or, in blood-feeders like mosquitoes, piercing mouthparts.
* Larvae of advanced flies (such as house flies) lack a head capsule, possess mouth hooks, and are called maggots.
* Larvae of lower forms (such as mosquitoes and fungus gnats) possess a head capsule.
* Blood-feeding flies (such as mosquitoes, horse flies, biting midges, and black flies) are a nuisance and can transmit diseases.



Hymenoptera: Bees, ants, wasps, sawflies, horntails

* Adults have two pairs of membranous wings.
* Larvae have no legs except for the sawflies, with three pairs of legs on the thorax and at least six pairs of legs on the abdomen.
* Adults have chewing mouthparts and soft or slightly hard bodies.
* They undergo complete metamorphosis.



Lepidoptera: Butterflies, moths, caterpillars, cutworms

* Adults are soft-bodied with two pairs of well-developed wings covered with scales.
* They undergo complete metamorphosis.
* Larvae have chewing mouthparts while adults have

a coiled, sucking tube adapted for feeding on nectar and other liquids.

* Larvae are called caterpillars; they are worm-like, voracious feeders on plants.
* Caterpillars have three pairs of legs on the thorax as well as multiple pairs of legs on the abdomen.

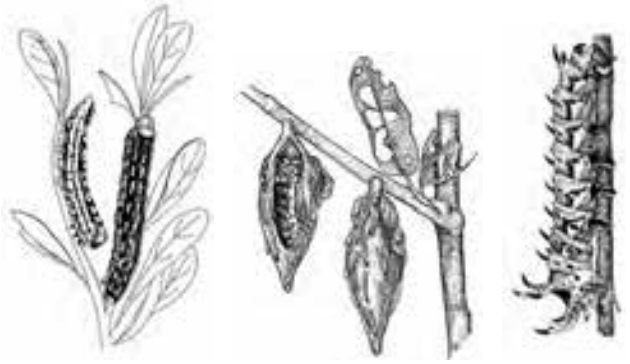
Lepidoptera Adults

Cabbageworm Adult Fritillary Imperial

Luna Moth Polyphemus Moth Codling Moth

Line art by Kathy Bourne

Lepidoptera Larvae



Azalea Caterpillar Bagworm Hickory Horned Devil

Linden Looper Yellow-Necked Caterpillar

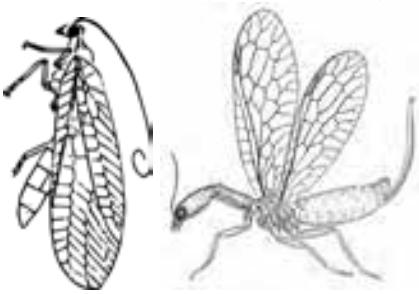
Corn Earworm Saddleback Caterpillar

Above Line art by Kathy Bourne (except corn earworm)

NEUROPTERA: LACEWINGS, ANTLIONS, SNAKEFLIES, DOBSONFLIES

* Many neuropterans are predators of other insects. Some are aquatic.
* Adults have two pairs of membranous wings held "roof-like" over the abdomen.
* Adults have chewing mouthparts and long antennae.
* They undergo complete metamorphosis.

Antlion Dobsonfly Dusty Wing



Lacewing Snakefly

Insect Orders of Lesser Importance

Examples, not a comprehensive list	
Order	*Example Insects*
Ephemeroptera	Mayflies
Embiidina	Webspinners
Mecoptera	Scorpionflies
Neuroptera	Antlions, lacewings
Odonata	Dragonflies, damselflies
Plecoptera	Stoneflies
Psocoptera	Booklice, barklice, parasitic lice
Siphonaptera	Fleas
Strepsiptera	Twisted-wing insects
Trichoptera	Caddisflies
Zoraptera	Angel insects
Zygentoma	Silverfish

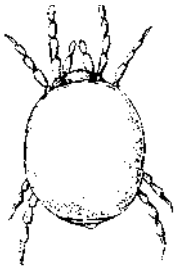
Commonly Encountered Non-Insect Arthropods

There are a variety of other arthropods seen in the average backyard. The following are some of the more common ones found in Virginia.

ARACHNIDA: SPIDERS, MITES, TICKS, DADDY-LONGLEGS

Spiders are soft-bodied arthropods with two distinct body regions. Spiders have four pairs of legs, although some of their specialized mouthparts may be mistaken

for legs. Spiders are important predators of insects and other arthropods. Many spiders spin webs to catch their prey but others ambush or actively hunt for food. Only a few species of spiders in Virginia have venom considered potentially harmful to humans. For more information, see the fact sheet "Spiders of Medical Concern in Virginia" from Virginia Cooperative Extension, http://pubs.ext.vt.edu/ENTO/ENTO-73/ENTO-73-pdf.pdf



Line art by Kathy Bourne

Spider Mite

Mites superficially resemble very tiny spiders. They have two body regions that appear undivided and lack antennae. Most adult mites have four pairs of legs while some of the immature stages have only three pairs of legs. Many mites are plant feeders, but some are predators of other mites while others feed on animals. Spider mites that attack plants often produce noticeable sheets of webbing when their populations are large.

Ticks look much like large mites. Adults have four pairs of legs while the youngest immature stage has only three pairs of legs. They are exclusively parasitic, feeding on the blood of animals. Some species are important vectors of diseases. For more information, see the fact sheet "Common Ticks of Virginia" from the Virginia Cooperative Extension, https://pubs.ext.vt.edu/2906/2906-1396/2906-1396_pdf.pdf

Daddy-longlegs are also known as harvestmen. These familiar arachnids have small bodies and long legs that are often several times longer than the length of the body. They are harmless and do not possess venom.

Diplopoda: Millipedes

Millipedes are long arthropods whose bodies are rounded in cross section and made up of many segments. All but the first four or five body segments behind the head have two pairs of legs. Millipedes move slowly and are found in leaf litter or on the soil. They prefer humid habitats. Most are detritivores, feeding on decaying organic matter. Sometimes they can be pests to tender young plants or in greenhouses.

Chilopoda: Centipedes

Centipedes are also long arthropods made up of many segments. They tend to be flatter than millipedes, with longer antennae and only one pair of leg per body segment. The last pair of legs is held extended behind the body. Centipedes are fast-moving predators of other arthropods, with a pair of legs modified into "poison claws" that they use to inject venom into their prey. Despite their fearsome appearance, most centipedes are too small to be of medical concern to humans.

Isopoda: Sowbugs, roly poly, pill bugs, woodlice

These are small, oval arthropods with highly segmented, hard bodies and seven pairs of legs. They require high humidity for survival. Only some isopods can roll themselves into a ball. Isopods feed on decaying plant matter and are generally harmless, but sometimes they attack young, tender plants.

Study Questions

8. Insects with chewing mouthparts include all of the following orders BUT: a) Coleoptera (beetles); b) Dermoptera (earwigs); c) Hemiptera (true bugs, leaf hoppers, cicadas, and allies); d) Hymenoptera (ants, bees, wasps).

9. Order Hemiptera includes many pests that carry plant pathogens. This order includes: a) flies; b) aphids; c) moths; d) wasps.

10. Insects that undergo a simple metamorphosis (immatures resemble the adults) include: a) Orthoptera (grasshoppers); b) Hymenoptera (ants); c) Coleoptera (weevils); d) all of the above.

11. A commonly found non-insect pest would be: a) earwigs; b) aphids; c) thrips; d) spider mites.

Answers: 8 - c; 9 - b; 10 - a; 11 - d

Types of Insect Injury

Sometimes it is useful to classify insects in groups according to how they feed or damage plants. Members of these groups, also called guilds, all share a common manner of injuring plants even though they may belong to different insect orders.

Injury by Chewing Insects

Insects take their food in a variety of ways. Many

insects feed by chewing off the external parts of a plant, so they are called "chewing insects." Examples of this type of plant injury are easy to find. Perhaps the best way to appreciate the prevalence of this type of damage is to look for leaves of plants in late summer that have no sign of leaf chewing. Cabbage worms, armyworms, grasshoppers, Colorado potato beetle, and fall webworm are common examples of chewing insects. Often chewing insects merely browse the leaves and do not cause a significant amount of plant damage beyond aesthetics. Significant plant damage occurs when large numbers of insects defoliate a significant portion of the leaf and impair its ability to make food for the plant. Plant species differ in their responses to insect damage, and this should be a consideration in pest management.

Injury by Piercing-Sucking Insects

Other insects feed by piercing plant tissue and sucking sap from the plant's cells. Only internal liquids from the plant are ingested, not portions of the tissue. Insects that feed this way have slender, sharp mouthparts that are inserted into the plant and used like a straw. The injury to the plant is physically small and very difficult to see with the naked eye, but the withdrawal of sap can result in: minute, spotty discolorations on leaves, fruit, and stems; curling or puckering of leaves; deformed fruit and seeds; witch's broom growths; or a general wilting and dying of the entire plant. Aphids, squash bugs, scale insects, leafhoppers, and other members of the order Hemiptera are all piercing-sucking insects. Many of these pests also carry plant diseases and transmit them when they feed.

Injury by Internal Feeders

Some insects feed within plant tissues for all or part of their development. They gain entrance to plants when adult females insert their eggs into the part of a plant, or by eating their way into the plant after hatching from eggs deposited on the plant. In either case, the entrance hole is small and hard to see. Large holes in fruit, seeds, stems, or trunks usually indicate where an insect has left the plant, not where it entered.

The chief guilds of internal plant feeders share a common name for their group. Borers feed in wood or pith; worms or weevils are found in fruits, nuts, or seeds; leaf miners live within the thin layers of leaf tissue; and gall insects form characteristic homes from leaves, stems, twigs, and roots. These guilds are some of the most important insect pests. Nearly all internal feeding insects live inside the plant only during part of their lives and usually emerge as adults. Control measures are most effective when aimed at emerging adults or the immature stages before they enter the plant, where they are hidden from sight and well protected.

Injury by Subterranean Insects

Insects that attack plants below the surface of the soil are also hidden from sight. These subterranean insects include chewing and sucking insects, root borers, and gall insects. Some subterranean insects spend their entire life cycle below ground. For example, the woolly apple aphid sucks sap from the roots of apple trees as both nymph and adult, causing the development of tumors and subsequent decay of the tree roots. Other subterranean insects have at least one life stage found above ground. Examples include wireworms, root maggots, strawberry root weevil, and corn rootworm. These larvae are root feeders while the adults live above ground.

Injury by Egg-laying

Probably 95% of the plant injury caused by insects is due by their feeding in the various ways just described. Some insects also cause damage by laying eggs in critical plant tissues. The periodical cicada deposits eggs in one-year-old-growth of deciduous trees, splitting the wood so much that the twig may break and die. When they hatch, the nymphs drop to the ground and feed on roots in the soil but cause no further damage to the canopy.

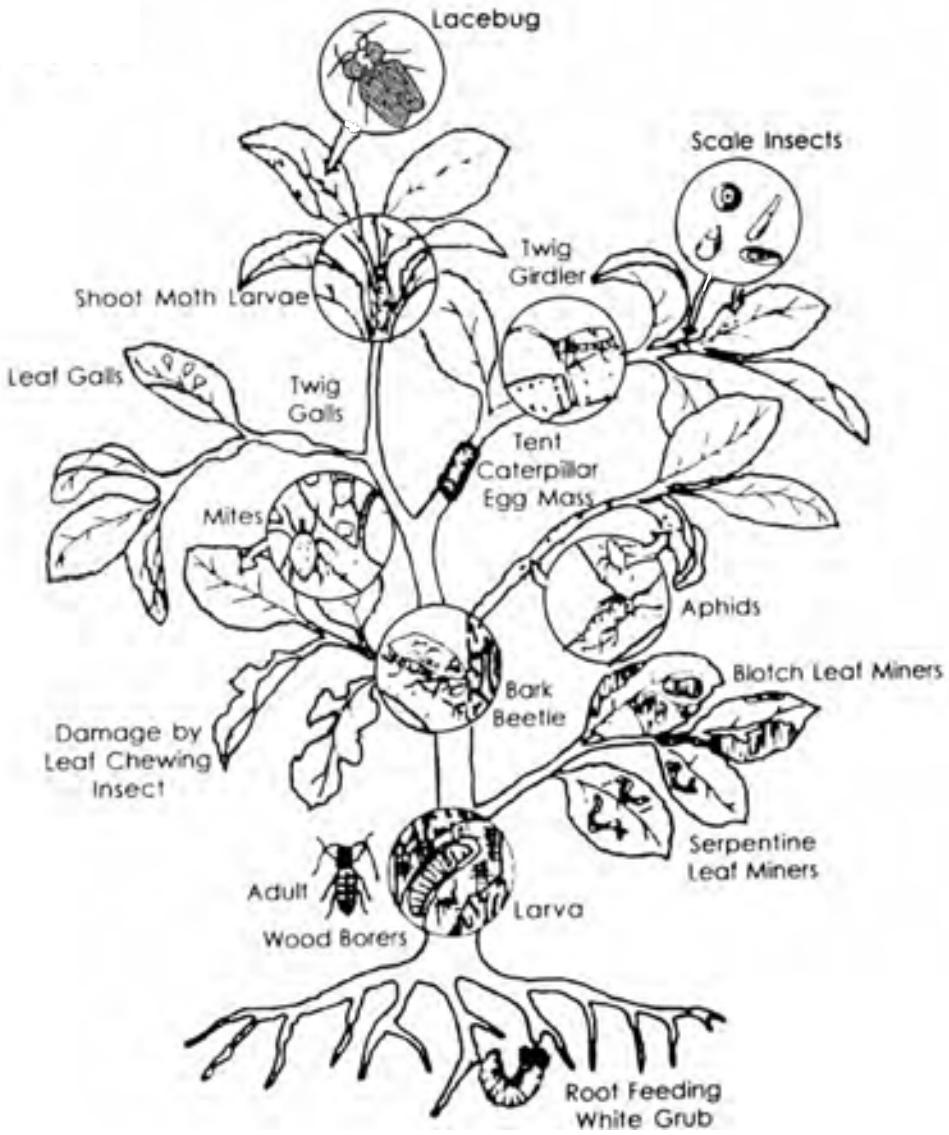
Female gall insects lay eggs in plant tissues. The plant responds to this by forming a gall where the female laid her eggs, which houses and feeds the developing immature insects. The galls are abnormal growths of deformed stem, leaf, root, or bud tissue; they can be distinctive enough that the attacking insect can be identified to species based solely on the size and shape of the gall. Gall formation is likely initiated by chemicals produced by the female laying her eggs, but continued development of the gall relies on the mechanical damage by larval feeding and secretions from the developing grubs.

Use of Plants for Nest Materials

Insects sometimes remove parts of plants for the construction of nests or to provision nests. Leaf-cutter bees neatly cut circular pieces of foliage from roses and other plants to line the brood cells of their young.

Insects as Vectors for Plant Diseases

There over 200 plant diseases spread by insects. Viruses produce the majority of plant diseases vectored by



insects, followed by fungi, bacteria, and some protozoa. One example is fire blight of apples and related fruit trees, which is caused by bacteria and spread by honey bees and other pollinators.

Insects can spread plant disease in the following ways:

* By creating wounds when feeding, laying eggs, or boring into plants. These are entrance points for a disease that is not actually carried by the insect.
* By carrying and disseminating the causative agent of a disease in or on their bodies from one plant to the next. This is a passive transfer of pathogens.
* By carrying pathogens in or on their bodies and actively transferring the pathogen into the host as they feed.
* By serving as an essential host for some part of the pathogen's life cycle. The pathogen could not survive without the insect host.

Examples of insect-vectored diseases and their insect hosts include:

* The fungus responsible for Dutch elm disease and the elm bark beetle.
* The virus responsible for tomato curly top and the beet leafhopper.
* The virus responsible for tomato spotted wilt and thrips.
* The bacteria responsible for Stewart's disease in corn and corn rootworm and flea beetles.
* The virus responsible for rose rosette disease and

eriophyid mites.

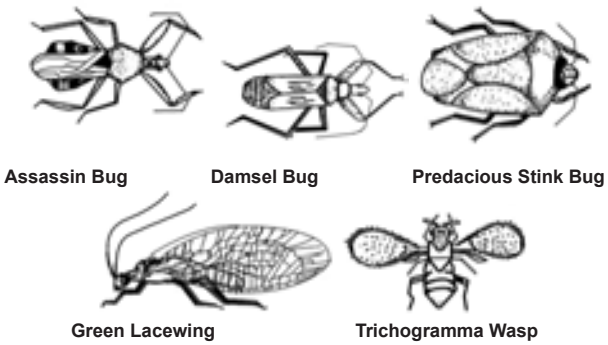
Benefits and Value of Insects

Not all insects are harmful or destructive. People have often gone to great trouble or expense to destroy insects only to learn that the insects were actually helpful by eating other insects. A good rule of thumb is that pest insects will usually be abundant and associated with plant damage. Beneficial insects, or those that are harmless, are generally less abundant and not associated with plant damage. If all else fails, make note of the insects you see in your yard. If you are unsure if they are pests or not, monitor and revisit areas where you saw them. Take action against them only if you find plant damage.

Insects are beneficial to the gardener in many ways. Insects aid in the production of fruit, seeds, vegetables, and flowers by pollinating the blooms. Many of our common fruits and vegetables are pollinated by insects. Squash, tomatoes, beans, okra, peppers, apples, peaches, citrus, berries, and grapes all require insect activity to set fruit. Insects also pollinate many ornamental plants. The lack of insect activity in greenhouses can be a problem if the plant requires an insect pollinator to produce fruits or seeds. Insects can attack undesirable weeds in the same way they injure crop plants. Insects improve the physical condition of the soil and promote soil fertility by burrowing through the surface layers. Their droppings and dead bodies fertilize the soil. Insects scavenge and consume dead plants, dead animals, and dung.

The greatest service offered by insects is the control of plant-feeding insects by insect predators and parasitoids. Predators are insects (or other animals) that catch and eat other animals (their prey), usually in a single meal. Prey animals are usually small and weaker than the predator. Ladybugs, lacewings, assassin bugs, and dragonflies are good examples of predators. In contrast, parasitoids are insects that live on or in the bodies of another living animal (the host), from which they get their food for at least one stage of their development. The hosts of parasites are usually larger and stronger than the parasitoid, but parasitoids eventually kill their host. Most parasitoids are found in the orders Hymenoptera and Diptera. These are important natural enemies of many plant-feeding pests.

Beneficial Insects



Summary

The class Insecta is larger than all of the other classes in the Animal kingdom combined. Insect species vary greatly in size, color, shape, life history, and favored habitat. Most insects are harmless or even beneficial, but the few that cause damage have tremendous impact on the world. Insects can usually be recognized with practice and some knowledge of their host, habitat, and life cycle. Feeding damage by pest insects varies according to the type of mouthparts possessed by the insect.

Study Questions

12. Deformed fruit, witches broom, and discoloration are signs of: a) chewing insect damage; b) piercing-sucking insect damage; c)flying insect damage; d) sponging insect damage.

13. Injury by insects laying eggs on a plant can result in the plant producing deformed tissue called a _____.

14. Beneficial insects that eat other insects are placed in two groups known as _____ and _____.

15. To promote beneficial insects in the landscape it is important to provide: a) pests; b) road kill; c) weeds; d) flowering plants.

Answers:
12 - b; 13 - gall; 14 - predators, parasitoids; 15 - d

Commonly Seen Classes of Phylum Arthropoda

Commonly Seen Classes of Phylum Arthropoda				
Class	*Examples*	*Body Regions*	*Pairs of Legs*	*Importance*
Arachnida	Spiders, mites, ticks, harvestmen, scorpi-ons, chiggers, etc.	1-2	4 (immature ticks have 3 pairs)	Spiders prey on insects; some mites are major plant pests while others are beneficial predators; ticks, some mites and spiders, and scorpions are of medical importance
Chilopoda	Centipedes	15+	15+, 1 per segment	Predators of insects, spiders, and other small animals; some are household pests
Collembola	Springtails	3	3	Feed on decaying organic matterl can be pests of houseplants
Diplopoda	Millipedes	2 (body can have many segments)	Generally 2 pairs per segment	Feed on decaying organic matter
Diplura	Two-pronged bristle-tails	3		Feed on decaying organic matter
Insecta	Beetles, true bugs, flies, butterflies, wasps, fleas, etc.	3	3	Mostly beneficial with some pest species
Malacostraca	Crabs, lobsters, shrimp, sowbugs	2	5	Many aquatic orders; some considered delicacies; predators and scavengers
Protura	Coneheads	3	3	Feed on decaying organic matter
Symphyla	Symphylans, garden centipedes	2 (body can have many segments)	10-12	Feed on decaying organic matter; can be pests in agriculture

Commonly Seen Orders of the Class Insecta

Order	*Common Name*	*Habitat*	*Metamorphosis*	*Mouthparts*	*Wings*
Zygentoma	Silverfish	Leaf litter and soil; indoors	Simple	Chewing	None
Ephemeroptera	Mayflies	Aquatic or near water	Simple	Vestigial	2 pairs
Odonata	Dragonflies, damselflies	Aquatic or near water	Simple	Chewing	2 pairs
Dermaptera	Earwigs	On vegetation; leaf litter	Simple	Chewing	2 pairs, sometimes reduced in size or absent
Plecoptera	Stoneflies	Aquatic or near water	Simple	Chewing	2 pairs, sometimes reduced in size or absent
Orthoptera	Grasshoppers, crickets, katydids	On vegetation; leaf litter	Simple	Chewing	2 pairs, sometimes reduced in size or absent
Phasmida	Walkingsticks	On vegetation	Simple	Chewing	In the U.S., none or 2 pairs very reduced in size
Mantodea	Mantids	On vegetation	Simple	Chewing	2 pairs
Blattodea	Cockroaches, termites	Leaf litter and woody plant debris; in buildings; subterranean	Simple	Chewing	2 pairs on reproductive termites; 2 pairs, sometimes reduced in size, on cockroaches
Thysanoptera	Thrips	On vegetation	Intermediate between simple and complex	Rasping-sucking	2 pairs
Hemiptera	True bugs, cicadas, aphids, leafhoppers, scales, and allies	On vegetation; aquatic; in leaf litter	Simple	Piercing-sucking	2 pairs, sometimes reduced or absent
Psocodea	Booklice, barklice, and parasitic lice	Book lice are found in buildings; barklice on trees; parasitic lice on birds and mammals	Simple	Chewing; piercing-sucking	2 pairs, sometimes reduced or absent in booklice and barklice; none in parasitic lice
Neuroptera	Dobsonflies, antlions, lacewings, and allies	Aquatic or near water; on vegetation; in soil and leaf litter	Complete	Chewing	2 pairs
Coleoptera	Beetles	Everywhere	Complete	Chewing	2 pairs, sometimes reduced in size or absent
Hymenoptera	Ants, bees, wasps, sawflies	Everywhere	Complete	Chewing-lapping	2 pairs, sometimes reduced in size or absent
Lepidoptera	Butterflies, moths	On vegetation or plant materials	Complete	Chewing siphoning	2 pairs, sometimes absent
Siphonaptera	Fleas	In association with birds and mammal hosts	Complete	Piercing-sucking	None
Diptera	Flies	Everywhere	Complete	Piercing-sucking, sponging	1 pair

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Chapter 6
Plant Pathology

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Organisms that cause plant disease can damage plants from the time the seed is put into the ground until the time the crop is harvested and in storage. Some diseases are capable of totally destroying a crop, while others may cause only cosmetic damage. However, cosmetic damage may be equivalent to total destruction in the case of ornamental plants. While many biological entities can cause plant diseases, the vast majority of plant pathogens are fungi.

Contents

Plant Diseases in History

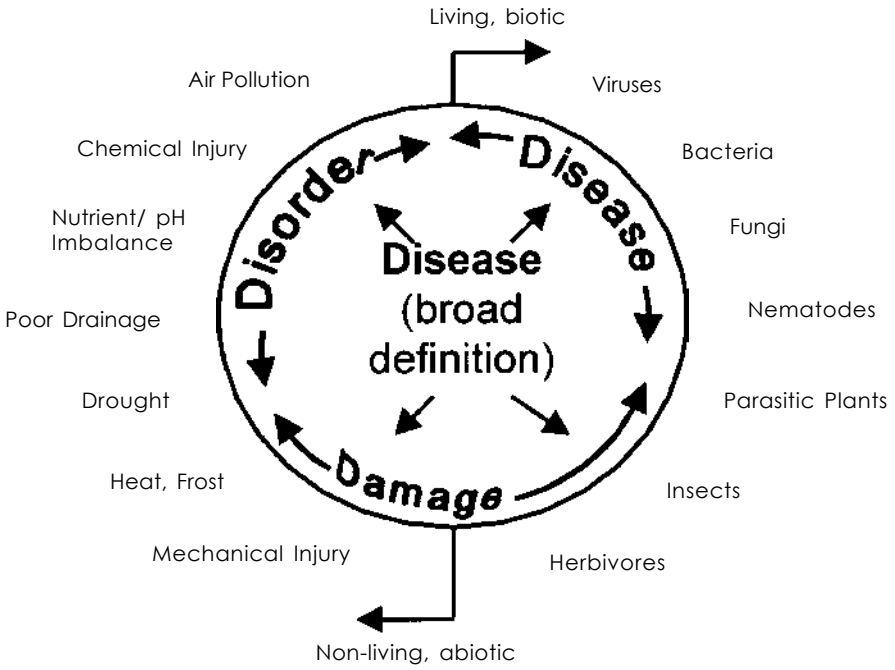
Certain diseases have had tremendous impacts on our society. Perhaps one of the most widely known among these is Phytophthora late blight, which caused the potato famine in Ireland (1845). As a result of this epidemic, approximately two million people either starved to death or emigrated, many to the United States.

Grape downy mildew ruined the French wine industry until Bordeaux mixture was accidentally found to control the fungus.

Two forest tree diseases that caused great economic and aesthetic losses in America are Dutch elm disease and chestnut blight. Both were introduced accidentally to the United States. Chestnut blight completely destroyed the most valuable trees in the Appalachians, while Dutch elm disease continues its destruction today. More recently, dogwood anthracnose (which appeared in the 1980s in our area) has caused the long-term prospects of natural dogwood populations in cool, moist locations to become questionable.

These examples are prominent because they caused extensive damage. However, plant diseases cause variable

Figure 1: Abiotic and biotic causes of plant diseases



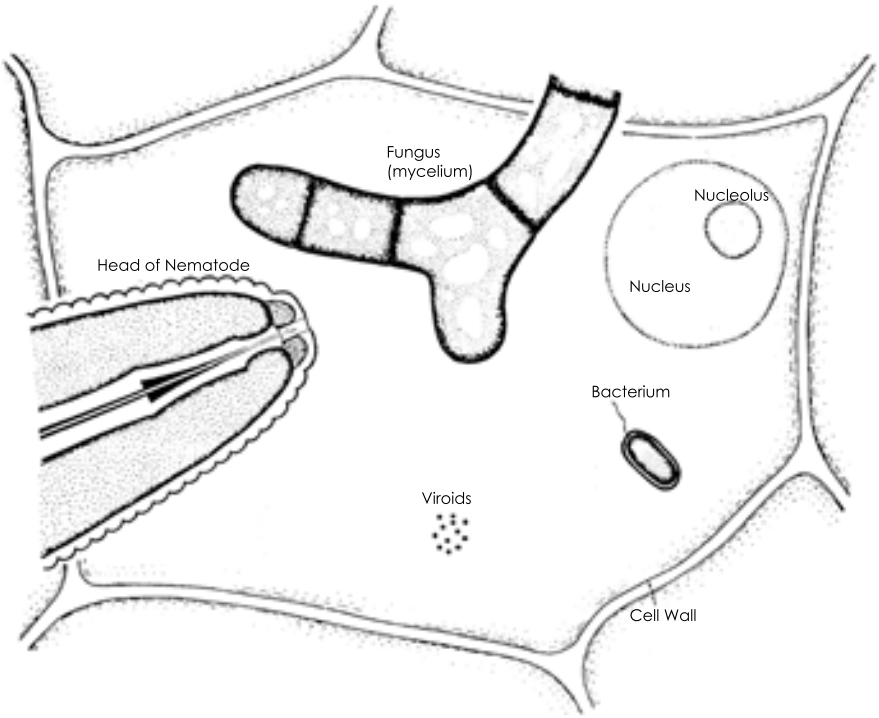
Infectious Agents		
Disease Cause	*Description*	*Common Symptoms*
Fungi	Usually filamentous (threadlike) organisms without chlorophyll. They are the most common causes of plant disease. The fungal filaments usually grow and ramify inside the plant tissue, but may also develop on the surface. Fungi typically reproduce, spread, and persist by minuscule spores. Fungus structures may be visible with the unaided eye (for example, mold, mildew, mushrooms, and conks), or may be microscopically small (for example, many fungi that cause leaf spots). There are thousands of different fungal plant pathogens.	Leaf spots and blights Fruit, stem, root, wood, and seedling rots Cankers Vascular wilts Galls Mildew diseases Rust diseases
Bacteria	Minute, one-celled organisms, much smaller and simpler than fungi. Sometimes, large masses of bacterial cells can be visible as bacterial slime or ooze, but more commonly nothing is visible without a microscope. There are several hundred different bacterial plant pathogens. *Mycoplasmas* or *phytoplasmas* are specialized bacteria that look like bacteria in the lab, but "behave" more like viruses in the field (for example, they are usually spread by insects and cause symptoms more similar to viruses).	Leaf spots and blights Stem and fruit rot Cankers Galls Vascular wilts
Viruses	Infectious molecules (or "clumps" of molecules) that take over plant metabolism and use the plant cell to produce more virus. Several hundred different viruses attack plants. *Viroids* are similar but even smaller.	Poor growth Mottling and mosaic Ring spots and wavy line patterns Leaf crinkling Distortion
Nematodes	A group of nonsegmented roundworms. The fact that these animals are usually covered in plant pathology texts or chapters, while insects and mites are treated separately, is purely an accident of history. Plant-parasitic nematodes are always small (less than 2 millimeters long, usually very thin and thus not easily visible without magnification), and many live in the soil, feeding on roots. A few kinds may live inside leaves or shoots.	Poor root development (and thus poor plant growth and wilt or yellowing) Root galls Swollen root tips Abnormal root branching

amounts of damage from year to year, depending often on weather patterns.

Diseases Defined; Cause of Disease

A plant disease may be defined as any disturbance that prevents the normal development of a plant and reduces its economic or aesthetic value. Plant disease is the rule rather than the exception. Every plant has disease problems of one sort or another. Fortunately, plants either tolerate these maladies, or the maladies are not very serious in most years. According to this broad definition, plant disease is caused by a large array of biotic (living) agents such as fungi, nematodes, bacteria, and viruses; by a large array of abiotic (nonliving) factors such as nutrient deficiencies and water or temperature stress; or sometimes by a combination or complex of these factors (Fig. 1). In common parlance, terms such as "disorder" and "damage" are often used to refer to abiotic problems, whereas the term "disease" is used to refer to biotic problems, but the boundaries are indistinct.

Figure 2: Schematic diagram of the shapes and sizes of certain plant pathogens in relation to a plant cell. Diagram adapted from Plant Pathology, by G. Agrios, 3rd ed., p. 7



Steps to Disease Diagnosis

(See chapter 8 for more details)

* Study the symptoms and signs; together, they form the disease **syndrome**. **Symptoms** are physical expressions of disease in the host tissue, e.g., changes in color, appearance, integrity, etc. **Primary symptoms** are symptoms at the point where the pathogen is active. **Secondary symptoms** are the result of pathogen activity somewhere else in the plant. For example, if a fungus invaded the roots of a plant, the resulting root rot is the primary symptom; the above-ground symptoms of poor growth, leaf yellowing, wilting, etc., are secondary symptoms. For correct diagnosis it is very important to find the primary symptoms, because it's only there that the pathogen can be found. A **lesion** is a well defined area of diseased or injured tissue, often dead spots or areas. Lesions are often a primary symptom. **Signs** are structures or products of the pathogen itself on a host plant on a host plant, for example, mold, fungal fruiting bodies, or bacterial slime/ooze. Examination with a hand lens may sometimes reveal structures that can aid in diagnosis. Placing the plant sample in a moist chamber (closed container or plastic bag) for a day or two may stimulate production of such structures. The presence of tiny, pimple-like, dark fruiting bodies in the spot indicate the presence of a fungus and may provide sufficient information for diagnosing the disease.
* Collect background information on the history of and patterns in the problem's development. For instance, the cause of sudden death of shoot tips is more easily diagnosed once one realizes that a night frost has occurred a few days earlier. If identical symptoms develop on several different species of plants, it is highly likely that the cause is abiotic (for instance, herbicide damage). The diagnostic form used by the Cooperative Extension Service requires much information that may be helpful in diagnosis, but one should always be on the lookout for additional clues.
* Consult reference books and the internet to compare syndromes with descriptions and pictures. Keep in mind that not all possible problems may be described or pictured in books, especially non plant-specific abiotic problems, which may be omitted. Be aware that not all web sites have been carefully reviewed by professional plant pathologists.
* Narrow down the possibilities. Refer to a lab for further testing if the diagnosis in unclear.

Symptoms & Signs of Plant Disease

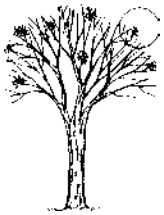
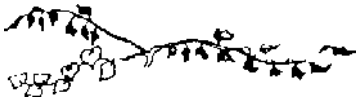
Symptoms - change in plant appearance

I.	Color Change		Causes
A.	*Chlorosis*	*Yellowing of normally green tissue. PATTERN of the discoloration may be helpful in diagnosis*	*Many*
	General Chlorosis	Yellowing of entire leaf or plant	Nutrient deficiencies, root problems, nematodes
	Interveinal Chlorosis	Yelllowing of the leaf tissue between veins while the veins themselves remain green	Poor root functioning, root rot, nematodes, nutrient deficiencies, improper pH, chemical injury
	Chlorosis along the Veins	Chlorotic areas along the veins	Viruses, some herbicides
	Marginal Chlorosis	Yellowing of leaf edges	Chemical injury, nutrient toxicity
	Mosaic, mottle 	Irregular light and dark green areas on the leaves, with distinct (mosaic) or less distinct (mottle) margins. Chlorotic areas may be on or between veins; pattern is more random on or between veins; pattern is more random that for interveinal chlorosis	Commonly virus, sometimes genetic abnormality, some nutrient deficiencies (esp. mottle)
	Ringspot 	A circular area of chlorosis or necrosis with a green center	Viruses, cold weather (African violet)
	Line Patterns	Irregular patterns or wavy lines; on some plants lines may form a more regular pattern in the outline of an oak leaf	Viruses, chemical injury
B.	*Other Color Changes*		
	Color Breaking	Abnormal streaks of different color in colored plant organs (usually flowers)	Virus, genetic (streaks usually more regular if genetic that with virus)
	Purpling, Reddening	Development of abnormal purple or red colors in normally green tissue	Phosphorus or boron deficiency, some herbicides, cold temperatures
	Bronzing	Foliage takes on gold or copper metallic appearance	Insects, mites, cold injury
	Browning	Plant tissue turns brown and may also become dry and brittle. Usually associated with tissue death; sometimes diagnostic as with vascular browning in vascular plants	Many
	Russeting	Superficial roughening of plant epidermis (surface tissue) (e.g., apple) due to cork formation	Some fungal diseases (e.g., powdery mildew), frost injury, some chemicals, nematodes (e.g., root knot on potato tubers)

II.	Necrosis (Tissue Death)		Causes
	Spot 	Distinct necrotic areas on leaves and superficial lesions on fruits and herbaceous stems. May be round, angular, or irregular; they may have concentric rings or be surrounded by purple rims or chlorotic haloes	Commonly fungi, bacteria, some abiotic causes (e.g., paraquat drift), uncommonly viruses or nematodes

II. Necrosis (Tissue Death)		Causes
Blight 	A general killing of plant parts (twigs, limbs, leaves, flowers, or shoots). Sometimes called Blast. May be primary or secondary symptom, for example, doe to root disease or a canker girdling a stem or trunk	Many
Blotch	Large, superficially discolored areas of irregular shape on leaves, shoots, fruits, and stems	Fungi, bacteria, chemical injury, sun scald
Scorch, Marginal Necrosis	"Burning" of leaf margins	Drought, excess salt or fertilizer, root problems, cankers, vascular fungi, bacteria
Rot	Affected tissues discolored, disintegrated (decayed), and often softened. Examples: wood rot (fungal), root rot (usually fungal), and soft rot (bacterial)	Fungi, bacteria
Canker 	Necrotic areas in the bark of woody or herbaceous stems or twigs. Surfaces may be smooth or rough, sunken with raised margins, or swollen and cracked. Raised margins may sometimes have concentric rings = target shape	Usually fungi, bacteria
Damping-Off 	Seed, seedling rot, or canker-like lesions girdling seedlings and young herbaceous plants at the ground-line that cause the seedling to fall over and rot. Seedling death before emerging above ground is pre-emergence damping off; seedling death after emergence is called post-emergence damping off	Usually fungi; sometimes insects, soil conditions
Shot-Hole	Dead areas of leaf spots fall away leaving holes in the leaves. Leaves may have tattered appearance if holes are numerous	Fungi, bacteria, insect-feeding
Dieback	Twigs, limbs, or shoots die from the tip back. Similar to, if not the same as, blight	See blight
Anthracnose 	Disease caused by a certain group of fungi that produce acervuli (a type of fruiting body--a small blister on the lesion surface which in moist area may become pink from spore masses). Symptoms may vary from leaf spots to fruit or twig lesions	Fungi (per definition)
Water-Soaked Appearance	Translucent appearance of tissue due to the intercellular spaces being filled with water. Often the first visible symptom of cell death.	Bacteria, fungi, frost injury

III. Miscellaneous		Causes
Dwarfing, Stunting 	Failure of a plant part or whole plant to attain normal size	Many

III. Miscellaneous		Causes
Gall, Tumor, Knot 	Localized enlargement of plant parts. Examples: root gall, crown gall, leaf gall 	Some fungi, some bacteria, some viruses, some nematodes (roots), MANY insects and mites
Witches' Broom 	A dense, broom-like clustering of branches resulting from development of numerous adventitious buds at one region	Fungi, phytoplasmas, some mites
Leaf Curl 	Leaf curl is due to irregular growth; parts grow excessively or growth of parts is retarded compared to the rest of the leaf blade	Viruses, some fungi, herbicides, ethylene, aphids
Wilt 	Plant parts limp from lack of water	Drought, root rot, root damage from nematodes, other root problems, vascular pathogens (fungi, bacteria), walnut toxicity
Leaf drop, Abscission	Falling off of leaves, flowers, fruit, or other tissues	Leaf spot pathogens, root pathogens, growth regulators, various abiotic conditions
Epinasty	Downward curvature of leaves due to abnormal growth in part of the petiole	Vascular wilt pathogens, ethylene injury, some herbicides
Gummosis	Production and exudation of a thick gummy liquid in response to injury or disease	Insects, fungal or bacterial infection, normal plant response to injury (e.g., in *Prunus* species)

Signs - Visible structures produced by pathogens

Signs	
Mildew   Downy Mildew   Powdery Mildew	Grayish or whitish growth of fungus, of two groups: downy mildew, (grayish, often on lower leaf surface) and powdery mildew (whitish, on both upper and lower leaf surfaces - the most common). The names reflect the appearance; the two groups are quite different in their biology.
Mold	Fungus mycelium and/or fruiting structures, similar to mildew but of different groups of fungi. Molds may be many colors, commonly gray, white, black, blue, or green.
Sooty Mold 	Black fungal growth on plant surface which can be scraped off. Caused by dark-colored fungi that grow on sticky secretions of sucking insects, such as aphids, whiteflies, and scale insects. Sooty mold fungi do not infect the plant itself.
Rust 	Spore pustules of a certain group of fungi called the rust fungi (sometimes also orange leaf spots and galls or cankers). Color of pustules may be yellow, orange, red, brown, or black.
Smut  	Spore masses of a certain group of fungi called the smut fungi, usually brown or black and powdery. May occur in inflorescences (for example wheat loose smut, corn smut), leaves (stripe smut of grasses), sometimes on stems (corn smut galls).
Mushroom	Large fruiting body of certain fungi; FEW are plant pathogens; most are secondary decay organisms.
Conk 	Large, woody, shelf-like fruiting body of many of the wood decay fungi
Bacterial Slime	Drops of sap containing bacteria. Found on the surface of plants infected by bacteria, or Slime especially under humid conditions.

Study Questions

1. Two forest diseases that have caused great economic and aesthetic losses in America are _____ and _____.

2. Some common symptoms of viruses are: a) leaf spots and blights, cankers, mildew, and rust diseases; b) stem and fruit rot, galls, vascular wilt; c) poor growth, mottling and mosaic, leaf crinkling; d) poor root development, root galls, swollen root tips.

3. Structures or products of the pathogen as seen on the host plant (mold, fungal fruiting bodies, bacterial slime/ooze) are called: a) primary symptoms; b) signs; c) syndromes; d) lesions.

4. _____ is yellowing of normally green tissues.

5. _____ is irregular light and dark green areas on leaves, with more or less distinct margins.

6. _____ is a general killing of plant parts.

7. _____ is the failure of all or part of a plant to attain normal size.

8. _____ is downward bending of leaves due to abnormal growth in part of the petiole.

9. Mildew can best be described as: a) grayish or whitish growth of fungi; b) black fungal growth on the plant surface which can easily be scraped off; c) a large fruiting body of certain fungi; d) drops of sap containing bacteria.

Answers:
1 - Dutch elm disease, chestnut blight; 2 - c; 3 - b; 4 - chlorosis; 5 - mosaic/mottle; 6 - blight; 7 - dwarfing; 8 - epinasty; 9 - a

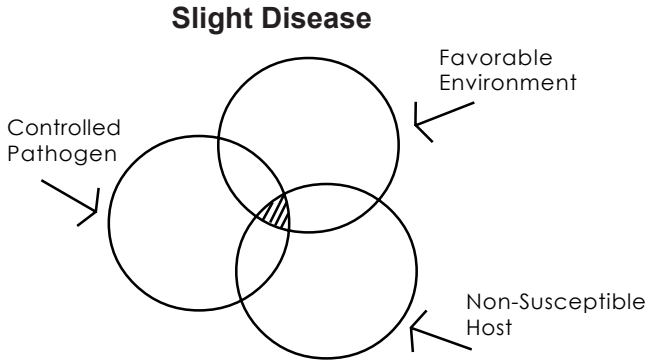
Disease Development

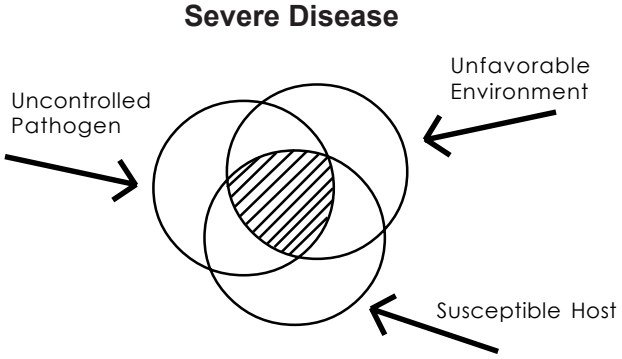
Development and severity of disease is determined by three conditions. First, it is necessary to have a susceptible host plant. Each species of plant is capable of being infected by only certain pathogens. The plant must be in a stage of development susceptible to infection by the disease agent. The second requirement is the presence of an active pathogen in a stage of development conducive to infecting the host plant. If there is no or little inoculum of the pathogen present, there can be no or only a little disease. The third condition is an environment suitable for the pathogen to infect the plant. Temperature and moisture are important factors.

Disease Cycle

The chain of events involved in disease development, including stages of pathogen, host, vectors, etc., is the disease cycle, which summarizes answers to questions such as:

* What are sources and forms of **inoculum**? (inoculum= part of a pathogen that can cause infection). Possibilities include: other infected plants, plant materials (for example, seed, tubers, cuttings, and transplants), plant debris (dead leaves, stems, and roots) from infected plants, or infested soil.
* When or under what conditions does the pathogen **infect**? (= become established on/in the plant and initiate disease development). For example, most fungi





and bacteria that cause leaf spots and blights can infect only when leaves are wet. Some of these pathogens may infect only young, developing leaves, while others infect only old, senescent leaves.

* How long does it take for the pathogen to colonize the plant and for symptoms to develop? This may range from a few days to a few weeks or sometimes months. During this stage, although symptoms do not yet show, it is often already too late to prevent a problem.
* After how long and under what conditions does the pathogen reproduce? Fungi and bacteria often need high humidity to produce more inoculum.
* How and under what conditions does the pathogen spread? Means of dispersal include: wind, water drip and splash, soil, anything that moves soil (e.g. shoes), running water (run-off, irrigation water), vectors (for example, aphids for many virus diseases, beetles for Dutch elm disease), equipment, tools, and moving plants from one location to another.
* How and where does the pathogen survive adverse conditions (for example, winter, dry spell, period of absence of host)? See above under sources of inoculum. Some pathogens produce specialized structures that are highly resistant to extremes in temperature or moisture (e.g. sclerotia of the fungus that causes southern blight).

Methods & Tools to Control Diseases

Cultural Practices

Plant only certified-as-disease-free seed or planting stock

* Certified seed is only free of those diseases for which it has been tested! Quality depends on the program.
* General nursery inspection program -- tries to make sure that only materials free of (important) diseases and pests are sold.

Sanitation

* Removal of diseased plants or plant parts (pruning, roguing).
* Removal and/or destruction of plant debris and leaf litter that may contain inoculum.
* Removal of other hosts (including weeds) of the pathogen.
* Prevention of introduction and spread of pathogens: clean tools, equipment, clothes, etc.

Tillage and cultivation

* Buries plant debris with inoculum, leads to faster degradation.
* May also bring inoculum to the surface where it is exposed to sun and drying cycles.

Crop rotation

* Rotation with a species of plant that is not a host for a particular pathogen prevents buildup of that pathogen over the years, and allows inoculum to decline due to natural causes.

Temperature management (make it optimum for crop, but unfavorable for pathogen)

* Direct: greenhouse, storage facilities.
* Indirect: shading, mulching to affect soil temperature, timing of planting (planting warm-season crops into cold soils may predispose them to damping-off diseases), solarization.

Moisture management (make conditions less favorable for pathogen)

* **Irrigation**: Furrow and flood irrigation may spread pathogens with flow of water and may saturate soil, which promotes some root diseases. Sprinkler irrigation may lead to splash dispersal of pathogens, and makes the leaves wet, creating conditions favorable for infection by many leaf pathogens. Timing may be important (late afternoon may be bad - leads to long periods of leaf wetness). To prevent pathogen dispersal and leaf wetness, it is usually best to water at the base of the plant, if possible. Drip irrigation reduces chances of spreading pathogens and creating conditions favorable for disease.
* **Drainage:** Avoid planting in poorly drained areas or choose plants that are adapted to wet sites for these areas. Install drainage tile before planting in poorly drained soil. Plant on raised beds to allow water to drain away from the roots.
* **Relative humidity**: Direct management: greenhouse, storage facilities. Indirect management: pruning and thinning for better canopy ventilation; foliar diseases tend to be more severe in shaded areas because the leaves stay wet longer.

Management of fertilization and soil pH

* Some diseases are worse when fertilization is excessive, others are worse when fertility is poor. Some diseases are favored by acid soil, others by

A Program Approach to Control Diseases

Plant disease control has never placed sole reliance on **chemicals**. *Other major pillars are* **cultural practices** *and* **resistant cultivars**. *The use of several simultaneous control practices is usually required for effective disease management. A combination of methods is always required to manage the numerous diseases (Integrated Disease Management) and other pests (Integrated Pest Management) that threaten a specific garden or landscape. A complete program for an annual plant might include the following steps (with modifications for establishment of perennial plants):*

- Assess inoculum based on EXPERIENCE from past years. Identify possible SOURCES.
- Use cultural practices or treatments that reduce inoculum; for example:
  - Rotate out of susceptible crop,
  - Eradicate reservoir hosts (weeds, etc.),
  - Remove or bury infested or diseases plant debris,
  - Steam or bleach (e.g., pots, flats, soil, tools)
- Select top-quality seed or planting stock that is:
  - Adapted to the area and site,
  - Disease-free (from a reputable source), and
  - Disease-resistant (Note that few plants are resistant to all diseases; choose plants that are resistant to the diseases that have been previously diagnosed in that plant.)
- Purchase treated seed (fungicide/insecticide) if experience shows it is needed
- Plant at optimum time, row spacing, and seeding rate; apply fertilizer and pesticide treatments as needed.
- Monitor plants for early detection of disease problems:
  - Get an accurate diagnosis of the problem. County Extension personnel can provide advice or forward sample to a lab for diagnosis.
  - Apply chemicals as needed. Most sprays are PREVENTATIVE.
  - Cultural practices -- e.g., canopy management
- Harvest at proper time; handle and store produce properly
- Remove and destroy plant debris to reduce survival of pathogens. Do not compost weeds or diseased plant material - place in trash
- Plan for next year. Take steps to prevent future problems (rotations, etc.). Keep accurate records and maps that show pest and disease problems

Notice how more than half of the steps need to be implemented before the plants or seeds are even in the ground. Twenty-eight grams of prevention is worth 454 grams of cure.

alkaline soil.

Soil amendments and mulches

* Organic matter may stimulate soil microbial activity that may inhibit growth of pathogens. Adding organic matter can also help to improve drainage.

Repel or control vectors

* For example, by insecticides or by placing reflective aluminum foil around young plants to repel aphid).

Plant at proper planting depth

* Roots may not get enough oxygen or the crown may rot when plants are too deep.

Avoid injury, which can invite decay organisms

Plant Resistance

* Genetically resistant cultivars may be **partially** resistant (some disease develops; nevertheless, these plants can be very useful) or **completely** resistant to a particular disease (but not necessarily to other diseases).
* Genetic resistance may be **defeated** when a pathogen develops new strains that can attack the resistant cultivars. Resistance may also sometimes “break down” when plant is under excessive stress, or when several pathogens attack at the same time.
* “Physiological” resistance refers to reducing the susceptibility of the plant by management of water, nutrients, light, and other cultural practices.

Chemical Controls

Both organic and synthetic chemicals are available for controlling plant diseases.

'Organic' methods involve growing and maintaining healthy plants without using synthetic (man-made) fertilizers, pesticides, hormones, and other materials. In organic disease control, natural materials (things found in nature or that exist in the environment) can be used to inhibit or prevent the activity of plant pathogens. The most common organic controls used against diseases are mineral fungicides, such as copper and sulfur. A few biological fungicides, such as *Bacillus subtilis* (bacterium), have also been developed in recent years. Sprays of copper and sulfur are effective in preventing disease but they are not effective in clearing up a disease once it becomes established. Note that just because a product is organic, it does not mean you should not take precautions. Read the pesticide label, it will give you information about the product and its toxicity. Some organic products do have their consequences too; you must weigh the options in every control method. For example, copper materials sprayed on an area year after year can accumulate in the soil and cause harm to beneficial microbial populations. Planting disease-resistant varieties, practicing crop rotation, maintaining balanced soil fertility, and using a trickle irrigation system rather than overhead irrigation should allow one to avoid disease while minimizing the use of chemical sprays.

Chemicals can be used for:

* Eradication of inoculum (e.g., soil fumigation before planting).
* Protection of plants by covering foliage or seed or drenching soil with chemical that inhibits development of the pathogen.
* Cure. SOME chemicals can be used to eliminate pathogens from infected plants (penetrant or systemic chemicals), but most have protectant rather than curative activity.

Regulatory Practices

* Quarantine laws and inspections at the borders to keep foreign pathogens out.
* Certification of seed and planting stock to minimize initial inoculum.

Physical Methods

* Soil treatment with **steam** to eliminate pathogens, weed seeds, and insects. This is done mostly in greenhouses and seedbeds; it is not very practical for

Control of Diseases: Avoiding Attack
Keep host and pathogen out of striking distance from each other by:
Exclusion - keep pathogen away from the crop.
Keep pathogen out of the country, state. Quarantine regulations ban importation of certain types of plant material; other kinds of plant material must be inspected before being admitted.
Keep pathogen out of the garden. Avoid spread of contaminated soil, equipment, boots, irrigation water, etc. Use pathogen-free planting material.
Avoidance or evasion - keep plants away from the pathogen.
Do not plant in already infested sites or in areas where the pathogen is a major problem.
Grow plants in areas, during times, and under conditions that are not favorable for pathogen development.
Reduce or eradicate inoculum. Complete eradication of a pathogen from an area or a country is rare. Reduction of inoculum by sanitation, deep plowing, crop rotation, etc., is common and often effective.
Protect plants by reducing or eliminating chances for infection (using both cultural and chemical protection).
Plant resistant plants (another way to protect the plant).

homeowners.

* Soil "solarization" in warm climates during the hot season by covering soil for several weeks with clear plastic. High temperatures eliminate many pathogens and weeds. This is most effective in tropical or subtropical areas where there is a long period of continuous sunlight and high temperatures.
* Hot-water treatment of seed and planting stock (not very practical for homeowners).

Biological Control

* Apply organisms that inhibit, eat, or parasitize plant pathogens. Currently, there are ONLY A FEW commercially available examples of this available for home use.
* Stimulate naturally occurring beneficial organisms by organic soil amendments, water management, etc.

Summary

Plant diseases are to be expected. Fortunately, in most years there are few truly devastating diseases.

For disease to occur, there must be a susceptible host, a suitable environment, and a living pathogen. When all three conditions are met, disease occurs. Severity of the disease depends on the degree to which the conditions are met.

Diagnosis depends on a careful evaluation of symptoms, but also on evaluation of the history and patterns of disease development.

Disease control involves more than the use of chemicals. Planting resistant cultivars, destruction of inoculum sources, and a variety of cultural practices should be considered first. A combination of control methods, based on understanding of the biology of the pathogen, will give best results.

Study Questions

10. Which of the following conditions does NOT determine the development and severity of disease?: a) a host plant that is in a susceptible stage of development; b) a pathogen that is in a stage of development conducive to infecting the host; c) the presence of symptoms on a host plant; d) an environment that is suitable for the pathogen.

11. When symptoms of a pathogen are first discovered on a plant, the first step to controlling the problem is to: a) remove and destroy the plant material; b) irrigate and fertilize; c) study the symptoms and identify the problem; d) use chemical sprays recommended by professionals.

12. An INEFFECTIVE strategy for disease prevention would be: a) exclusion and evasion; b) reducing or eradicating inoculum; c) planting resistant varieties; d) avoiding native plants, especially perennials.

13. Sanitation, tillage, crop rotation, temperature management, and controlling vectors are examples of _____ (type of) disease control.

14. Pathogens can be introduced to host plants by: a) other infected plants; b) untreated tools, pots, soil; c) water splash or run off; d) all of the above.

Answers:
10 - c; 11 - c; 12 - d; 13 - cultural; 14 - d

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Chapter 7
Abiotic Stress

Abiotic Stress Effects on Plant Growth and Development

Chapter 7

Abiotic Stress Effects on Plant Growth and Development

Chapter 7

Prepared by *David M. Orcutt, Professor Emeritus, Plant Physiology (2015)*

This chapter is devoted to understanding the effects of abiotic stresses (chemical and physical) on the growth and development of plants. Crop losses due to abiotic stress is considered to be the principal cause of crop yield loss worldwide wide resulting in more than 50% reduction in yield. Economic losses are in the billions of dollars and with the possibility of increased global warming and climate change it is increasingly important to have an understanding of how abiotic stress affects plant growth and distribution. Not only are crop plants impacted by abiotic stresses but landscape, vegetable gardens and natural ecosystems are affected. The goal here is to provide a frame work for a basic understanding of how plants respond to abiotic stress and hopefully stimulate further interest by reading the internet links provided.

Contents

What is Abiotic Stress?

Definition of Plant Stress

One way of defining stress is any change in environmental conditions that adversely affects survival, growth, development and yield in plants. Stress can be divided into two different types, biotic and abiotic. Biotic stresses are caused by another living organism, whereas, abiotic stresses are caused by the physical/chemical environment. In this chapter we are going to be concerned with the abiotic stresses and their impact on plant growth and development.

Examples of Abiotic Stress

Abiotic stress can divide into physical and chemical stresses. Physical stresses include water (drought/flooding), temperature (high/low), light (quantity/quality), and mechanical (ice/snow/wind). Chemical stresses include nutrient (high/low), salinity, soil characteristics (pH/soil composition), air pollution (CO_2/O_2/NO_2/SO_2) and pesticides (herbicides/insecticides/fungicides). Each of these types of stress will be discussed in this chapter.

Plant Responses to Abiotic Stress

Plant responses to stress depend on the severity, duration, number of exposures and if a single stress or multiple stresses are involved. Rarely are plants in nature exposed to a single stress. For example, if a plant is exposed to freezing temperatures the duration and frequency of exposure may be critical. If the temperature is low enough to freeze the soil in which the plant is growing the plant may suffer from water deficit as well as nutrient deficiency.

Plant part, stage of development and genetics are all plant characteristics that can determine susceptibility to stress. Using freezing temperatures as an example, young actively growing tissues are more susceptible to freezing than old, slower growing tissues. Flowering in fruit trees may be reduced during freezing temperatures resulting in failure of fruits to develop. Some plants such as spinach and peas are genetically more resistant to cold than are tomato plants.

Study Questions

1. Which of the following is not an abiotic stress?
   a) light; b) temperature; c) insects; d) pH
2. Which of the following is not a physical stress?
   a) temperature; b) drought; c) air pollution; d) wind
3. Name three characteristics of plants that can determine their susceptibility to stress. a)
   b) c)

Answers:
1 - c; 2 - c; 3 - plant part, growth stage, and genetics.

Chemical Stress

Air Pollution Stress

There are many chemicals that comprise what is referred to as air pollution. Such chemicals include: carbon dioxide, ozone, sulphur dioxide, hydrogen fluoride, oxides of nitrogen, olefins such as ethylene a natural plant hormone, ammonia, chlorine, hydrogen chloride and metals. The burning of fossil fuels, natural processes, industrial activities, and atmospheric photochemical activity can produce air pollution. In this section only carbon dioxide, ozone, nitrous oxide, sulphur dioxide and ozone will be discussed. These are produced directly or indirectly from the combustion of fossil fuels.

Carbon Dioxide Pollution

Burning of fossil fuels, or any carbon containing substance, produces carbon dioxide (CO_2) as a result of combining carbon with atmospheric O_2 under high temperature.

Increasing CO_2 concentrations can influence plant growth directly through its effects on photosynthesis. As a greenhouse gas, it also affects plant growth by impacting atmospheric CO_2 levels, which could be a contributor to global warming and global climate change. Atmospheric CO_2 levels have increased from about 315 ppm in the mid 1950s to 400 ppm in 2015. Plants use CO_2, sunlight and water in photosynthesis to produce sugars that are used as an energy source to make other constituents necessary for plant growth and development.

Effects of Increased CO_2 Levels on Plant Growth, Development, and Distribution

All plants are not the same with respect to how they will respond to rising CO_2 levels. These differences have to do with how a plant captures (fixes) CO_2 from the air and processes it into sugar.

Plants can be divided into 3 groups based on how they remove CO_2 from the atmosphere. These are referred to as C_3, C_4, and CAM plants. Each plant type has adapted to a different environmental niche and has a different way to fix CO_2 from the atmosphere. Most C_3 plants are found in temperate to cold climates with high moisture environments and represent the majority of plant species. They typically are slower growing plants than C_4 plants and use CO_2 less efficiently as a result of a energy wasting process called photorespiration.

C_4 plants are found in hot dry, subtropical to tropical environments are fast growers and have higher rates of photosynthesis than C_3 plants. Because C_4 plants do not photorespire they are more efficient in fixing CO_2 than C_3 plants and thus when growing under high light and limited water C_4 plants can out perform C_3 plants.

CAM plants are found in very hot dry desert areas. Like C_4 plants CAM plants are not susceptible to photorespiration because, unlike C_3 and C_4 plants, they open their stomata at night thus conserving water and fixing CO_2 and storing it for use during the day to make sugar.

Examples of C_3 plants include: forest trees, woody shrubs, cool season grasses, soybean, wheat and most vegetable crops. Corn, crab grass, millet, sorghum, sedge, nut grass and sugar cane are considered C_4 plants and pineapple, yucca, cactus, orchids, and jade plants are CAM plants. Interestingly, although C_4 plants comprise only about 5% of the world's biomass they fix roughly 30% of the terrestrial CO_2.

The types of environments occupied by C_3, C_4 and CAM plants can be observed in the United States as one travels from the east coast to the west. The eastern deciduous forests (mostly C_3 plants) start in the east and end near the border of Oklahoma followed by the grasslands (mostly C_4 plants) of the prairie states and into the deserts (CAM plants) of the far west. Figure 1 shows the approximate number of species that thus far have been categorized into each plant type.

Possible responses of C_3, C_4, and CAM plants to increasing temperature and elevated CO_2

Experiments have shown that C_3 and C_4 plants grown at elevated CO_2 levels grow faster. However, the growth response is usually greater in C_3 plants because they are considered to be CO_2 limited compared to C_4 plants. In some cases increased growth in C_3 plants has been shown to be temporary and some C_4 plants do not respond to elevated CO_2 levels at all. But photosynthesis also depends on temperature and the amount of light and water available. Since C_4 plants have greater water use efficiency and are more heat tolerant than C_3 plants it is possible as temperature increases and water availability declines C_4 plants may have an advantage over C_3 plants.

In other words there may be a cross over point where higher temperature and lower water availability favor C_4 plants over C_3 plants even though C_3 plants may benefit more from elevated CO_2 levels.

Although not as much has been done with CAM plants relative to how climate change will affect these plants it appears that CAM plants also will benefit from elevated CO_2 levels as well. On average, when CO_2 levels are doubled, the biomass of CAM plants has been observed to increase as much as 35%. This suggests that this group of plants may do well as temperature and CO_2 levels increase and occupy an expanded environmental niche in which C_3 and C_4 plants cannot exist.

All of this has ramifications for plant competition in natural ecosystems as well as agro-ecosystems. As global warming increases natural plant communities are shifting toward northern latitudes or alpine environments. Agricultural production areas and types of plants that grow in specific regions may have to be adjusted to accommodate climate change with the possibility that entire regions once productive agriculturally may cease to be productive and competition from weeds may produce new challenges with respect to control. Recently, USDA issued new growth zone designations for the United States in which climate zones have been pushed toward northern latitudes.

Comparison of numbers of known C_3, C_4, and CAM plant species	
C_3:	250,000 species (1854 weed species)
C_4:	7500 species (146 weed species)
CAM:	16,00 species

If you are interested in more in depth discussions of C_3, C_4, and CAM plants and the effects of climate change on plant distribution the following links are recommended:

* http://www.slideshare.net/stubeck/ap-bio-ch-10-c3-c4-and-cam-plants
* http://www.youtube.com/watch?v=YhtpekedXNU

Study Questions

4. Which of the following are not considered sources of air pollution today? a) carbon dioxide; b) ozone; c) sulfur dioxide; d) nitrogen oxides; e) none of the above
5. What is the main source of CO_2 pollution? _____
6. Name 3 groups of plants that remove (fix) CO_2 from the atmosphere in different ways. a)_____; b)_____; c)_____.
7. Which of the following plants is characterized as being slow growing, uses water inefficiently and occurs in temperate environments? a) C_3; b) C_4; c) CAM.
8. Which of the following plants opens its stomata at night and is found in dry arid regions? a) C_3; b) C_4; c) CAM
9. Which of the following is not a CAM plant? a) yucca; b) cactus; c) jade; d) rice; e) pineapple.
10. Which of the following is considered to be CO_2 limited and responds best to elevated CO_2 levels? a) C_3; b) C_4; c) CAM.
11. If temperature and CO_2 levels continue to rise which of the following would least likely be able to compete with the other plant types? a) C_3; b) C_4; c) CAM.

Answers:
4 - e; 5 - Fossil fuel; 6 - C3, C4, CAM; 7 - a; 8 - c; 9 - d; 10 - a; 11 - a.

Nitrogen Oxides, Sulphur Dioxide and Ozone Pollution

Oxides of carbon (CO_2 and CO), sulfur (SO_2) and nitrogen (NO and NO_2) are considered to be primary air pollutants because they come directly from a source such as automobile exhausts, burning of coal, refuse, or natural sources such as vegetation fires and volcanic activity. In the air, some of these pollutants (SO_2 & NO_2) combine with water to form acids and can fall as acid precipitation or nitrogen oxides can undergo photochemical reactions to produce ozone (O_3). These are considered to be secondary pollutants formed from the primary pollutants.

Effects of acid rain from nitrogen oxides and sulfur oxides on plant growth

Considerable research has been conducted on acid rain effects on forest trees. Results suggest that acid rain can impact forest ecosystems by leaching nutrients from leaves and/or affecting soil pH by making it more acidic.

This in turn affects nutrient availability either directly or through leaching of nutrients out of the soil. Also, at these lower soil pH levels, aluminum in soils is more readily available to plants and may be at toxic levels affecting tree growth. As a result, this weakens trees and makes them more susceptible to disease, insects, cold, drought and other air pollutants such as O_3 (ozone). There may be a more direct effect on trees that grow in elevated areas where they may be exposed to acid fog/clouds resulting in longer exposure of of leaves to acid conditions.

Agricultural crops are not as drastically affected by acid rain as are plants in natural ecosystems. One reason for this is that a grower can control soil pH and nutrient levels as needed. For more information on acid rain go to the following link.

* https://www.epa.gov/acidrain/effects-acid-rain

The good news about atmospheric levels of nitrogen oxides and sulfur oxides is they have declined since 1980. EPA estimates indicate that emissions in 1980 of nitrogen oxides and sulfur oxides were 26 and 27 million tons, respectively, while in 2013 they were 5 and 13 million tons annually.

* https://www.epa.gov/air-trends

O_3 effects on plant growth

Ozone is a strong oxidizing agent. It enters the plant through stomata during the day. It impacts plants by oxidizing and degrading membrane lipids and proteins that control permeability and biochemical reactions. Photosynthesis is very susceptible to O_3 and is part of the reason reductions in growth and yield have been observed in crop plants. Dicots appear to be more susceptible to O_3 than monocots. This may be because many monocots are C_4 plants and more efficient than C_3 plants at fixing CO_2 and conserving water under high temperature dry conditions. USDA has determined that soybean yields can be reduced by 10% at O_3 levels of 50 ppb amounting to $1 billion in losses per year just to that single crop. Peanuts and cotton show reductions of 11% and 8%, respectively, at 50 ppb O_3. Sorghum and field corn, both C_4 plants, show little to no reductions in yield at that concentration. From 1980 to 2013 O_3 levels have dropped by 33% but are still high enough to cause significant damage to natural and agricultural vegetation.

The following links are good references for more information on O_3 and its affects on crop plants.

* http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_008861.pdf
* https://www.epa.gov/air-trends

Study Questions

12. Which of the following pollutants under go photochemical reactions in sunlight to form ozone? a) SO_2; b) CO_2; c) CO; d) HCl; e) NO_2
13. What 2 pollutants are primarily responsible for acid rain? _____,_____
14. Acid rain is less detrimental to agricultural crops than to natural forested ecosystems? (True or False?)
15. Which of the following describes how acid rain affects plants: a) leaching nutrients out of plant tissues; b) leaching nutrients from the soil; c) making soil pH more acid; d) increasing toxic elements in the soil; e) predisposing plants to disease; insects and other abiotic stresses; f) all the above.
16. Which of the following is false concerning the effects of ozone on plants? a) enters the plant through stomata; b) enters plants through the roots; c) breaks down cell membranes; d) is a strong oxidizing agent; e) causes significant yield reductions in some crop plants.

Answers:
12 - e; 13 - NO_2 and SO_2; 14 - True; 15 - f; 16 - b

Plant Nutrient Stress

Nutritional stress in plants can be caused by either high or low concentrations of essential elements in the soil. It is important to have the soil analyzed for the concentrations of essential elements and also to determine the pH of the soil before planting (see the Soils Chapter for more information on soil testing). This will prevent addition of too much or too little fertilizer if the soil needs amending. Determining pH is important because soils may have plenty of nutrients but simply are not available because extremes in pH can influence their availability to plants.

Essential Elements Needed for Plant Growth

Plants generally require thirteen elements, which they absorb as inorganic ions. This is in addition to carbon, hydrogen and oxygen, which they obtain from carbon dioxide, water and molecular oxygen. Six of these elements are required in greater amounts than the others and are called "macro-nutrients" or "major" elements. They are nitrogen, phosphorus, potassium, sulfur, calcium, and magnesium. The seven "micro-nutrients," "minor," or "trace" elements are iron, manganese, boron, copper, zinc, chlorine, and molybdenum. Several elements are required by some species but not by others. For example, sodium is required for certain blue green algae and the halophyte *Atriplex vescicaria*. Cobalt is a micro-nutrient for some microorganisms and symbionts, although it has not been demonstrated to be essential for green plants. Silicon is indispensable for diatoms and vanadium is reported to be essential for the green alga *Scenedesmus obliquus*. Twelve of the thirteen elements in Table 2 are derived from parent rock and are, therefore, "mineral elements". The ultimate source of nitrogen is molecular nitrogen (N_2) of the earth's atmosphere. However, aside from those plants that fix atmospheric nitrogen (blue-green algae/ bacteria either alone or symbiotically (nitrogen fixing bacteria on legume roots), nitrogen is absorbed as an inorganic ion (nitrate or ammonium). If any one of these elements is missing plants will not grow and reproduce. For more detailed information about the role of essential elements in plants, see the Botany Chapter.

Table 2. Essential Elements and Form Absorbed by Most Plants

Element	*Symbol*	*Ions Most Frequently Absorbed*	*Conc. in Dry Tissue (ppm)*
Micronutrient Elements			
Molybdenum	Mo	MoO_4	0.1
Copper	Cu	Cu^+ Cu^{++}	6
Zinc	Zn	Zn^{++}	20
Manganese	Mn	Mn^{++}	50
Iron	Fe	Fe^{++} Fe^{+++}	100
Boron	B	BO_3^- $B_4O_7^-$	20
Chlorine	Cl	Cl	100
Macronutrient Elements			

Table 3. Diagnosing Nutrient Disorders

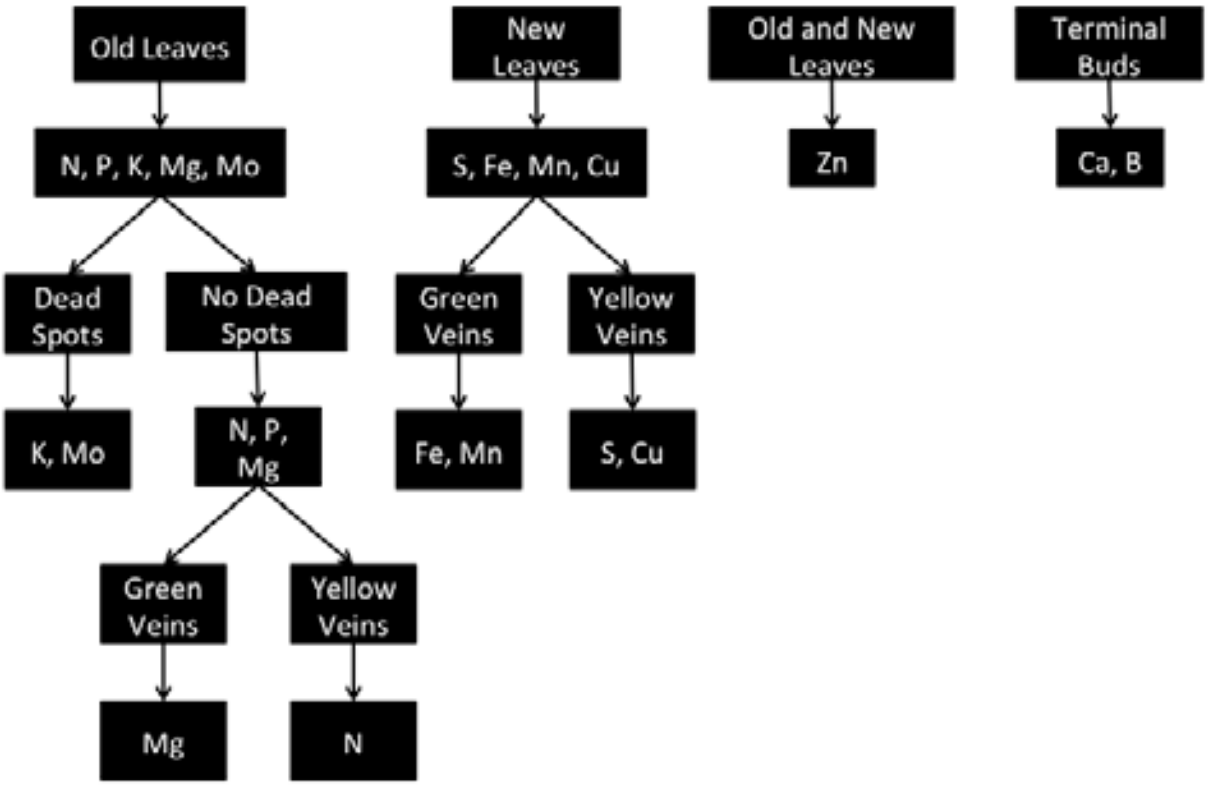

Table 2. Essential Elements and Form Absorbed by Most Plants

Element	*Symbol*	*Ions Most Frequently Absorbed*	*Conc. in Dry Tissue (ppm)*
Nitrogen	N	NO_3^- NO_4^-	15,000
Potassium	K	K^+	10,000
Calcium	Ca	Ca^{++}	5,000
Phosphorus	P	$H_2PO_4^-$ HPO_4^+	2,000
Magnesium	Mg	Mg^{++}	2,000
Sulfur	S	SO_4^+	1,000

Functions of Nutrients and Diagnosing Deficiencies

Diagnosing nutrient deficiencies is not an easy task. Familiarity with a particular plant species helps since nutrient deficiencies are not always expressed the same in all plants. In addition, other environmental factors have to be considered because plants may express similar symptoms as nutrient deficiency when exposed to pathogens, insects, air pollutants, pesticides and abiotic stresses.

Chapter 8 "Diagnosing Plant Damage" outlines under "Key to Symptoms of Chemical Disorders," the general descriptions of symptoms associated with nutrient deficiencies in plants. Table 3, below, is a very useful tool for diagnosing nutrient disorders.

Nutrient deficiencies are typically initiated in old leaves, new leaves or terminal buds. If terminal buds are dying, or dead and the leaves appear leathery then the plant is likely deficient in either boron or calcium. If symptoms develop in both old and young leaves then the element lacking is likely Zn. If symptoms show in the old leaves you can narrow the elements down to N, P, K, Mg or Mo. These elements are mobile in plant tissues. This means as the older leaves die, because of a lack of one of these elements, those elements that are remaining are moved out of those leaves to sustain the actively growing terminal meristems.

If symptoms develop in young terminal leaves then the deficiency is likely due to a lack of S, Fe, Mn, or Cu. These elements are considered to be immobile in plants since they are tightly bound to organic molecules in the healthy plant tissues and cannot be moved to the new leaves to support growth.

These groups of elements are further subdivided based on whether the leaves have dead spots and green or yellow veins. The following links will give some visual examples and descriptions of nutrient deficiencies in plants:

* http://www.haifa-group.com/knowledge_center/deficiencies/nutrients/micro_nutrients/b_boron/
* https://cropwatch.unl.edu/soils/soybean-nutrients
* http://growabundant.com/nutrient-deficiencies/
* http://hort.ufl.edu/database/nutdef/index_common_element.shtml

Effects of pH on Nutrient Deficiencies and Toxicities

pH is a measure of the hydrogen ion concentration in the soil (see the Soils Chapter for more details). The higher the hydrogen ion concentration the more acid is the soil. pH ranges from 0-14, with zero being the most acidic and 14 the most alkaline or basic. A pH of 7 is neutral and most plants grow best around 6.5 to 7. Some plants, like azaleas and rhododendrons, prefer a more acid pH and desert plants prefer a more alkaline pH.

Nutrient uptake by plants is affected by pH, generally, an acid soil tends to make micronutrients more readily available to plants and at extremes can result in toxic levels. The element Mo is the exception and its availability decreases. Macronutrients on the other hand are more available in slightly acid to slightly alkaline soils. The graph in Chapter 4 illustrates how pH affects nutrient uptake by plants. This graph does not represent all soil types since the chemistry, structure and composition of soils varies. Aberrations in uptake of some elements, such as B and P, is a result of the nature of the soil and complex chemical reactions that occur between soil particles and the element at different pH.

For additional reading regarding soils and pH see the following link:

* http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex6607

Physiological and Biochemical Functions of Essential Elements in Plants

The list below reviews some of the functions elements have in plants. It is obvious from this list that limiting any single element would significantly limit plant growth

and development. C, H, and O (not listed) make up the greatest percentage of elements in plants and represent the basic building blocks of plant tissues. Some elements are listed as beneficial since they have not been shown to be essential for growth in all plants. For example some plants may substitute Na for K to control osmotic relations in tissues. Others such as diatoms (a unicellular alga) have an absolute requirement for Si in the cell wall. Heavy metals are frequently toxic to plants particularly under extremely acidic conditions.

A. Essential Elements	
Nitrogen (N)	Constituent of many compounds, amino acids, nucleic acids, chlorophyll
Phosphorus (P)	Constituent of nucleic acids, phospholipids, ATP, NAD, NADP
Potassium (K)	Cofactor for enzyme reactions; osmotic balance particularly stomata
Sulfur (S)	Constituent of proteins; coenzyme A
Calcium (Ca)	Calcium pectate of middle lamella; important in membrane selectivity
Magnesium (Mg)	Constituent of chlorophyll, important in nucleic acid structure, coenzyme
Iron (Fe)	Constituent of cytochromes, ferredoxin; needed for chlorophyll synthesis
Manganese (Mn)	Coenzyme for numerous reactions; Krebs cycle, nitrate reductase
Copper (Cu)	Coenzyme – oxidases in plastocyanin a carrier in photosynthetic phosphorylation
Zinc (Zn)	Needed for IAA synthesis and protein synthesis; cofactor numerous dehydrogenases
Molybdenum (Mo)	Important in nitrate reduction and nitrogen fixation; probably also a cofactor
Boron (B)	Uncertain. Possibly involved in sugar translocation cross cell membranes, may alter hormone balance in plants
Chlorine (Cl)	Photosynthesis (deficiency never seen in nature)

B. Beneficial Elements	
Cobalt (Co)	Nitrogen fixation
Sodium (Na)	Can partly replace K
Selenium (Se)	Can reverse P toxicity in susceptible plants
Silicon (Si)	Can improve growth in cereals. Reduces Fe, Mn toxicity by precipitation

C. Toxicity
Most heavy metals are toxic.

C. Toxicity
Low pH can lead to toxicity of Fe, Mn, Al particularly, in tropical soils.

Study Questions

17. Which of the following elements is not considered a macro-nutrient? a) nitrogen; b) potassium; c) phosphorus; d) iron; e) magnesium
18. How many essential elements are required by plants including carbon, hydrogen and oxygen?_____
19. Nutrient deficiencies in S, Fe, Mn, and Cu are typically found in: a) old leaves; b) terminal buds; c) new leaves; d) old and new leaves; e) roots
20. Which of the following elements is considered immobile in plant tissues? a) nitrogen; b) phosphorous; c) potassium; d) magnesium; e) manganese
21. Which are more readily available in acid soils micro or macronutrients?_____
22. Which is more acidic a pH of 5 or a pH of 6.5?_____
23. What is the range of pH values?_____
24. What is a neutral pH?_____
25. What is the best pH for most plants?_____
26. Advanced level question: A macronutrient needed as a cofactor, for stomata opening and closing and osmotic balance____
27. Advanced level question: A micronutrient needed for cytochrome, chlorophyll and ferredoxin production_____

Answers: 17 - d; 18 - 16; 19 - c; 20 - e; 21 - Micronutrients; 22 - pH 5; 23 - 0-14; 24 - pH 7; 25 - 6.5-7.0; 26 - K; 27 - Fe

Salinity Stress

The Origin of High Saline Soils

There are 2 types of salinity relative to how such soils are formed.

Primary salinity results from natural causes such as weathering and erosion or from land near the ocean that accumulates salt as a result of salt spray carried inland by wind and deposited in the soil by rain. Primary salinity can occur over very long periods of time depending on location and weather conditions.

Secondary salinity results from human activity such as irrigation and removal of natural vegetation and can occur much more quickly than primary salinity. Continuous irrigation and fertilization of agricultural areas results in a build up of salts in the top layers of the soil unless salts are leached out by rainfall or carefully controlled irrigation practices. The source of irrigation water may also have high levels of salts in the water that contributes to salt accumulation. Removal of natural vegetation often destroys deep-rooted perennials that have adapted to environments where water would be unavailable to shallow rooted annual crop plants. Removing perennials and replacing them with annual crops often requires irrigation that ultimately raises the water table in the soil profile and exposes plants to higher salinities. Evaporation of high salinity irrigation water also contributes to increased soil salinity in the upper soil profile.

Differences Between Saline and Sodic Soils

Soils with high salt concentrations are further divided into saline and sodic soils. Saline soils have a high concentration of soluble salts particularly sodium salts, whereas sodic soils have low concentrations of soluble salts. In sodic soils, monovalent cations such as sodium, displace divalent cations that hold clay particles together. This causes clay particles to dissociate and disperse. Over time dispersed particles are leached deeper into the soil profile blocking pores in the soil leading to water logging and poor drainage. Alkaline soils are a type of sodic soil with a high pH and are typical of semi-arid to arid regions. Salts typical of saline soils include: NaCl, Na_2SO_4 while salts typical of sodic/alkaline soils are: Na_2CO_3, $NaHCO_3$. Salts of the cations, Na^+, Ca^{2+}, Mg^{2+}, K^+ and anions Cl^-, SO_4^{2-}, HCO^{3-}, CO_3^{2-}, NO^{3-}, can also form in soils.

About 6.5% of the world's soils are considered to be sodic or saline. Approximately, 20% of all irrigated land is either sodic or saline.

Plant Responses to High Salinity Environments

Plants can be classified relative to salinity tolerance as glycophytes, halophytes, obligate halophytes, and facultative halophytes. Glycophytes cannot tolerate salinity levels in excess of 10mM, halophytes can tolerate a concentration of up to 50mM (millimolar), obligate halophytes do not grow well below 10mM but grow well between 10-50mM, and facultative halophytes only become halophytic after being exposed to moderate soil salinity.

Two problems develop in plants as a result of high saline conditions. One is an osmotic problem due to high salt concentrations in the soil. This results in drought stress for the plant since water moves out of the plant into the soil. The other problem is one of toxic ion accumulation in the tissues of the plant.

The osmotic problem is countered in some plants by producing organic solutes in the cytoplasm that retains the water in the plant instead of allowing water to move into the soil. This requires metabolic expenditure of energy and thus slows the growth of the plant. Another adjustment the plant my make is the uptake of potassium ions or other low toxicity ions to counter the soil salt concentrations. Controlling ionic balance in the plant is critical in maintaining pH conducive to enzyme function and metabolism.

Toxic ion accumulation is prevented in some plants by exclusion by the roots or prevention of transport in the shoots to growing meristems of the plant. If salts reach the shoots and leaves they can be compartmentalized in vacuoles or extruded by way of salt glands in some plants. If salts are not excluded or compartmentalized they can have deleterious effects on proteins and cell membranes and ultimately decrease growth and result in death. Table 4 summarizes some of the physiological effects of salinity stress on plants:

Table 4. Salinity Stress Effects on Plants
High Na^+ transport to shoot
Low K^+ uptake
High Cl^- uptake
Low P and Zn uptake
Preferential accumulation of Na^+ in old leaves
Increase in non-toxic organic solutes
Increase in free radical oxygen species
Lower fresh and dry weight of shoots and roots
Low germination of seeds
Partial closure of stomata in response to water deficit

The tolerance of a plant depends on its ability to exclude, compartmentalize, or remove salt from tissues. In addition, adjusting the ion balance in the plant and the

production of organic chemicals that help to retain water in the plant are fundamental to tolerance.

For additional reading on soil salinity and its affects on plants see the following link:

* http://www.plantstress.com/articles/salinity_i/salinity_i.htm

Symptoms of Salinity Stress in Plants

In the home landscape, like many other stresses, it is difficult to determine if the stress is caused by high salinity or some other stress presenting similar symptoms. One must carefully examine the environment in which the plant is growing to determine the surroundings of the plant and try to eliminate other possibilities.

Some of the symptoms of salinity stress in plants include: reduced shoot growth, marginal necrosis of leaves, delay in bud break and flowering, premature defoliation, early leaf color formation, crown thinning, and twig death.

Salt injury to plants along roadways is common as a result of using salts to melt snow and ice. Sources of salt damage can include salt spray from passing vehicles or salt that has seeped into the soil around plant roots. Symptoms usually start to show in the early to late spring depending on the amount of salt to which the plant is exposed, soil types and weather conditions. Symptoms may not develop for quite sometime if soils are affected. Homeowners using salt on drive ways and side walks may also experience salt damage to their plants. Watering plants with softened water may also contribute to salt injury in sensitive plants. The following links give additional information on salt sensitive tolerant plants, images of salt damage in plants and alternatives to NaCl for melting snow and ice.

* https://www.extension.purdue.edu/extmedia/id/id-412-w.pdf
* http://www.salinitymanagement.org/Salinity%20Management%20Guide/sp/sp_7a.html

Study Questions

28. Name 2 types of salinity relative to how saline soils are formed. _____,_____ _____
29. Which of the following is/are not included as primary sources of salination? Select all that apply. a) irrigation; b) removal of natural plant vegetation; c) marine salt spray; d) weathering and erosion; e) application of inorganic fertilizers
30. High concentrations of Na_2CO_3, $NaHCO_3$ are typical of: a) sodic or b) saline soils?
31. Which of the following plant types is most sensitive to saline conditions? a) halophytes; b) glycophytes; c) facultative halophytes; d) obligate halophytes
32. Name 2 fundamental problems plants have to deal with when growing under high saline conditions. _____,_____
33. Which of the following are physiological responses a plant may have to high saline environments? Select all that apply. a) increased K^+ levels; b) increased Na^+ levels; c) stomates open; d) free radicals increase; e) reduced water uptake
34. Of the following symptoms, which do not typify salinity stress in plants? a) increased root and shoot growth; b) normal flower and fruit production; c) early leaf defoliation; d) early Fall color formation; e) marginal necrosis of leaves

Answers: 28 – Primary and secondary; 29 – a, b, e; 30 – sodic; 31 – b; 32 – drought, toxic ions; 33 – a, b, d, e; 34 – a, b

Herbicide Injury

Most herbicide injury to landscape plants is most likely a result of using herbicides on lawns unless you live near an agricultural production area.

There are several ways non-target plants can be exposed to herbicides and include:

* *Drift and volatilization:* Herbicides should never be applied on windy days because pesticides can drift to non-target plants and cause injury. Some pesticides are volatile and can vaporize in the hot sun and the vapors carried by wind to other plants. Also, when applying herbicides spray particle size is important, the smaller the particle size of the spray the more likely it can be carried by the wind or be vaporized.
* *Leaching and run-off from the soil:* Some herbicides are applied to soils and are referred to as pre-emergence

herbicides. These form a thin layer of chemical on the soil and when newly germinating seedlings attempt to break through the soil they are killed by the herbicide. Some of these chemicals can run off in rain water and affect other plants or potentially leach down through the soil and possibly be taken up by deep rooted plants such as trees.

* *Misapplication:* Bottom line, read the label on the product you are using. Only use the herbicide on plants listed on the label and follow the recommended rates.
* *Soil or soil amendment application:* Make sure you know the history and source of any top soils or soil amendments you may use around plants. Be particularly aware of agricultural fertilizers and compost that may have originated from previous treatment of hay fields with weed control herbicides these can be carried over in livestock manure and compost.

Herbicide application and effects on plants

(For more information on pesticides, see the Pesticide Use and Safety Chapter)

Herbicides are either applied to soils (pre-emergence) to control newly germinating seedlings or directly to shoots and foliage (post-emergence) to control already established growing plants. Herbicides can further be divided based on whether the chemical affects the plant at the site of application (contact) or whether it moves around in the vascular system of the plant (systemic). Herbicides can be selective, that is some will kill only broadleaf plants or only grasses or they can be non-selective and kill both. Factors such as how the herbicide is used (pre/post-emergence), and whether it is a contact or systemic herbicide, or whether it is selective or non-selective has to do with the herbicides mode of action. The mode of action refers to how a chemical affects the physiology, biochemistry and development in the plant.

Differentiating herbicide damage in plants from other environmental stresses is sometimes difficult. Nutrient, air pollution, salinity, pathogens, insects and other environmental stress can sometimes mimic herbicide damage symptoms. However, if one can eliminate these other potential stress factors, knowledge of herbicide modes of action can be helpful in determining if a specific herbicide may have caused the damage.

Herbicide modes of action

The following outlines the different categories of herbicides relative to their mode of action and how they affect plant metabolism.

* Amino acid synthesis inhibitors prevent the synthesis of aromatic and branched chain amino acids required for the synthesis of enzymes and membrane proteins.
* Plant growth regulator herbicides mimic or disrupt auxin (indole acetic acid) functions in plants. Auxin controls many aspects of plant development including: cell division, sex, tropisms, and polarity.
* Pigment inhibitors prevent the formation of carotenoids in plants that are crucial for protection of chlorophyll from photodecomposition. These are also called bleaching herbicides because the leaves of treated plants are white.
* Photosynthesis inhibitors prevent the light reactions of photosynthesis from functioning. Photosynthesis is divided into two phases, the light reactions, which captures the energy of light (photons) and stores it as stable chemical energy and the dark reactions, which uses the energy produced in the light reactions to make sugar.
* Cell membrane disruption herbicides oxidize membranes directly and cause membranes to break down and decompose. Contact herbicides are examples.
* Seedling growth inhibitors affect apical cell division of roots and shoots.
* Lipid synthesis inhibitors affect plant cell membranes and membranes surrounding chloroplasts, mitochondria, vacuoles and other organelles in the cell. This disrupts the ability of each to perform a specific function.
* Nitrogen metabolism inhibitors affect the metabolism of ammonium into amino acids, which can accumulate to toxic levels in the plant.

The Virginia Pest Management Guide, (ver. Home Grounds and Animals) lists a variety of herbicides that are approved for use on Virginia lawns. Most of these are used to control broadleaf weeds, nuisance grasses, and sedges. Although there is a possibility that any of these could be used in lawns it is most probable that the plant growth regulator (PGR) type herbicides are going to be the most prominent since they are found most frequently in weed and feed fertilizers. So where weed and feed

fertilizers are used in lawn care and non-target plants show injury symptoms the most likely suspect would be the PGR group of herbicides.

The following links are very good references for describing symptoms associated with herbicide damage and more information on modes of action.

* http://twig.tamu.edu/B6081.pdf
* https://www.btny.purdue.edu/Extension/Weeds/HerbInj2/InjuryHerb1.html
* https://ag.purdue.edu/btny/weedscience/Documents/Herbicide_MOA_CornSoy_12_2012%5B1%5D.pdf
* https://www.pioneer.com/CMRoot/Pioneer/US/products/stewardship/Oklahoma_Herbicide_MOA.pdf

Study Questions

35. Name 4 ways non-target plants can be exposed to herbicides. _____,_____,_____,_____.
36. Which of the following is a type of herbicide that is applied to soils? a) pre-emergence; b) post-emergence
37. Which of the following types of herbicide kills the plant at the point of application? a) contact herbicide; b) systemic herbicide
38. Which of the following affects auxin function in plants? a) lipid synthesis inhibitors; b) photosynthesis inhibitors; c) plant growth regulator herbicides; d) amino acid inhibitors; e. plant pigment inhibitors
39. Which of the following affect ammonium synthesis in plants? a) lipid synthesis inhibitors; b) pigment inhibitors; c) plant growth regulator herbicides; d) amino acid inhibitors; e) nitrogen metabolism inhibitors

Answers:
35 – Drift and volatilization, leaching and run off, misapplication, soil or soil amendment application; 36 – a; 37 – a; 38 – c; 39 – e

Physical Stress

Plant-Water Relations

Drought, Heat, and Flooding Stress

The Importance of Water to Plants

Water is important to plants for maintaining tissue turgidity. That means there needs to be an internal water content that allows cells and tissues to maintain maximum cell volume and thus tissue surface area. A tissue that is not turgid is said to be flaccid and often is accompanied by wilting. Wilting is a defensive mechanism to reduce water loss from the plant but it also reduces leaf surface area to sunlight and thus reduces photosynthesis and growth (for more information on this topic, see the Botany Chapter).

Water is also important for transporting nutrients from the soil to the tissues of the plant. The xylem is the main water and nutrient transport system extending from the roots through the stems and into the veins of the leaf. In the leaf, water is lost through the stomata when they are open during the day thus providing another important function for water and that is cooling the leaf surface through the process referred to as evapotranspiration. Water is also required for photosynthesis.

Drought Stress

Causes of drought stress in plants

High temperature, low soil moisture, low humidity, wind, frozen soil, high salt concentrations and low genetic tolerance to moisture stress all contribute to water deficit stress in plants. Many of these stresses can act at the same time and frequently do. Each deprives the plant of moisture through the lack of availability as in low soil moisture and frozen soils or through moisture removal from the plant as a result of high salt concentrations, high wind, and low humidity.

Plant control of water loss (Physiological/developmental responses)

One of the primary ways plants control water loss is through opening and closing stomata on the surface of leaves. Stomata in most plants are open during the day and close at night. The exception being: plants growing in hot dry climates such as CAM plants that open stomata at night to conserve precious water during the day. However, most plants under water deficit stress can partially or totally close stomata during the day to conserve water. Other responses plants have include leaf, flower and

fruit drop, early flowering, die back in trees, increased root growth, wilting/leaf rolling and internal production of molecules in cells that help retain water. All of these reflect survival strategies at the expense of growth.

(Genetic adaptations for conserving water)

Plant adaptations to low moisture environments include: More stomata on under surface of leaves than on the top, sunken stomata, thick leaf cuticle and high wax production, modified leaves (no leaves to narrow pointed leaves), hairy and light colored leaf surfaces, low plant profile, different strategies for opening and closing stomata, and leaf movements to avoid direct sun exposure.

Water use in plants

Plants are part of the hydrologic cycle and are important in recycling of water from the soil to the air. Some plants are more efficient at water usage than others. It has been estimated that about 1/3 of the rainfall that falls on a forested ecosystem is transpired through evapotranspiration back to the atmosphere. Generally, C_4 plants are more efficient than C_3 plants in water use. However, even a C_4 plant, such as corn, uses considerable amounts of water to grow. It has been estimated that it takes about 16.6 gallons of water to produce an ear of corn and at a planting rate of about 30,000 plants per acre that translates to 500,000 gallons per acre not including the water needed for the vegetative growth of the corn stalk.

Trees also transpire large amounts of water during the summer. For example a 46' silver maple tree can transpire as much as 60 gallons per hour.

Flooding Stress

Effects of flooding on soils

When a soil is saturated with water after a heavy rain or during a flood it can impact plant growth severely. Short periods of flooding can have significant impacts on crops and plants in general. Flooding deprives plants of O_2 (anaerobic conditions) in the root system and prevents CO_2, due to respiration, from escaping from the soil into the air. This creates an O_2 deficit in the soil and inhibits root growth. As CO_2 builds up carbonic acid is formed from the reaction of CO_2 with water making the soil more acidic. In so doing, it makes some elements in the soil more readily available sometimes in toxic amounts. Other essential elements such as nitrogen can be leached from the soil or made less available because of acidic conditions. In addition, anaerobic bacteria become more active producing toxic metabolites such as methane, ethylene, and hydrogen sulfide. These conditions weaken the plant root system making it more susceptible to root pathogens. This scenario can also be applied to over watering of potted plants in the home or nursery.

Physiological changes in flooded plants

Flooding puts plants into a survival mode rather than a growth mode. Plants respond by growing adventitious roots on the stem near the water line thus being closer to available atmospheric O_2. Ethylene production increases, which is a natural plant hormone that inhibits growth rate and induces a condition called epinasty in the leaves. Plants showing epinasty appear wilted. This is not wilting as a result of lack of available water but rather a loss turgidity of petiole basal cells in response to ethylene. In woody plants flooding causes an increased production of openings in the bark called lenticels, which facilitate gaseous exchange. Also, plants that are flooded for extended periods produce a type of tissue in the roots called aerenchyma, which is a degradation of root cellular structure to facilitate movement of O_2 among plant tissues and removal of CO_2. Interestingly, plants that normally live in aquatic environments, such as cattails, normally have this type of tissue in root systems and stems. Finally, some plants that normally live in aquatic environments such as mangroves produce structures called pneumatophores, which have been shown to be involved with O_2 transfer to the roots of these plants. Analogous structures in cypress do not appear to have that function.

The following link is very good for additional information regarding temperature stress in plants:

* http://cmg.colostate.edu/Gardennotes/143.pdf

Study Questions

40. In a flooded soil which of the following happens? a) oxygen increases; b) carbon acid dioxide decreases; c) soil pH becomes more acid; d) nitrogen levels increase; e) carbonic acid decreases

41. Physiological changes or adaptations for living in or surviving flooded conditions include which of the following: a) formation of aerenchyma tissue; b) development of lenticels in the bark of woody plants; c) formation of roots near the surface of

water; d) production of pneumatophores; e) all of the above

Answers:
40 – c; 41 – e.

Heat Stress

Water deficit stress is most frequently linked to high temperature or heat stress. All plants have an optimum temperature for good growth. Exceeding that temperature can have profound effects on the physiology and biochemistry of the plant. When temperature exceeds the optimum for a given plant a number of things start to happen. Stomata start to close or shut down completely to limit water loss. However, this limits CO_2 uptake causing a reduction in photosynthesis. Also, O_2 cannot get out of the leaves and builds up in the leaf tissues and can result in the formation of free radical O_2, which oxidizes cell membrane lipids making them leaky and non-functional. Respiration increases in the cells causing an increased use of stored energy in the plant thus resulting in reduced growth and possibly death of the plant depending on the severity and length of exposure.

Plants tolerant to heat stress are capable of altering their membranes to protect them from oxidation or producing molecules (heat shock proteins) that can be incorporated into plant membranes or that help to conserve cellular water and make them less susceptible to heat stress.

Study Questions

42. List 4 functions of water in plants. _____,_____,_____,_____

43. List 4 causes of drought stress in plants. _____,_____,_____._____

44. Which 2 of the following are not physiological/ developmental responses to drought stress in plants? a) stomata closing; b) leaf drop; c) sunken stomata; d) light colored leaf surfaces; e) leaf wilting/rolling

45. Select the answer that does not represent what happens to a plant experiencing heat stress. a) stomata close; b) photosynthesis increases; c) oxygen accumulates in the leaves; d) respiration increases; e) heat shock proteins produced to help protect membrane

Answers:
42 – turgor, transport nutrients, cool leaves, photosynthesis; 43 – wind, lack of soil moisture, soil freezing, high salt, low humidity; 44 – c, d; 45 – b.

Chilling and Freezing Stress

The Difference Between Chilling and Freezing Stress

Chilling stress occurs in plants sensitive to temperatures in the range of 68-32° F. These include plants that are tropical to subtropical in origin such as many indoor species, beans, corn, rice, tomatoes, squash and bananas.

Freezing stress occurs in plants sensitive to temperatures below the freezing point of water or 32°F. Some plants are frost hardy and can acclimate to temperatures just below freezing and can recover if the temperature is not too prolonged. Peas, spinach, lettuce are examples of such plants.

Other plants are cold hardy and include temperate trees and woody shrubs some of which can with stand temperatures of -70°F and lower.

Physiological and Biochemical Differences Between Cold Sensitive and Tolerant Plants

Several things are involved biochemically and physiologically that separate plants that are sensitive from those that are tolerant to cold temperatures. Plants that are freezing tolerant can prevent ice from forming inside the cell. If this occurs in plants it is lethal. Plants that are susceptible to freezing temperatures cannot do this. Cold tolerance is accomplished through changes in membrane composition and the production of substances inside the cell that lower the freezing point.

Structurally the plant cell is comprised of an outer cell wall comprised of cellulose and immediately inside the cell wall is the cytoplasmic membrane. The membrane controls the movement of water and dissolved substances in and out of the cell. Membranes also surround important organelles inside the cell including, chloroplasts, mitochondria, vacuoles as well as many other structures. Plant membrane composition changes with temperature. Since membranes are comprised of primarily lipid with some protein and carbohydrate, lipids can change viscosity with changing temperature. That is, they become more fluid-like with elevated temperature and more solid like at lower temperatures. The challenge for the plant is

to control how fluid or how solid the membrane becomes because this affects the ability of the membrane to transport water and dissolved substances across. Plants can control this fluid/solid nature by interjecting unsaturated or saturated fats into the membrane structure. If you have ever baked pastries you have experienced saturated and unsaturated fats. An example of an unsaturated fat is vegetable oil, which is liquid at room temperature. On the other hand lard is a saturated fat and is solid at room temperature. So this is basically what you find in plant membranes, combinations of saturated and unsaturated fats that change with temperature to affect membrane permeability and function when it gets too hot or too cold. So when plants experience increasing cold temperatures they interject unsaturated fatty acids so as to maintain a more fluid membrane, which is functional at lower temperatures. Conversely, when it gets hot membranes can become more permeable and the plant injects more saturated fats into the membrane to make it less fluid. This is basically what happens when you harden off your tomato plants in early spring. The ability to make such changes in membrane structure is genetically determined and is part of the basis for differences in temperature sensitivity in plants.

Along with membrane changes plant cells also produce substances called sugar alcohols that lower the freezing point of the cytoplasm so it does not form ice crystals. Some plants have the ability to move water out of the cell into the area of the cell wall where freezing is less likely to damage the cell. When ice starts to form, however, water diffuses out of the cell to form more ice. This may be both beneficial or harmful depending on how much water is removed. Some plants, mostly trees, undergo a process called supercooling where water can stay liquid down to a temperature of -70°F.

The Symptoms, Cellular, and Physiological Affects of Chilling and Freezing

Symptoms: reduced growth, leaf necrosis or damage, water soaking and a flaccid appearance of plant tissues.

Cellular affects: loss of membrane function, dehydration, salt injury, membrane rupture as a result of ice formation, air bubbles(embolisms) in the xylem.

Physiological affects: decreased photosynthesis, protein degradation, reduced transport in vascular tissues, increase respiration.

For additional reading see the following link:

* http://www.plantstress.com/articles/cold_i/cold_i.htm#environmenta_physiologica

Study Questions

46. Indicate the temperature/range to which each of the following groups of plants are susceptible: a) chilling sensitive_____; b) freezing sensitive_____; c) extreme cold tolerance_____

47. Changes in cell membrane lipid composition are important for a plant to survive in different temperature environments. If a plant is to survive in an extremely cold climate, how will the membrane lipids change? a) lipids will increase in saturated fats; b) lipids will increase in unsaturated fats

48. Does increasing the amount of unsaturated fat in the membrane make it more or less permeable/ fluid?

49. If ice forms inside a plant cell membrane (in the cytoplasm) it will die, if it forms outside the cell membrane in the cell wall area it may not die. True or False?

50. Plant cells can die not only from freezing stress but dehydration stress as a result of freezing. True or False?

51. Sugar alcohols, produced by plants, act as a kind of anti-freeze to help lower the freezing point of the cytoplasm. True or False?

52. Which is not a symptom of freezing stress in plants: a) flaccid; wilted appearance; b) water soaking of leaves; c) leaf necrosis or damage; d) increased growth

Answers:
46 – a: 68-32°F, b: 32°F, c: -70°F; 47 – b; 48 – more fluid; 49 – true; 50 – true; 51 – true; 52 – d.

Light Stress

Definition of Light Stress and Its Effects on Plants

Light is important in promoting photosynthesis, affecting plant orientation, promoting/inhibiting flowering, germination and dormancy, stomatal opening and closing

and developmental processes (photomorphogenesis).

Plants can either be exposed to too much light, too little light (quantity), or the wrong kind of light (quality). Some plants are considered to be sun plants in that they grow well in full sunlight while others prefer shade or partial sun. Characteristics of sun plants include: reduced leaf area, thick leaves and cuticle, and abundant stomata. Shade plants have the opposite characteristics.

The quality of light is important as well in that red and blue wavelengths of light are needed for photosynthesis, phototropism (growth of plants toward light), stomatal opening, and solar tracking (plants adjusting leaves during the day to follow the sun). Red light and far-red light are important in flowering, seed germination and dormancy. UVB light can damage plants and inhibit growth. This is particularly true at higher elevations.

Plants growing in the under-story of a forest have the ability to capture what little light that may penetrate the canopy in a very efficient way. As you may have noticed when walking though the forest on a sunny, slightly windy day you may have noticed the flickers of light that come and go with the tree canopy movements. These flickers of light are referred to as sunflecks and important in the growth of under-story plants.

The following links are very good for exploring additional information.

* http://cmg.colostate.edu/Gardennotes/142.pdf
* http://plantsinmotion.bio.indiana.edu/plantmotion/movements/nastic/nastic.html

Study Questions

53. Which of the following wavelengths of light is not important to plants? a) red; b) far-red; c) blue; d) green; e) UVB

54. Which of the following characteristics apply to sun plants? Select all that apply. a) thick, small leaves; b) abundant stomata; c) thin cuticle

55. Which of the following are blue light responses in plants? Select all that apply. a) flowering; b) seed germination; c) phototropism; d) dormancy; e) stomatal opening

56. Sun flecks in a forest under story have no significant effect on plants growing there. True or False?

Answers:
53 – d; 54 – a & b; 55 – c & e; 56 – false

Mechanical Stress

Definition of Mechanical Stress

Mechanical stress includes wind, rain, hail, snow, ice and animal movement. Plants can sense touch or movement that may be caused by any of the above mechanical stimuli. In some cases the response is not obvious but in others such as the Venus fly trap or the sensitive plant perception of touch can be very rapid and obvious.

Effects of mechanical stress on plants

Wind is probably one of the most prevalent mechanical stresses and causes plants to respond in several ways. Wind can be beneficial as well as harmful to plants. When wind is strong it can cause physical damage to the plant but subtle and less obvious effects are changes in photosynthesis. On a calm clear warm day plants have their stomata open and O_2 from photosynthesis diffuses out and CO_2 goes in. However, on calm days a layer of high humidity produced from evaporative transpiration forms near the surface of leaves called a boundary layer. This layer creates a resistance to the exchange of gases between the atmosphere and the leaf and slows down photosynthesis and retains O_2, which slows growth. Consequently a slight breeze can be beneficial to plants in that the boundary layer is removed and allows gas exchange more efficiently.

However, if the wind is rapid, it could create a water deficit stress for the plant; the stomata close and again photosynthesis is reduced and growth is slowed.

There is still another effect that is a result of constant flexing and movement of plant leaves and branches as a result of wind or other mechanical stimuli. This results in chemical signals that are transmitted in the tissues of the plant causing changes in growth patterns usually reducing the height of plants and increasing the diameter of shoots or branches. If you have ever observed trees growing on mountaintops you have observed the effects of wind on growth. Such plants are usually small and misshapen reflecting the wind direction.

Practical applications of this knowledge have been used in fruit and nursery production. For example, attaching weights to fruit tree branches or bending branches down and tying them to the ground causes the branches to increase in diameter and shortens elongation growth thus providing a stronger branch that is capable of supporting a larger, heavier fruit load without causing damage to the tree. Researchers have also shown that by using mechanical devices that gently pass across the tops of greenhouse grown plants causes decreases in height growth and increased stem diameter. This is beneficial to growers in that it prevents plants from becoming leggy and better able to support inflorescences. It also avoids the use of plant growth regulator chemicals often used for this purpose.

Rain, hail, snow and ice can cause observable mechanical damage to plants such as leaf tearing/removal and limb damage but can also induce similar responses as wind causing changes in growth distribution in tissues. However, these conditions are usually short term as opposed to almost daily plant encounters with wind.

Effects of soil compaction on root and seedling growth

Another aspect that impacts differential growth in plant tissues, particularly the roots and germinating seeds is soil compaction. Persistent pedestrian traffic, animal grazing, construction machinery and the nature of the soil can cause soil compaction. Compaction can affect many things that influence plant growth including gas exchange in the soil and water and nutrient movement. However, soil compaction also imparts a physical resistance to the growth of plant roots and the growth and penetration of germinating seedlings. This resistance causes roots and shoots to increase in diameter in a similar fashion to wind stress. This is thought to give the root or young shoot a greater mechanical advantage to penetrate and grow through a compacted soil. Certainly soil compaction will affect growth and survival of plants depending on plant species.

Summary of Physical Stresses

We now know that creating and defining microclimates in crops (wind breaks/terraces) and in urban landscapes (plantings around buildings etc.) can influence the physiology of plants in favorable and unfavorable ways. So when considering all of the physical and chemical stresses plants must endure to grow well it is important that we know as much about how theses stresses impact plants so we can make the best decisions for optimum plant growth.

For further information on mechanical stress in plants see the following links:

* http://www.sciencedirect.com/science/article/pii/0167880988900084
* http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0082256
* http://www.plantphysiol.org/content/116/2/643.full
* http://horttech.ashspublications.org/content/8/4/529.full.pdf

Study Questions

57. Which of the following are not mechanical stresses? Select all that apply. a) drought; b) temperature; c) hail; d) wind; e) air pollution

58. Which of the following will not slow growth in plants? Select all that apply. a) soil compaction; b) high wind; c) slight wind; d) good aeration; e) hail storm.

59. Which of the following does not cause soil compaction? a) soil characteristics; b) animal grazing; c) pedestrian traffic; d) construction machinery; e) none of the above.

Answers:
57 – a, b, e; 58 – c, d; 59 – e.

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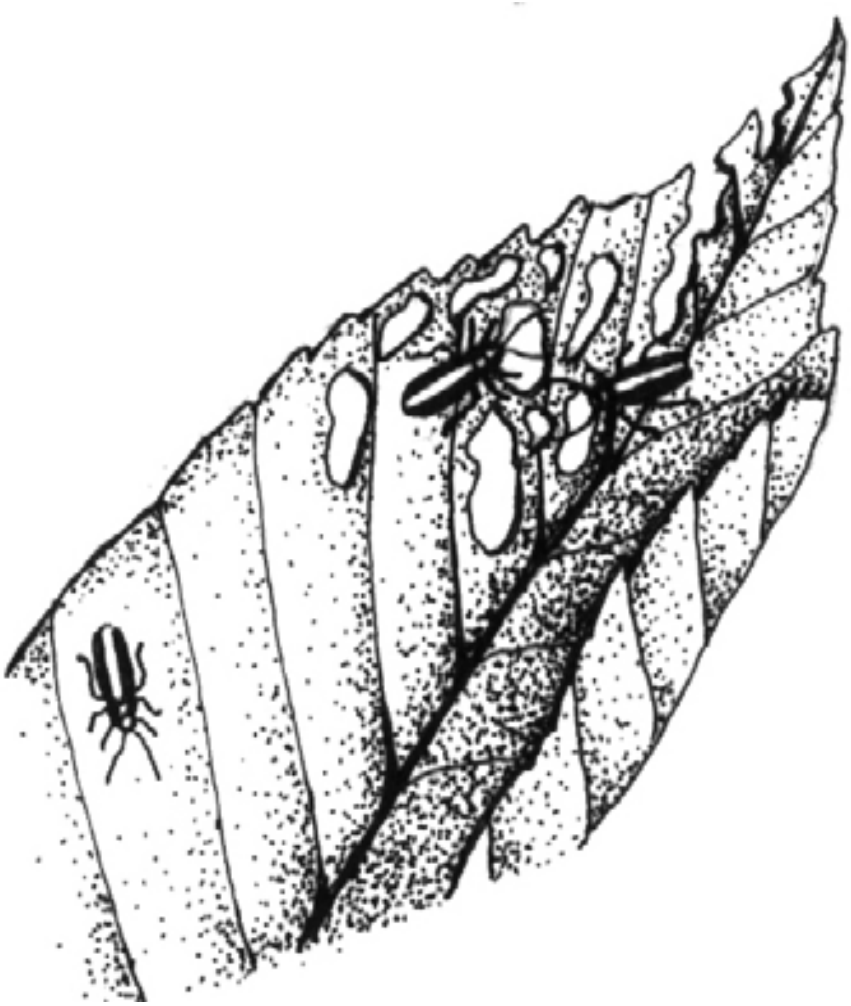
Chapter 8
Diagnosing Plant Damage

Diagnosing Plant Damage

Chapter 8



Diagnosing Plant Damage

Chapter 8

Revised by *Adria C. Bordas, Extension Agent, Agriculture and Natural Resources (2015)*

James L. Green, Extension Horticulture Specialist, Oregon State University; adapted for Virginia (2009)

Diagnostic Key revised by Mary Ann Hansen, Plant Disease Diagnostician (2009) and Eric Day, Insect Identification Lab Manager, Virginia Tech (2009)

Diagnosis of plant problems is often a very difficult task since there can be many different causes for a given symptom, not all of which are pathogenic organisms. Soil nutrition and texture, weather conditions, lighting, and many other environmental and cultural conditions influence the overall health of a plant. Insect damage can sometimes be confused with plant disease caused by microorganisms or abiotic factors. Knowing a complete history of the plant is essential to making an accurate diagnosis. Also, a plant specimen should be in the early stages of deterioration when it is examined in order for an accurate diagnosis to be made. Once it has decayed, secondary organisms invade the tissue and evidence of the primary pathogen is often obscured.

For these reasons, it is difficult to construct a foolproof key for the diagnosis of plant problems. Even with the necessary laboratory equipment at one's disposal, it is often difficult to determine the exact cause of a plant's problem. The following pages provide an aid to diagnosing some of the common problems of urban plants. This chapter was constructed for Master Gardeners to help solve consumer's plant problems — it is not meant for diagnosis of commercial problems or use by laboratory diagnosticians. The information provided is by no means comprehensive and other resources will be needed for many of your diagnoses. The Ortho Problem Solver is particularly useful as it contains color pictures. Other references are listed at the end of this chapter.

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Introduction

A Systemic Approach to Diagnosing Plant Damage

Determining what factors caused damage to a plant requires an inquisitive, investigative approach combined with careful observation and the ability to put all the pieces together to reconstruct the event(s) that produced the plant damage. Accurate diagnosis must be made before corrective action can be taken. Even if no corrective measures are available, there is satisfaction in simply knowing what the problem is and what its future development might be.

Living factors: Living organisms such as *pathogens* (fungi, bacteria, viruses, nematodes), and *pests* (insects, mites, mollusks, rodents, etc.). With living factors, *"Something is missing, and something is gained."*

Nonliving factors: *Mechanical factors* (i.e. breakage, abrasions, etc.), *physical/environmental factors* (extremes of temperature, light, moisture, oxygen, lightning), and *chemical factors* (chemical phytotoxicities, nutritional disorders, etc.).

If we suspect that it is a **living damaging factor**, we will look for signs and symptoms to distinguish between pathogens and pests. If the accumulated evidence suggests that it is a pathogen, we will seek evidence to distinguish among fungal, bacterial, viral pathogens, and nematodes. If the evidence indicates the damaging factor is an insect or other animal, we will seek further evidence to distinguish between sucking and chewing types.

The probability of a correct diagnosis based on only one or two clues or symptoms is low. Similarities of symptoms produced on the same plant by completely different factors frequently make the use of symptoms alone inadequate.

In diagnosing plant damage, a series of deductive steps can be followed to gather information and clues from the big, general situation down to the specific, individual plant or plant part. Through this systematic, diagnostic process of deduction and elimination, the most probable cause of the plant damage can be determined. Steps to follow in gathering diagnostic information are presented in Table 1. Each step will then be expanded and guidelines presented as we proceed through the diagnostic process. We will first identify the problem, then attempt to distinguish between living and nonliving damaging factors based on the observed damage patterns, development of the patterns with time, and other diagnostic signs.

Factors causing plant damage can be grouped into two major categories: If evidence indicates that the damage is being caused by a nonliving factor, we will seek further evidence as to whether the initial damage is occurring in the root or aerial environment. We will then attempt to determine if the damage results from mechanical factors, from extremes in physical factors (i.e. environmental factors such as extremes of temperature, light, moisture, oxygen), or from chemical factors (i.e. phytotoxic chemicals or nutritional disorders). Once we have identified the plant and limited the range of probable causes of the damage, we can obtain further information to confirm our diagnosis from reference books, specialists such as plant pathologists, entomologists, horticulturists, and/or laboratory analyses.

Table 1. Model for Diagnosing Plant Damage

I. Define the Problem (Determine that a "real" problem exists):

A. **Identify plants and know characteristics.** Establish what the "normal" plant would look like at this time of year. Describe the "abnormality": Symptoms & Signs.

B. **Examine the entire plant and its community.** Determine the primary problem and part of the plant where initial damage occurred.

II. Look for Patterns: On more than one plant? On more than one plant species?

A. **Understand nonuniform damage pattern** (scattered damage on one or only a few plant species) is indicative of living factors (pathogens, insects, etc.).

B. **Understand uniform damage pattern** over a large area (i.e. damage pattern on several plant species) and uniform pattern on the individual plant and plant parts indicates nonliving factors (mechanical, physical, or chemical factors).

C. **Compare Patterns of living and nonliving factors on plant community, plan, plant part.**

III. **Delineate Time-Development of Damage Pattern**

A. Progressive spread of the damage on a plant onto other plants or over an area with time indicates damage caused by living organisms.

B. Damage occurs, does not spread to other plants or parts of the affected plant. Clear line of demarcation between damaged and undamaged tissues. These clues indicate nonliving damaging factors.

IV. Determine Causes of the Plant Damage Ask questions and gather information.

A. **Distinguish among living factors**

1. Symptoms and signs of **pathogens**.
2. Symptoms and signs of **insects, mites, and other animals**.

B. **Distinguish among nonliving factors**

1. **Mechanical factors**
2. **Physical factors**
   a. Temperature extremes
   b. Light extremes
   c. Oxygen and moisture extremes
3. **Chemical factors**
   a. Analyze damage patterns in fields and other plantings
   b. Injury patterns on individual plants.
   c. Pesticide-pollutant phytotoxicities - damage, patterns.
   d. Nutritional disorders-key to nutritional disorders.

C. References (check reports of damaging factors on identified plant); may need laboratory analysis to narrow range of probable causes.

V. Synthesis of Information to Determine Probable Causes

Define the Problem

Identify Plant & Know Characteristics

Is the growth and appearance of the identified plant normal? Is it abnormal?

Determine that a real problem exists. It is essential that the plant be identified (genus, species, and cultivar or variety) so that the normal appearance of that plant can be established either by personal knowledge or by utilizing plant reference books. Many horticultural plants or structures on those plants such as fruits, seeds, lenticels, etc. may appear to be abnormal to the person who is not familiar with the specific plant. For example, the 'Sunburst' honey locust might appear to be suffering from a nutrient deficiency because of its chlorotic yellow-green leaf color, but it was selected because of this genetic characteristic. It is not abnormal for this plant; therefore, it is not a problem.

Always compare the typical diseased plant with a healthy or normal plant, since normal plant parts or seasonal changes are sometimes mistakenly assumed to be evidence of disease. Examples are the brown, spore-producing bodies on the lower surface of leaves of ferns.

These are the normal propagative organs of ferns. Also in this category are the small, brown, club like tips that develop on arborvitae foliage in early spring. These are the male flowers, not deformed shoots. Small galls on the roots of legumes, such as beans and peas, are most likely nitrogen-fixing nodules essential to normal development and are not symptoms of root-knot nematode infection. The leaves of some plants, such as some rhododendron cultivars, are covered by conspicuous fuzz-like epidermal hairs. This is sometimes thought to be evidence of disease, but it is a normal part of the leaf. Varieties of some plants have variegated foliage that may resemble certain virus diseases. These examples illustrate the importance of knowing what the normal plant looks like before attributing some characteristic to disease.

In describing the plant "abnormality", distinguish between symptoms and signs. **Symptom**s are changes in the growth or appearance of the plant in response to living or nonliving damaging factors. Many damaging factors can produce the same symptoms; symptoms are not definitive. Signs are evidence of the damaging factor (pest or pathogen life stages, secretions, mechanical damage, chemical residues, records of weather extremes or chemical applications, damage patterns). Patterns of damage are excellent signs and are definitive diagnostic clues.

Examine the Entire Plant & Its Community

In defining a plant problem, it is essential to determine the real primary problem. There are foliage symptoms that may occur due to root damage. The primary problem would be root damage, not chlorosis of the foliage--examine the roots. In general, if the entire top of the plant or entire branches are exhibiting abnormal characteristics, examine the plant downward to determine the location of the primary damage. Look for the factor causing the damage at the periphery of the plant damage.

Some pathogens and insects as well as nonliving factors are only damaging if the plant has been predisposed by other primary factors. For example, borers generally only attack trees that are already predisposed by moisture or other physical stress. Premature dropping of leaves by foliage plants (i.e. *Ficus benjamina*) and of needles by conifers frequently causes alarm. Evergreen plants normally retain their leaves for 3-6 years and lose the oldest gradually during each growing season (Figure 1). This normal leaf drop is not noticed. However, prolonged drought or other stress factors may cause the tree as a whole to take on a yellow color for a short period and may accelerate leaf loss. If the factors involved are not understood, this often causes alarm. The leaves that drop or turn yellow are actually the oldest leaves on the tree, and their dropping is a protective mechanism which results in reduced water loss from the plant as a whole.

Look for Patterns

Here is where we start making the distinction between living and nonliving factors that cause plant damage.

Understand Nonuniform Damage Pattern

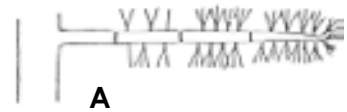
Living Factors

There is usually no discernible widespread pattern

Figure 1. Normal vs. Abnormal Needle Drop or Leaf Drop From Evergreens

Non-deciduous plants normally retain their leaves for several years but eventually they fall. This drop is usually gradual and production of new leaves obscures the loss of older leaves.

A. *Normal*: If drop is confined to older leaves, alarm is unnecessary because it is a normal response to a condition of stress (e.g. drought). Unfavorable growing conditions such as drought may accelerate leaf fall so that it becomes apparent and of concern.



B. *Abnormal*: If newly produced leaves are lost, it is a problem. The drop of current year's leaves may result from a pathogen or insect attack or from chemical deficiencies or toxicities.

of damage. Living organisms generally produce no uniformly repeated pattern of damage on a planting. Damage produced by living organisms, such as pathogens or pests, generally results from their using the plant as a food source. Living organisms are generally rather specific in their feeding habits and do not initially produce a wide-spread, discernible damage pattern. Plants become abnormal. Tissues are destroyed or removed, become deformed, or proliferate into galls.

Living organisms are specific, i.e., damage may be greatest on or limited to one species of plant.

Living organisms multiply and grow with time, therefore they rarely afflict 100% of the host plants at one time. The damage is progressive over time. Likewise, the damage generally is initially limited to only one part of the plant and spreads from that initial point of attack with time.

Living organisms usually leave "signs", i.e. excrement cast skins, mycelium, eggs, etc.

Understand Uniform Damage Pattern

Nonliving Factors

Damage patterns produced by nonliving factors such as frost or applications of toxic chemicals are generally recognizable and widespread. Damage will appear on all leaves of a certain age (for example, on all the leaves forming the plant canopy at the time a toxic spray was applied) or exposure (i.e. all leaves not shaded by overlapping leaves on the southwest side of a plant may be damaged by high temperatures resulting from intense sunlight). Damage will likely appear on more than one type or species of plant (look for similar damage patterns on weeds, neighboring plants, etc.) and over a relatively large area.

Compare Patterns

Figures 2, 3, and 4 provide a comparison of patterns of living and nonliving factors on plant community, plant, and plant part and discuss these factors.

A. *Entire or major portion of top dying:* If all or a major portion of a tree or shrub dies, suspect a problem with the roots. Look for damaging factor at junction of normal and abnormal plant tissue.

Gradual decline of entire plant or a major portion of it is caused by living factors such as Armillaria root rot, Verticillium wilt, and root weevil.

Sudden decline: Is generally caused by a nonliving factor such as a toxic chemical in soil or drastic climatic changes such as freezing or drought.

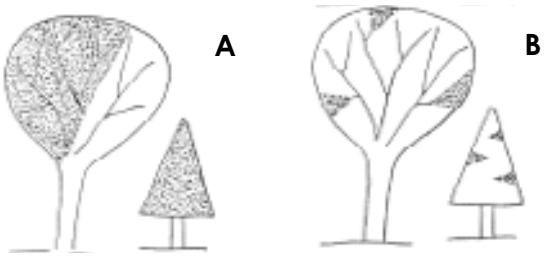


Figure 2. Patterns on Plant Canopy

B. *Single branch dying:* If scattered damage occurs in the plant canopy, suspect that the primary problem is related to the foliage or aerial environment, not the roots.

Gradual death of a branch: If scattered branches start to decline and eventually die, suspect a living organism such as a canker pathogen, a shoot blight, or borers.

Sudden death of a branch: If a branch dies suddenly, and especially if affected branches are concentrated on one side of the plant, suspect a nonliving factor such as weather (wind, snow, etc.), animal damage, or chemical drift.

Figure 3. Shoot Dieback

A. *Shoot dieback caused by nonliving factors:* Sudden dying back of a shoot usually indicates a nonliving cause such as climatic or chemical damage, not a living factor. Damage caused by nonliving factors usually results in a sharp line between affected and healthy bark.

If dieback is more gradual and there is also cracking of the bark and wood, suspect winter injury.

B. *Shoot dieback (blight) caused by living factors:* Gradual decline of shoots and B retention of dead leaves may indicate a living factor.

The margin between affected and healthy tissue is often

irregular and sunken.

There may be small, pin-like projections or bumps over surface of dead bark: These are spore-producing structures of pathogenic fungi.

However, small, woody bumps radiating from all sides of twigs of Dwarf Alberta Spruce are pulvinus, woody projections where needles were attached. This is a taxonomic identifying characteristic of spruce.

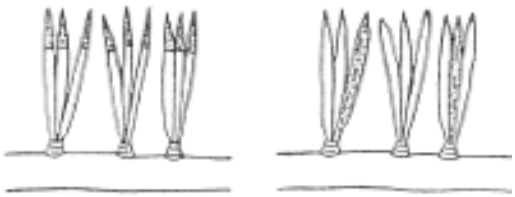


Figure 4. Needle Damage

Death of the tips of conifer needles producing a uniform pattern usually indicates a nonliving factor such as a toxic chemical or unfavorable climatic condition. Air pollutants frequently cause tip burn on conifers as do certain soil-applied herbicides or excess fertilizer.

Drought and freezing may have a similar effect. In these cases all needles of a specific growth period are usually affected, and usually the same length on each needle is affected.

The margin between the affected tissue (usually reddish brown) and healthy tissue is sharp and distinct.

Damage by living organisms, such as fungi and insects, to needles usually occurs in a random, scattered pattern and rarely kills all needles of a particular growth period. Needles are usually affected over varying lengths and often appear straw yellow or light tan in color. Black fruiting bodies of causal fungus may be present on diseased needles.

Delineate Development

As already mentioned, another clue for distinguishing between living and nonliving factors causing plant damage is to observe the development of the pattern.

Living organisms generally multiply with time and produce an increasing spread of the damage over a plant or planting with time, and therefore are progressive.

Figure 5. Foliar Chemical Spray Injury Pattern on Leaf

Spots are usually uniformly and evenly distributed over the leaf surface, and generally will be of uniform size. Color is usually uniform across the spot.

The margin between the affected and healthy tissue is usually sharp. Injury pattern does not spread with time or move to previously undamaged parts.

Figure 6. Leaf Damage Pattern by Nonliving Factors

(i.e. toxic chemicals taken up through roots or from polluted air filtered through the leaf, or from moisture stress.)

Injury from chemicals taken up by plants from soil through roots or from air through leaves usually results in scorching (necrosis) of leaf margins and interveinal areas. If severe, necrotic tissue may drop out giving a ragged appearance. Similar patterns are produced by moisture stress. If uptake of toxic chemical is to a fully expanded leaf, toxicity is marginal and interveinal. If uptake is to an unexpanded leaf, toxicity occurs in veins.

Nonliving factors generally damage the plant at a given point in time, for example, death of leaf tissue caused by a phytotoxic chemical is immediate and does not spread with time (Figure 5). There are exceptions. If a nonliving damaging factor is maintained over time, the damage will also continue to intensify with time. For example, if a toxic soil or air chemical is not removed, damage

to plants within the contaminated area will continue to develop (Figure 6), but damage will not spread to plants in uncontaminated areas. Nonliving factors are not progressive. This again reemphasizes the necessity of piecing together multiple clues to identify the most probable factor causing plant damage.

Study Questions

1. The two main categories of factors that cause plant damage are _____ and _____.
2. _____ is necessary before attempting to diagnose a plant problem in order to establish that a real problem exists.
3. _____ are changes in the growth or appearance of the plant in response to living or non-living damaging factors.
4. A symptom that could occur due to root damage would be: a) the entire top of the plant is abnormal; b) the outermost leaves are abnormal; c) the innermost leaves are abnormal; d) not apparent on foliage
5. A uniform pattern of damage over many plants would indicate a _____ factor.
6. Drop of older leaves on evergreens is considered to be _____.
7. If uptake of a toxic chemical is to a non-expanded leaf, toxicity occurs: a) in veins; b) at margins; c) interveinally; d) on the petiole

Answers:
1 - living, non-living; 2 - identification of the plant; 3 - symptoms; 4 - a; 5 - non-living; 6 - normal; 7 - a

Determine Causes

Patterns of damage distribution and time patterns in development of damage have been valuable in making the gross distinction between damage caused by living factors and damage caused by nonliving factors. Additional clues must be obtained to distinguish among factors within the living and nonliving categories.

Distinguish Among Living Factors

To further identify which subcategory of living factor caused the damage, a close examination of the symptoms and signs is required.

Symptoms are the modified appearance of the affected plant, for example necrotic tissues, chlorosis, cankers, galls, leaf distortion.

Signs are the presence of the actual organism or evidence directly related to it: visual observation of the insect on the leaf, presence of fungal mycelium, spores, insect egg masses, insect frass, mite webbing, etc. Signs can be used as clues in identifying the specific living organism that produced the plant damage.

A combination of clues from both symptoms and signs are required for preliminary distinction between pathogen and insect-mite damage.

Symptoms and Signs of Pathogens

Differentiating between bacterial and fungal pathogens is not always clear cut (Table 2).

Table 2. Symptoms and Signs of Fungal and Bacterial Leaf Spots

Abnormality	*Fungal*	*Bacterial*
Water-Soaking	Uncommon	Common
Texture	Dryish-papery	Slimy-sticky
Odor	Usually none	Fishy, rotten
Pattern	Circular with concentric rings	Irregular-angular; initially does not cross veins
Disintegration	Uncommon	Common
Color Changes	Common: red, yellow, purple halos	Uncommon
Pathogen Structures	Common -mycelia, spores, etc.	Uncommon

FUNGAL DISEASES

(Figure 7). Fungal leaf spots and stem rots are characterized by various symptoms: dry texture, concentric rings, discoloration, and fruiting structures. Fungal leaf spots and stem rots are usually dry or papery. This is especially true in dry climates. The most distinguishing clue of a fungal disease is the presence of signs: mycelium and fruiting bodies of the fungus itself. The fruiting bodies range in size from microscopic to those easily detected with the naked eye. They are found within the leaf spot or stem rot area. Each type of fungus has its own characteristic structures which enable plant pathologists to identify them.

Figure 7. Fungal leaf spots

Spots usually vary in size, are generally round, and occasionally elongate on stems.

Zones of different color or texture may develop giving the spot a bull's eye effect. The dead tissue (tan) is in the center of the spot where the fungal spore germinated. Then as the fungal mycelium front moves outward from the point of dead tissue to healthy, not yet infected tissue on the perimeter, the foliage color changes from dead tan in the center to healthy green on the perimeter.

Spots are not limited by leaf veins since mycelium grows on leaf surface.

Figure 8. Bacterial leaf spots

Bacterial leaf spots are often angular because they are initially limited by the leaf veins.
Color of the bacterial spots is usually uniform. Bacteria are one-celled organisms that kill as they go. Tissue may first appear oily or water-soaked when fresh, but upon drying becomes translucent and papery tan.

Foliar Pathogens: The leaf spots caused by fungi generally have distinct margins (Fig. 7). Many times they are circular with concentric rings resulting from growth of the mycelium from the center point of initial infection outward (much like crocheting a doily). The condition of the leaf tissue and associated color ranges from dead (necrotic tan) in the center, to recently dead (darker brown ring), to dying (darker ring with possible light yellow, chlorotic edge indicating the advancing edge of the fungal infection). The margins of fungal leaf spots (Fig. 7) and stem rots (Fig. 3) can be brightly discolored, such as purple (Fusarium stem rot) or yellow (Helminthosporium leaf spot), making these symptoms quite striking.

Root and Stem Pathogens: Root rot and vascular wilt result from fungal infection and destruction of root and stem tissues. The most common visual symptom is gradual wilting of the above ground shoots.

BACTERIAL DISEASES

(Figure 8). Bacteria do not actively penetrate healthy plant tissue like fungi. They enter through wounds or natural openings such as leaf stomata or twig lenticels. Once bacteria enter the plant, they reproduce rapidly, killing the plant cells.

Bacterial galls: In some cases, toxic materials are produced that cause plant tissues of roots, stems, or leaves to grow abnormally as in crown gall.

Bacterial leaf spot disease: The bacteria usually enter through leaf stomata. Symptoms include water-soaking, slimy texture, fishy or rotten-odor, confined initially between leaf veins resulting in discrete spots that have straight sides and appear angular. Many bacterial leaf spots, such as Xanthomonas leaf spot on Philodendron (also called red edge disease), expand until they reach a large leaf vein. This vein frequently acts as a barrier and inhibits the bacteria from spreading further. A chlorotic halo frequently surrounds a lesion. Lesions may enlarge through coalescence to develop blight lesions. Some lesions exude fluid containing bacteria. Water-soaking frequently occurs in bacterial leaf spot diseases such as Erwinia blight of Dieffenbachia. Holding the leaf to light usually reveals the water-soaking. The ability of bacteria (usually Erwinia species) to dissolve the material holding plant cells together results in a complete destruction of leaf or stem integrity. Some fungi also produce this symptom but not usually as extensively as Erwinia. In general, bacterial infections show this characteristic more than fungal infections. In final stages, cracks form in the tissue and disintegration follows.

Vascular wilt: In some cases the bacteria poison or plug the water conducting tissue and cause yellowing, wilting, browning, and dieback of leaves, stems, and roots.

VIRAL DISEASES

(Figure 9). Viruses are "submicroscopic" entities that infect individual host plant cells. Once inside a plant cell

they are able to infect other cells. Viruses are obligate parasites. They can only replicate themselves within a host's cell. Because the virus commandeers the host cell to manufacture viruses identical to itself, the plant cell is unable to function and grow normally. In the virus infected plant, production of chlorophyll may cease (chlorosis, necrosis); cells may either grow and divide rapidly or may grow very slowly and be unable to divide (distortion, stunting).

Figure 9. Vein clearing and mosaic leaf patterns

Left side of leaf: Vein clearing (chlorosis) with interveinal tissue remaining green usually indicates a virus disease or uptake and xylem translocation of a herbicide such as diuron. This is in contrast to the leaf veins remaining green with surrounding chlorotic tissue associated with nutrient deficiencies such as iron deficiency.

Right side of leaf: Mosaic is a patchwork of green and yellow areas over the surface of a leaf. The leaf may also be puckered and distorted. These symptoms usually indicate a virus disease, especially if yellow areas blend gradually into green areas. If margins are distinct, mottling may indicate a nutritional problem or genetic variegation.

The symptoms of most virus diseases can be put into four categories:

1) Lack of chlorophyll formation in normally green organs.

Foliage may be mottled green and yellow, mosaic, or ringed (yellow or other pigmented ring patterns), or be a rather uniform yellow (virus yellows).

Veins: Vein clearing is a common first symptom of some viral diseases. The veins have a somewhat translucent or transparent appearance. In vein banding there is a darker green, lighter green or yellow band of tissue along the veins.

2) Stunting or other growth inhibition. The reduction in photosynthesis due to less chlorophyll leads to shorter internodes, smaller leaves and blossoms, and reduced yield.

3) Distortions of leaves and flowers. Witches' brooms or rosettes result from non-uniform growth within a tissue or uncontrolled growth.

4) Necrotic areas or lesions. Being obligate parasites, viruses require the survival of their host plant for their own procreation. Hence, viruses rarely cause death. Necrosis that does occur is usually confined to discrete areas of the plant; necrosis rarely occurs to such an extent that the entire plant is killed.

Viruses typically discolor, deform, or stunt plants rather than induce necrosis or cause death. Expressed symptoms (chlorosis, stunting, distortions) can be valuable clues for virus identification, but can be easily confused with symptoms induced by other problems such as nutritional disorders, spray injuries, or certain feeding damage induced by mites or insects. In addition, because of their extremely small size, the virus or signs of the virus are not visible to the unaided eye. The virus particles are detectable within the plant cell through the electron microscope.

Viruses are transmitted from plant to plant by insects, mites, fungi and nematodes, rubbing, abrasion, or other mechanical means (including grafting or other forms of vegetative propagation). Viruses are occasionally transmitted in seed. Because of the nature of virus transmission, virus symptoms generally spread with time from one infected plant tissue to other plant tissues or from one infected plant to other plants in the community.

NEMATODES

Plant nematodes are microscopic roundworms that damage plant tissues as they feed on them. Many feed on or in root tissues. A few feed on foliage or other above-ground organs.

Shoot Nematodes (*Aphelenchoides* spp.): Foliar nematodes feed inside leaves between major veins causing chlorosis and necrosis. Injury is most often seen at the base of older foliage. When plants with a net-like pattern of veins become infested with foliar nematodes, the tissues collapse in wedge-shaped areas and then change color.

Root Nematodes: The most common above-ground

symptoms caused by root-infesting nematodes result from damaged root systems. Moisture and nutrient stress symptoms and general stunting are common. The root lesion nematodes (*Pratylenchus* spp.) and burrowing nematodes (*Radopholus similis*) destroy the root cortex tissues as they feed. The root-knot nematodes (*Meloidogyne* spp.) inject growth-regulating substances into root tissues as they feed, stimulating growth of large tender cells to provide themselves a permanent feeding site, and causing overgrowth of root tissues around them to form visible, swollen galls or knots. Other root nematodes stunt growth, apparently by killing root meristems.

Study Questions

8. A progressive, increasing spread of damage over time indicates a _____ factor.

9. Signs of a living factor would include: a) necrotic tissue; b) galls; c) mite webbing; d) root rot

10. A fungal pathogen might be recognized by:
a) water-soaking on leaves; b) a fishy, rotten odor; c) disintegration of leaf tissue; d) circular spots with concentric rings

11. An abnormal, slimy, sticky texture would indicate a _____ pathogen.

12. Symptoms of a virus do NOT include:
a) a lack of chlorophyll formation; b) profuse flowering; c) distorted leaves/ flowers; d) necrotic areas or lesions

13. Viruses can be transmitted by:
a) insects and mites; b) fungi; c) abrasion and rubbing; d) all of the above

14. Moisture and nutrient stress along with general stunting are symptoms of _____ feeding nematodes.

Answers: 8 - living; 9 - c; 10 - d; 11 - bacterial; 12 - b; 13 - d; 14 - root

Symptoms and Signs of Insects, Mites, and Other Animals

Insects

The location of the feeding damage on the plant caused by the insect's feeding, and the type of damage (damage from chewing or from sucking mouth parts) are the most important clues in determining that the plant damage is insect-caused and in identifying the responsible insect.

An insect's life cycle (complete or incomplete) is important when attempting to detect the insect or design a control program.

Feeding Habits:

Chewing damage or rasping damage:

* *Entire Leaf Blade Consumed* by various caterpillars, canker worms, and webworms. Only tougher midvein remains.
* *Distinct Portions of Leaf Missing:* Distinct notches cut from leaf margin (black vine weevil adult), circular holes cut from margin of leaf (leaf cutter bees), small randomly scattered holes in leaf (beetles, chafers, weevils, grasshoppers).
* *Leaf Surfaces Damaged:* "*Skeletonization*" of leaf surface. Slugs, beetle larvae, pear slug (pear sawfly larvae), elm leaf beetle, and thrips.
* *Leaves "rolled":* Leaves that are tied together with silken threads or rolled into a tube often harbor leafrollers or leaftiers, i.e. omnivorous leaftier.
* *Leaf Miners Feed Between the Upper and Lower Leaf Surfaces:* If the leaf is held up to the light, one can see either the insect or frass in the damaged area (discolored or swollen leaf tissue area), i.e. boxwood, holly, birch, elm leaf miners.
* *Petiole and Leaf Stalk Borers* burrow into the petiole near the blade or near the base of the leaf. Tissues are weakened and leaf falls in early summer. Sectioning petiole reveals insect-larva of small moth or sawfly larva, i.e. maple petiole borer.
* *Twig Girdlers and Pruners*, i.e. vine weevil and twig girdling beetle.
* *Borers Feed under the Bark* in the cambium tissue or in the solid wood or xylem tissue, i.e. Mountain pine beetle and smaller European elm bark beetle galleries. Damage is often recognized by a general decline of the plant or a specific branch. Close examination will often reveal the presence of holes in the bark, accumulation of frass or sawdust-like material or pitch, i.e. raspberry crown borer, Sequoia pitch moth.
* *Root Feeders:* Larval stages of weevils, beetles, and moths cause general decline of plant, chewed areas of roots, i.e. sod webworm, Japanese beetle, root weevil.

Sucking damage:

In addition to direct mechanical damage from feeding, some phloem-feeding insects cause damage by injecting toxic substances when feeding. This can cause symptoms which range from simple stippling of the leaves to extensive disruption of the entire plant. Insect species which secrete phytotoxic substances are called toxicogenic (toxin-producing) insects. The resulting plant damage is called "phytotoxemia" or "toxemia." (Chapman, R.K 1985. Insects that poison plants. American Vegetable Grower 33-10:3138, October 1985).

* *Spotting or Stippling* result from little diffusion of the toxin and localized destruction of the chlorophyll by the injected enzymes at the feeding site. Aphids, leafhoppers, and lygus bugs are commonly associated with this type of injury.
* *Leaf curling or Puckering:* More severe toxemias such as tissue malformations develop when toxic saliva causes the leaf to curl and pucker around the insect. Severe aphid infestations may cause this type of damage.
* *Systemic Toxemia:* In some cases the toxic effects from toxicogenic insect feeding spread throughout the plant resulting in reduced growth and chlorosis. Psyllid yellows of potatoes and tomatoes and scale and mealybug infestations may cause systemic toxemia.
* *General (uniform) "Stipple," Flecking, or Chlorotic Pattern:* on leaf, i.e. adelgid damage on spruce needles and bronzing by lace bugs.
* *Random Stipple Pattern:* on leaf, i.e. leafhoppers, mites.
* *Leaf and Stem "Distortion"* associated with off-color foliage = aphids (distortion often confused with growth regulator injury), i.e. rose aphid, black cherry aphid, leaf curl plum aphid.
* *Galls, Swellings* on leaf and stem tissue may be caused by an assortment of insects, i.e. aphids, wasps, midge, mossyrose gall wasp, poplar petiole gall midge, azalea leaf gall.
* *Damaged Twigs are Split:* Damage resembling split by some sharp instrument is due to egg laying (oviposition) by sucking insects such as tree hoppers and cicadas. Splitting of the branch is often enough to kill the end of the branch, i.e. cicada.
* *Root, Stem, Branch Feeders: General Decline of Entire Plant or Section of a Plant* as indicated by poor color, reduced growth, dieback. Scales, mealybugs, pine needle scale.

Insect Life Cycles:

Knowledge of life cycles assists in identifying the damaging insect.

Incomplete life cycle: Insects resemble the adult upon hatching, except they are smaller and without wings. As the insect grows, it sheds its skin or molts leaving cast skins as a diagnostic sign. The adult stage is most damaging. Lygus bugs, leafhoppers, and grasshoppers are examples of insects with incomplete life cycles.

Complete life cycle: Eggs, larva (wormlike or grub-like creature that may feed on various plant parts), pupa (relatively inactive, often enclosed in some form of cocoon), and adult insect are completely different in appearance. The larval stage with chewing and rasping feeding is most damaging. Examples of insects with complete life cycles are butterflies, moths, weevils, beetles, and flies.

Other Animal Damage

Arachnids have sucking mouth parts and 8 legs instead of 6 like the insects. *Spider mites* have an incomplete life cycle (mite resembles adult throughout life cycle). Damage is often a characteristic stipple pattern on leaf which then becomes pale color on underside (severe infestation causes leaf bronzing and death). Presence of "dirty" foliage indicates small fine webbing on the underside of the foliage mixed with eggs and frass. *Eriophyid mites* cause distorted new growth, leaf margins roll, leaf veins swell and distort the leaf (symptoms often confused with growth regulator damage).

Crustacea: Sow bugs and pill bugs feed on decaying vegetation. Not considered to be damaging to live plants.

Mollusca: Slugs and snails. Feeding injury to low growing foliage resembles skeletonizing or actual destruction of soft tissue. Signs: Presence of 'silvering' and slime trails on foliage.

Miscellaneous Animals: Millipedes and centipedes (arthropods) feed on decaying plant vegetation (many

small legs, brownish or white in color, vary in size from 1/2 - 2"). Not considered to be injurious to live plants.

Small Mammals: Chewing of bark and cambium tissue on small trees and shrubs is most frequently by rodents (mice, rabbits, squirrels, and possibly beavers). Signs: Note teeth marks.

Large Mammals: Branches torn or clean cut by cattle, goats, deer, and horses.

Birds: Yellow-bellied sap-sucker (even rows of holes in the tree trunk). Missing flower petals, puncture splitting of bark.

Study Questions

15. Chewing or rasping insect damage does NOT result in: a) spotting or stippling; b) missing leaf portions; c) rolled leaves; d) twig girdling
16. Sucking insect damage does NOT include: a) leaf curl; b) systemic toxemia; c) entire leaf consumption; d) galls
17. Leafhoppers, grasshoppers, and Lygus bugs have a/an _____ life cycle.
18. Fine webbing on the underside of foliage along with a stipple pattern on leaves are a symptom of _____.
19. Skeletonizing or destruction of soft plant tissue are symptoms of: a) small mammals; b) mollusks; c) birds; d) millipedes and centipedes

Answers:
15 - a; 16 - c; 17 - incomplete; 18 - spider mites; 19 - b

Distinguishing Among Nonliving Factors

If patterns of damage in the field planting and on the individual plant are uniform and repeated, this indicates that a nonliving factor is the probable cause of the damage. We will now examine additional information and clues to determine whether the nonliving damaging factor was a mechanical, physical, or chemical factor.

Look for changes in the three categories of nonliving factors of the affected plant's environment:

* Mechanical Factors - (damage/breakage) - plant damage caused by site changes - "construction damage," transplanting damage, "lawn mower blight," abrasion, bruising.
* Physical Factors - environment or weather changes causing extremes of temperature, light, moisture, aeration.
* Chemical Factors - chemical pesticide applications, aerial and soil pollutants, nutritional disorders.

Mechanical Factors

Close visual examination and questioning will often determine if the stems or roots have been broken or girdled or if the leaves have been bruised, punctured, or broken. For example, if a large *Ficus elastica* is dropped while being transplanted and the stem is broken, rapid wilting of the portion of the plant above the break will occur. Examine the plant site for signs of recent excavation, construction, paving, etc.

Physical Factors *(Environmental Factors)*

Primary sources of diagnostic information are damage patterns and weather records to pinpoint time and location of weather extremes. Records are "signs" of the factor that caused the plant damage.

Temperature Extremes:

Heat: The highest leaf temperatures will occur in the early afternoon when the sun is located in the southwest quadrant of the sky. Therefore, lethal leaf temperatures produced by solar radiation absorption will occur primarily on unshaded leaves on the outer surface of the plant canopy on the southwest side. Portions of leaves shaded by other leaves or leaves on the shaded northeast side may be undamaged. Most severe damage occurs on the leaves most exposed and furthest from the vascular (roots, stem, leaf vein) source of water, i.e. leaves on outer perimeter of plant, leaf tips, and interveinal areas. A recognizable pattern related to leaf tissue that would have the highest potential temperature and be most readily desiccated will occur uniformly over all plants in the area.

Cold: Damage will occur on the least hardy plants and will be most severe on the least hardy tissues of those specific plants. In fall acclimation, cold hardiness is first achieved by the terminal buds, and then with time the lower regions achieve hardiness; the branch crotches are often the last tissues to achieve cold hardiness. Generally the root systems will not survive as low a temperature as will the tops - root systems are damaged at higher temperatures than are the tops. On the other hand, after hardiness has been achieved, if warm temperatures induce

deacclimation (i.e. in the early spring), the terminals (buds) are first to become less cold hardy.

The portion of plant damaged will indicate if low temperature damage occurred before the plant achieved cold hardiness in the fall, or if it occurred after cold hardiness was lost in the spring. Reverse patterns are produced.

On a given structure (i.e. leaf or bud), the damage will be death of exposed, nonhardy tissues in a recognizable (repeated) pattern. For example, **frost damage to foliage**, i.e. conifer needles, in the spring will uniformly kill all needles of a given age from the tip of the needle back toward the stem a given distance on each needle. Frost cracks are longitudinal separations of the bark and wood generally on the southwest sides of the trunk -most likely to occur because of daily, wide temperature fluctuations. **Freezing death** of dividing cells on outer portions of leaf folds inside the bud will cause distorted or lace-like leaf blade because of non-uniform cell division and growth during leaf expansion. **Cold damage to the root system** is primarily a concern with container-grown plants where the root temperature fluctuates more and can be expected to reach lower temperatures than would occur with the same plant if field-grown. Cold damage to the root system can be detected by examining the roots. Damage generally occurs from the periphery of the root ball (near the container edge) and evidence includes blackened or spongy roots with lack of new growth or new root hairs. Above ground symptoms generally will not be evident until new shoot growth in the spring; at that time leaf expansion may be incomplete (small leaf size) because of the restricted uptake of water and nutrients by the damaged root system. With increased air temperatures, the water loss from the shoots and leaves may exceed the root uptake capacity, and the plants may defoliate due to this water deficiency.

Plants Vary in their Cold Tolerance: The cold tolerance (hardiness) of various plants in the landscape has been rated by the USDA (see Plant Hardiness Zone Map, USDA-ARS Misc. Pub. No. 814). The "indicator" plants listed for the various cold hardiness zones on the map are useful in surveying a group of landscape plants, observing which ones show cold damage and then estimating how low the temperature dropped based on the damaged/undamaged indicator plants.

Light Extremes:
Plants can acclimate to various conditions, but the primary requirement for acclimation is time. Plants respond adversely to rapid changes in the environment. Rapid change from low to high light intensity will result in destruction of the chlorophyll pigments in the leaf (yellowing and necrosis = sunburn). Rapid change from high to low light intensity will result in reduced growth and leaf drop; new leaves will be larger. "Sun leaves" are smaller, thicker and lighter green in color than are "shade leaves." Flowering will be reduced, delayed, or absent under low light.

Oxygen and Moisture Extremes:
Here we are primarily considering the root environment where oxygen and moisture are inversely related. Water logging (moisture saturation) of the root environment results in oxygen deficiency. Without oxygen, root metabolism and growth come to a standstill. Consequently, uptake of water and nutrients is restricted with subsequent wilting and nutritional deficiency symptoms occurring on the above ground portions of the plant. Drought and water logging produce many of the same symptoms on the above ground portion of the plant. The first symptoms will be chlorosis and abscission of older leaves. Under severe, continuing moisture stress, wilting and necrosis will occur on tips and interveinal regions of recently expanded leaves and new growth (Figure 6).

Study Questions

20. Three types of non-living factors are _____, _____, and _____.

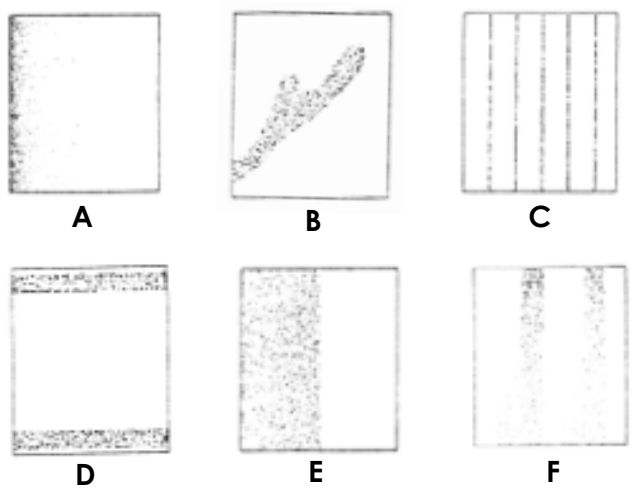
21. In fall acclimatization, the last tissues to achieve cold hardiness are the: a) outermost branch tips; b) cambium; c) branch crotches; d) largest limbs

22. Frost cracks due to daily temperature fluctuations generally appear on the _____ side of trunks.

23. A rapid change from high to low light will result in: a) destruction of chlorophyll pigment; b) leaf drop; c) increased flowering; d) all of the above

24. Compared to drought, water logging symptoms: a) do not include wilt; b) do not include chlorosis; c) do not include leaf drop; d) are the same

Answers: 20 - mechanical, physical/environmental, chemical; 21 - c; 22 - southwest; 23 - b; 24 - d



A. Drift of spray droplets.
B. Spots of injury from low temperature, accumulation of volatile chemicals, or accumulation of chemical runoff in low areas of the field; or, injury associated with soil variables.
C. Stripes indicating overlapping application pattern, or one or more faulty applicator openings.
D. Plant injury at end of field due to double application.
E. Definite break between injured and uninjured sections of the planting. Application discontinued or change in applied chemical.
F. Increasing injury within an application band due to poor mixing or inadequate chemical agitation.

Figure 10. Patterns of plant damage related to chemical applications to field or bed plantings

Chemical Factors

Field Patterns of Plant Injury Related to Chemical Applications:

Look for application, drift, or runoff accumulation patterns in the field: (Figure 10). The pattern of plant injury in a field or other group of plants and date of injury appearance can be helpful in relating the damage to a specific chemical application.

Damage diminishing uniformly from one side to another: (Figure 10.A). A pattern in a field, yard, or on a group of plants that starts on one side and diminishes gradually and uniformly away from that area is typical of wind-drift of droplets.

Damage in individual spots or irregular patterns: (Figure 10.B). Low lying areas in a field where air masses settle would enhance the accumulation of fumes from volatile chemicals, would be frost pockets, and might enhance pathogens. These damage spots might also be related to differences in the soil's texture, organic matter, pH, or moisture. High pH spots might induce nutritional disorders such as iron deficiency, increase the toxicity of triazine herbicides, etc.

Damage in linear stripes at regular intervals: (Figure 10.C), indicates non-uniform application of a chemical. Regularly recurring stripes of damaged plants at intervals within the width of the application equipment (fertilizer applicator, pesticide spray boom, etc.) indicate an over-sized or worn nozzle, improper setting on one applicator opening, or an overlap in application. Another cause may be carryover of a residual chemical from bands applied the year before. This pattern would match the row width and direction from the previous season.

Damage at ends of field: (Figure 10.D), may be due to double application of a chemical either the year before or the year the injury is observed.

Damage on one part of the field only with a definite break between the damaged portion and the remainder of the field: (Figure 10.E). 1) Was the chemical applicator reloaded or recalibrated at the break-point? If so, mistake might have been made in chemical selected or in rate of application, or the applicator might not have been adequately cleaned of a toxic chemical. The toxic residue was removed in application of the first load of chemical. Check equipment-use records. 2) Check tillage methods, dates, and soil conditions (moisture). Resulting differences in soil texture or depth of tillage may cause differences in dilution of carryover chemical residue, differences in volatilization and dilution of an applied chemical, etc.

Damage intensity increasing along a broad band: (Figure 10.F), indicates inadequate mixing or poor agitation of a wettable chemical powder in a spray tank resulting in increased concentration of the applied chemical toward the end of the tank load.

Chemical Injury Patterns on an Individual Plant:

A general uniform pattern of damage occurring over several plant species and over a relatively large area indicates a nonliving factor such as a chemical phytotoxicity. Questions-answers, records, the plant symptoms, and knowledge about the mobility within the plant of the common chemicals (nutrients and pesticides) should help determine which chemical caused the damage.

Patterns of injury symptoms on an individual plant that develop because of deficiency, excess, or toxicity of a chemical differ depending primarily upon whether the chemical causes damage directly on contact or is absorbed and distributed within the plant through phloem-translocation or through xylem-translocation.

Symptoms from Direct Contact of Chemicals with the Plant:

Shoot foliage contact: Symptoms from shoot contact chemicals occur over the general plant canopy. If the toxic chemical is applied directly to the above ground parts of the plant (shoot-foliage contact chemical), the physical pattern of application may be detected, i.e. spray droplet size, etc. If the toxic chemical is spray-applied, the pattern of spray droplets or areas where spray accumulated to runoff along the leaf edges will show the most severe damage. If it is a toxic gas (a volatile chemical acting as an aerial pollutant), the areas between the leaf veins and along the leaf margins where the concentration of water within the leaf is lower will be the first to show damage. Injury from foliar applications of insecticides, fungicides, and fertilizers is primarily of the direct-contact type and is typified by chlorotic-necrotic spotting, especially interveinally and along leaf edges and other areas where chemical concentrates and is least diluted by inter-cellular moisture. Examples of shoot-foliage contact chemicals are foliar-applied fertilizer salts and the herbicides paraquat, acifluorfen, dinoseb, and herbicidal oils.

Root Contact: Toxic contact chemicals in the root zone, including excess fertilizer, result in poor root development. Symptoms from root-contact chemicals are localized where the chemical contacts the root, but produce general symptoms in the shoot. The shoots may show water and nutrient stress symptoms, i.e. reduced growth, wilting, nutrient deficiency symptoms. The injury symptoms on the shoot and foliage from root damage by direct contact with toxic chemicals or excessive salts resembles a drying injury; the roots are unable to obtain water. Roots are injured and root tips may be killed. This will result in a general stunting of the plant. In severe cases, wilting can occur even though the soil is wet. Lower leaves generally wilt first and this is followed by a marginal drying of the leaves. Many factors injuring or inhibiting root growth may produce similar shoot symptoms. Nematodes, soil compaction, cold weather, salinity, nutritional disorders, and certain herbicides (dinitroanilines, DCPA, and diphenamid) cause root inhibition.

Symptoms of Deficient or Toxic Translocated Chemicals:

The effects of mobile chemicals absorbed by the plant are dependent upon whether the chemical is transported in the phloem or in the xylem. If transported solely in the xylem system, the chemical will move upward in the plant in the xylem-transpiration stream. Toxic symptoms from xylem-translocated chemicals occur primarily in the older foliage. Deficiency symptoms of xylem-transported (phloem-immobile) nutrient ions will occur first in the new growth.

If the chemical is translocated in the phloem, it may move multidirectional from the point of absorption, i.e. it may move from the shoot to the root or the reverse. Toxic symptoms from phloem-translocated chemicals occur primarily in the new growth and meristematic regions of the plant. Deficiency symptoms of phloem-retranslocated nutrient ions occur first in the older foliage.

Xylem translocated chemicals move primarily upward in the plant to the foliage. A chemical is translocated upward in the xylem (apoplastic movement) of the plant from the point of absorption. Symptoms occur in tissues formed after the toxicity or deficiency occurs.

Toxic Chemicals -xylem translocated: When toxic chemicals are translocated to fully expanded, older leaves, the toxicity symptoms generally appear on the leaf margins and interveinal areas. When toxic chemicals are translocated to immature, young leaves, the toxicity symptoms generally appear associated with the veins, especially the midrib.

Photosynthetic-inhibiting chemicals: Injury from translocated toxic chemicals is primarily to the foliage. Plant injury generally progresses from the lower, older foliage to the top. Individual leaves show greatest injury

(chlorosis) along their tips and margins or along the veins. Examples of xylem-translocated herbicides include the photosynthetic inhibitors such as the triazine, urea, and uracil herbicides.

Shoot-inhibiting chemicals: Examples of toxic chemicals absorbed by the roots and translocated in the xylem to the shoots are the "shoot inhibiting herbicides." The shoot inhibitors cause malformed and twisted tops with major injury at the tips and edges of the leaves; looping of the leaves may occur since the base of the leaf may continue to grow while the leaf tips remain twisted together. Thiocarbamate herbicides cause these symptoms on both grasses and broadleaves. Alachlor and metolachlor herbicides cause similar injury symptoms on grasses.

Deficient Nutrient Ions, xylem-translocated (phloem immobile): Several nutrient ions are immobile after upward translocation in the xylem and incorporation in plant tissue. They cannot be withdrawn when deficiencies develop in the root zone and retranslocated in the phloem to the new growth. Deficiency symptoms of phloem-immobile nutrient ions develop on the new growth. Boron and calcium are quite phloem-immobile which means that if the external supply becomes deficient, the symptoms of boron and calcium deficiency will appear first on the new growth. And, with severe deficiencies, the terminal bud dies. Iron, manganese, zinc, copper, and molybdenum are also relatively phloem-immobile and are not readily withdrawn from the older leaves for translocation through the phloem to younger leaves and organs. Deficiency symptoms are most pronounced on the new growth.

Phloem-translocated chemicals move multidirectionally from point of application or source of the chemical to the meristematic regions.

Toxic Chemicals - Phloem translocated: Injury from phloem-translocated toxic chemicals is primarily to new leaves and roots because of translocation of chemical to the meristems. Whether taken up by the roots or shoots, these compounds are moved through the living plant cells and phloem (symplastic movement) to both the root and shoot tips. The young tissue (shoots or roots) will be discolored or deformed and injury may persist for several sets of new leaves. Examples of phloem-translocated toxic chemicals, whether absorbed by the roots or shoots, include the herbicides 2,4-D, dicamba, picloram, glyphosate, amitrole, dalapon, sethoxydim, and fluazifopbutyl. These compounds move to the meristems and typically injure the youngest tissues of the plant.

Deficient Nutrient Ions - Phloem mobile: If phloem mobile nutrient ions become deficient in the root zone, these ions may be withdrawn from the older plant tissue and retranslocated in the phloem to the new growth. In such situations, deficiency symptoms will first occur on the older leaves. Elements that may be withdrawn from older leaves and retranslocated in the phloem to younger leaves and storage organs include nitrogen, phosphorus, potassium, magnesium, chlorine, and, in some plant species, sulfur. In plant species where sulfur can be withdrawn from the older leaves and translocated to the newer growth, deficiency symptoms may initially occur on the older leaves or over the plant in general. In plants where sulfur is not readily retranslocated, the older leaves may remain green and the sulfur deficiency symptoms occur only on the new growth.

Study Questions

25. Damage diminishing uniformly from one side to another is typical of: a) wind-drift; b) low lying areas; c) double application; d) runoff

26. Poor mixing or inadequate chemical agitation results in patterns of: a) irregular spots; b) stripes; c) increasing injury along one band; d) damage at ends of the field

27. Patterns of toxic chemical injury on individual plants depends on the three ways chemicals can cause damage, which do NOT include:
a) direct contact; b) phloem translocation;
c) xylem translocation ; d) hormone synthesis

28. Water and nutrient stress symptoms on the entire plant canopy indicate injury by: a) a spray-applied chemical shoot-foliage contact; b) toxic gas shoot-foliage contact; c) direct chemical root contact;
d) all toxic chemical contact

29. Toxic symptoms of _____ translocated chemicals occur primarily in the older foliage.

30. Deficiency symptoms of phloem-immobile nutrient ions develop in:
a) new growth; b) old growth; c) shoots; d) roots

Answers:
25 - a; 26 - c; 27 - d; 28 - c; 29 - xylem; 30 - a

Key to Symptoms of Chemical Disorders

I. Symptoms appearing first or most severely on new growth (root and shoot tips, new leaves,flowers, fruits, buds).

A. Terminal bud usually dies. Symptoms on new growth.

1. Basal part of young leaves and internal tissues of organs may become necrotic. One of the earliest symptoms is failure of the root tips to elongate normally. Terminal shoot meristems also die giving rise to a witch's broom. Young leaves become very thick, leathery, and chlorotic; in some species young leaves may be crinkled because of necrotic spots on leaf edge during development. Young leaves of terminal buds become light green then necrotic and stem finally dies back at terminal bud. Rust colored cracks and corking occur on young stems, petioles, and flower stalks. "Heart rot" of beets, "stem crack" of celery.

...Boron deficiency

2. Necrosis occurs at tip and margin of leaves causing a definite hook at leaf tip. Calcium is essential for the growth of shoot and root tips (meristems). The growing point dies. Margins of young leaves are scalloped and abnormally green and, due to inhibition of cell wall formation, the leaf tips may be "gelatinous" and stuck together inhibiting leaf unfolding. Stem structure is weak and peduncle collapse or shoot topple may occur. Roots are stunted. Premature shedding of fruit and buds is common. Downward curl of leaf tips (hooking) occurs near terminal bud. Ammonium or magnesium excess may induce a calcium deficiency in plants.

...Calcium deficiency

a. Differentiating between calcium and boron deficiency symptoms: when calcium is deficient, there is a characteristic hooking of the youngest leaf tips. However, when boron is deficient, the breakdown occurs at the bases of the youngest leaves. Death of the terminal growing points is the final result in both cases.

3. Tissue breakdown - necrosis and firing of the tip and margins of the leaf. The ammonium cation in itself may become phytotoxic and result in breakdown of the plant tissue (proteolysis breakdown of plant proteins) initially producing a wet, dark-green, "steamed" appearance at the leaf tips and margins. This destroyed tissue eventually desiccates and becomes a light tan color. Excess ammonium may also induce calcium deficiency (abnormally dark green foliage, scalloped leaf margins, weak stem structure, death of terminal bud or growing point of the plant, premature shedding of the blossoms and buds).

...Ammonium excess

B. Terminal bud remaining alive. Symptoms on new growth.

1. Interveinal chlorosis on young leaves.

a. Interveinal chlorosis on young leaves with larger veins only remaining green. Necrotic spots usually absent; however, with extreme deficiencies, young leaves are almost white and may have necrotic margins and tips; necrotic spots may extend inward. Potassium, zinc or copper excess can inhibit uptake of iron. High pH may also induce iron deficiency.

...Iron deficiency

i. Iron deficiency symptoms are similar to those of magnesium deficiency but iron deficiencies occur in young leaves first. Iron accumulated in older leaves is relatively immobile in the phloem.

b. Interveinal chlorosis with smallest veins remaining green producing a checkered or finely netted effect. Grey or tan necrotic spots usually develop in chlorotic areas; the dead spots of tissue may drop out of the leaf giving a ragged appearance. Poor bloom -both size and color. Potassium excess can inhibit uptake of manganese.

...Manganese deficiency

c. Stunted new growth with interveinal chlorosis: young leaves are very small ("little leaf"), sometimes missing leaf blades altogether, and internodes are short giving a rosette appearance.

...Zinc deficiency

2. Interveinal chlorosis is not the main symptom on new growth.

a. Wilting and loss of turgor of young, terminal leaves and stem tips is common. Symptoms are highly dependent upon plant species. In some species younger leaves may show interveinal chlorosis while tips and lobes of older leaves remain green followed by veinal chlorosis and rapid, extensive necrosis of leaf blade.

...Copper deficiency

i. There are no known reports of H_2PO_4 toxicity; however, plants may take up the phosphate anion in luxury amounts.

ii. Phosphorus excess is associated with impeded uptake and possible deficiency of copper and sometimes of zinc.

...Phosphorus excess

b. Leaves light green, veins lighter in color than adjoining interveinal areas. Leaves over entire plant may become yellowish green, roots and stems are small in diameter and are hard and woody. Young leaves may appear to be uniformly yellow. Some necrotic spots.

.....Sulfur deficiency

Key to Symptoms of Chemical Disorders

c. Shoot inhibition causing malformed and twisted tops with major injury at the tips and edges of the leaves.

.....Xylem- translocated "shoot-inhibiting chemicals"

i. Examples of toxic xylem-translocated chemicals include the thiocarbamate herbicides (symptoms on grasses and broadleaves) and alachlor and metolachlor (symptoms on grasses).

d. Young tissues discolored or deformed and injury may persist for several sets of new leaves.

...Xylem- translocated chemicals

i. Examples of toxic phloem-translocated chemicals include the herbicides 2,4-D, dicamba, picloram, glyphosate, amitrole, dalapon, sethoxydim, and fluazifopbutyl.

II. Symptoms do not appear first or most severely on youngest leaves: effect general on whole plant or localized on older, lower leaves.

A. Chlorosis general, no interveinal chlorosis. Effects usually general on whole plant.

1. Visible symptoms include yellowing and dying of older leaves. Foliage light green, growth stunted, stems slender, yellow.

...Nitrogen deficiency

a. Plants receiving enough nitrogen to attain limited growth exhibit deficiency symptoms consisting of a general chlorosis, especially in older leaves. In severe cases, these leaves become completely yellow and then light tan as they die. They frequently fall off the plant in the yellow or tan stage.

2. Older leaves wilt. Entire leaf is affected by chlorosis, but edges and leaf tissues near main veins often retain more color (chlorophyll).

...Zinc excess

B. Vein-clearing, chlorosis-necrosis at leaf tips and margins on older-younger foliage.

...Xylem- transported photosynthetic- inhibitors

1. When toxic chemicals are xylem-translocated to older, fully-expanded leaves, the toxicity symptoms generally occur on the margins and interveinal areas of the leaf. When translocated to young, expanding leaves, toxicity symptoms are generally associated with the veins, especially the midrib.

2. Examples of xylem-translocated, photosynthetic inhibitors include the triazine, urea, and uracil herbicides.

C. Interveinal chlorosis. Interveinal chlorosis first appears on oldest leaves.

1. Older leaves chlorotic, usually necrotic in late stages. Chlorosis along leaf margins extending between veins produces a "Christmas tree" pattern. Veins normal green. Leaf margins may curl downward or upward with puckering effect. Necrosis may suddenly occur between veins. Potassium or calcium excess can inhibit uptake of magnesium.

...Magnesium deficiency

a. When the external magnesium supply is deficient, interveinal chlorosis of the older leaves is the first symptom because as the magnesium of the chlorophyll is remobilized, the mesophyll cells next to the vascular bundles retain chlorophyll for longer periods than do the parenchyma cells between them. Leaves lose green color at tips and between veins followed by chlorosis or development of brilliant colors, starting with lower leaves and proceeding upwards. The chlorosis/brilliant colors (unmasking of other leaf pigments due to the lack of chlorophyll) may start at the leaf margins or tips and progress inward interveinally producing a "Christmas tree" pattern. Leaves are abnormally thin, plants are brittle, and branches have a tendency to curve upward. Twigs are weak, subject to fungus infection, usually leaves drop prematurely; plant may die the following spring.

2. Smaller veins in older leaves may turn brown. Small necrotic spots in older leaves spread margins inwards, and finally desiccate the entire leaf blade. At severe, advanced stages, young leaves also display this spotting.

...Manganese excess

3. Chlorotic areas (pale yellow) on whole plant; leaf edges curl upwards.

...Molybdenum deficiency

a. General symptoms are similar to those of nitrogen deficiency. Interveinal chlorosis occurring first on the older or midstem leaves, then progressing to the youngest. Sometimes, as in the "whiptail" disease, plants grown on ammonium nitrogen may not become chlorotic, but develop severely twisted young leaves which eventually die. Other characteristic molybdenum deficiency symptoms include marginal scorching and rolling or cupping of leaves. With molybdenum deficiency, nitrogen deficiency symptoms may develop in the presence of adequate levels of nitrate nitrogen in the root environment and high levels of nitrate nitrogen in the plant. Nitrate nitrogen must be reduced in the plant before it can be utilized. Molybdenum is required for this reduction, and if it is deficient, nitrate may accumulate to a high level in the plant, yet at the same time the plant may exhibit nitrogen deficiency symptoms. Molybdenum differs from other trace nutrients in that many plants can develop in its absence provided that ammonium nitrogen is present. Molybdenum appears to be essential for the nitrate-reducing enzyme to function.

Key to Symptoms of Chemical Disorders

4. Foliar marginal necrosis is the most common symptom of fluoride toxicity along with chlorosis. Chlorosis along and between the veins occurs in fluorine-sensitive plants. With many plants, the marginal necrosis is preceded by the appearance of gray or light-green, water-soaked lesions which later turn tan or reddish-brown. Injury generally occurs at the tips of the leaves first, then moves inward and downward until a large part of the leaf is affected.

...Fluoride excess

D. Leaf chlorosis is not the dominant symptom. Symptoms appear on older leaves at the base of the plant.

1. Plant dark green.

a. At first, all leaves are dark green and growth is stunted. Purple pigment often develops in older leaves, particularly on the underside of the leaf along the veins. Leaves drop early.

...Phosphorus deficiency

i. Phosphorus deficiency is not readily identified by visual symptoms alone. Visual symptoms of phosphorus deficiency are not always definite, but many phosphorus deficient plants exhibit off-color green foliage with purple venation, especially on the underside of leaves, and plants are stunted and remain stunted even when fertilizers supplying potassium and nitrogen are applied. Older leaves assume a purple-bronze color. Small growth, especially root development; spindly growth with tips of older leaves often dead. Phosphorus is phloem retranslocated from older leaves to new growth.

ii. Aluminum appears to affect root growth in particular: root tips blacken, no longer lengthen, but become thickened. Excess aluminum accumulation in roots reduces their capacity for translocating phosphorus. Amelioration involves suppression of aluminum activity, for example by liming to bring the medium's pH above 5.5, And not by addition of phosphorus. The toxic amount of aluminum in a soil will depend upon other soil properties such as pH and phosphorus content and upon the plant grown. Media amendments such as perlite may release toxic quantities of aluminum if the media pH is extremely acid.

...Aluminum excess

b. Leaves are thick , brittle, and deep green. In acute toxicity, older leaves wilt and scorch from the margins inward.

...Nitrate excess

2. Necrotic spots develop on older leaves.

a. Margins of older leaves become chlorotic and then burn, or small, chlorotic spots progressing to necrosis appear scattered on old leaf blades. Calcium excess impedes uptake of potassium cations.

...Potassium deficiency

i. Potassium deficiency symptoms first appear on the recently matured leaves of the plant (not on the young, immature leaves at the growing point). In some plants, the first sign of potassium deficiency is a white specking or freckling of the leaf blades. With time, the symptoms become more pronounced on the older leaves, and they become mottled or yellowish between the veins and scorched at the margins. These progress inward until the entire leaf blade is scorched. If sodium cations are present and taken up in place of k+, leaf flecking (necrotic spots scattered on leaf surface) and reduced growth occur. Seed or fruit is shriveled. Potassium is phloem retranslocated from old leaves to new growth.

b. Tips and edges of leaves exhibit necrotic spots coalescing into a marginal scorch. Symptom from the plant's base upwards with older leaves being affected first. In advanced, severe toxicity, necrotic spots with a pale brown center also appear in the inner parts of the leaf blade.

...Boron excess

c. Mottling and necrotic spots primarily on margin and interveinally may be due to excessive amounts of fertilizers or pesticides applied as foliar sprays.

...Direct- contact of toxic chemical with shoot & foliage

i. Examples of shoot direct-contact toxic chemicals include the shoot-foliage applied herbicides paraquat, acifluofen, dinoseb, and the herbicidal oils which produce this type of symptom.

3. Reduced growth and wilting of older leaves with development of chlorotic and necrotic spots. Roots become stunted in length and thickened, or club-shaped, near the tips: the shoots remain normal but may show nutrient and moisture stress. Under severe conditions, root tips may be killed causing general stunting of the plant and wilting followed by marginal drying of the lower leaves first.

...Direct-contact injury by toxic chemicals
or other factors in the root zone, i.e., low temperatures, nematodes, root weevils.

i. Examples of root direct-contact toxic chemicals include excess salts or presence of toxic chemical such as the herbicides dcpa, dinitroanilines, diphenamid.

a. Leaves often eventually become bronze colored.

...Chloride deficiency

Key to Symptoms of Chemical Disorders

4. Marginal scorching that may progress to general leaf scorching. Generally no spotting.

...Excess salt or sodium excess

5. Intense yellow or purple color in leaves. Molybdenum excess or toxicity in field grown plants is rarely observed. Plants appear to tolerate relatively high tissue concentrations of molybdenum. Isolated reports of symptoms from excess molybdenum include development of intense yellow color in tomato leaves and intense purple color in cauliflower leaves.

...Molybdenum excess

Table 3. Summary: Systematic Approach to Diagnosing Plant Damage

I. Define the problem (determine a "real" problem exists):

- A. Identify plant and know characteristics. Establish what the "normal" plant would look like at this time of year. Describe the "abnormality": symptoms & signs.
- B. Examine the entire plant and its community. Determine the primary problem and part of the plant where initial damage occurred.

II. Look for patterns: on more than one plant? On more than one plant species?

- A. Understand nonuniform damage pattern (scattered damage on one or only a few plant species) is indicative of living factors (pathogens, insects, etc.).
- B. Understand uniform damage pattern over a large area (i.e., damage pattern on several plant species) and uniform pattern on the individual plant and plant parts indicates nonliving factors (mechanical, physical, or chemical factors).
- C. Compare patterns of living and nonliving factors on plant community, plant, plant part.

III. Delineate time-development of damage pattern.

- A. Progressive spread of the damage on a plant onto other plants or over an area with time indicates damage caused by living organisms.
- B. Damage occurs, does not spread to other plants or parts of the affected plant. Clear line of demarcation between damaged and undamaged tissues. These clues indicate nonliving damaging factors.

IV. Determine causes of the plant damage. Ask questions and gather information.

- A. Distinguish among living factors.
  - 1. Symptoms and signs of pathogens.
  - 2. Symptoms and signs of insects, mites, and other animals.
- B. Distinguish among nonliving factors.
  - 1. Mechanical factors.
  - 2. Physical factors.
    - a. Temperature extremes.
    - b. Light extremes.
    - c. Oxygen and moisture extremes.
  - 3. Chemical factors.
    - a. Analyze damage patterns in fields and other plantings.
    - b. Injury patterns on individual plants.
    - c. Pesticide-pollutant phytotoxicities - damage, patterns.
    - d. Nutritional disorders-key to nutritional disorders.
- C. References (check reports of damaging factors on identified plant); may need laboratory analyses to narrow range of probable causes.

V. Synthesis of information to determine probable causes.

References, Laboratory Analysis

If you have identified the plant and have narrowed the probable cause down through the various categories, (i.e., distinguished between living and nonliving - then if living, distinguished between pathogens and animal factors - then if pathogen, distinguished between fungal and bacterial organisms), you will probably need assistance in identifying the specific responsible organism or nonliving factor. But, by now you know what specialist to contact (plant pathologist, entomologist, physiologist etc.) And what specific reference book would provide further assistance in narrowing down the search for the specific factor causing the observed plant damage. Laboratory analyses and examination may be required to further narrow the range of probable causes.

Synthesis of Information to Determine Causes

The detective work to find the "signs" (residues of the living, damaging organism or nonliving factor, records, etc.) is time consuming and methodical. But, without this process of elimination and synthesis, the probability of making a correct diagnosis is low.

Study Questions

31. "Heart rot" of beets and "stem crack" of celery are caused by _____ deficiency.

32. Poor bloom from manganese deficiency can be a result of: a) nitrogen deficiency; b) potassium excess; c) copper excess; d) sulfur deficiency

33. General chlorosis of an entire plant with yellowing and dying of older leaves is due to:
    a) nitrogen deficiency; b) nitrogen excess;
    c) potassium deficiency; d) sulfur excess

34. A "Christmas-tree" pattern of bright colors on a leaf indicates: a) magnesium deficiency, b) potassium excess; c) calcium excess; d) any/all of the above

35. Leaves that are brittle, thick, and dark green result from a nitrate _____.

36. In order to find more information about treatment for an abnormal, non-uniform, progressive plant damage with symptoms of leaf curling and puckering, contact:
    a) a physiologist; b) an entomologist; c) a plant pathologist; d) an optometrist

Answers:
31 - Boron; 32 - b; 33 -a; 34 - d; 35 - excess; 36 - b

Diagnostic Key to Urban Plant Problems

Much of the information for the key was taken directly from the second edition of *The Ortho Problem Solver*. Other resources used were *Diseases of Vegetables*, published by Penn State, the compendium series published by the American Phytopathological Society, Wescott's *Plant Disease Handbook*, *The Gardener's Bug Book*, and *Insects That Feed on Trees and Shrubs*, in addition to the personal experience of the authors who are plant disease and insect diagnosticians at Virginia Tech. If you have the resources listed above at your disposal, they should be consulted for more detail on particular problems.

The key is modeled after *The Ortho Problem Solver*. Each plant category has a general section for problems common to many plants in that category and a specific section for problems characteristic of certain plants. Be sure to check both the section on general problems and the section specific to the plant in question each time you make a diagnosis. If the symptom is not in the specific category, it may be in the general section.

Introduction

The list should help you, as a Master Gardener, to ask the right questions to determine the cause of the problem or, at least, to narrow down the possibilities. For example, since both dry weather and excess fertilizer can cause marginal leaf burn, you would want to ask the grower about recent rainfall in the area and fertilizer application. Or, since wilt can result from both dry and waterlogged soil, you would want to ask about rainfall and how well the soil drains. In many cases you will not be able to determine what caused the problem, but if you can narrow down the possibilities and mention these when you send the sample to a diagnostic laboratory, you will save the diagnostician a lot of time.

Control Recommendations

The control recommendations listed in the key are abbreviated for the sake of saving space. A more complete explanation of each control is provided in the following paragraphs. You will notice that many of the cultural controls, such as rotation, removing old plant debris, and planting in well-drained soil, are repeated many times throughout the key. These are good general practices and it can never hurt to recommend them. When registered pesticides are recommended, please consult the most current version of the Home Grounds and Animals Pest Management Guide (PMG), found at https://pubs.ext.vt.edu/456/456-018/456-018.html Note that all pesticide recommendations must come from the PMG. Recommendations for other states may be different than those listed for Virginia. Use of resistant varieties is only recommended for problems for which resistance has been developed.

Rotation

Plant a crop in a different area for 2 to 3 years, unless longer time periods are stated. This practice helps reduce the amount of inoculum of pathogens and insects that survive in the soil or on plant debris. It is best to grow plants of a completely different family in the area from which plants are removed or rotated, since some diseases affect different species of the same family (e.g., late blight of tomato and potato).

Remove Plant Debris

Remove diseased or insect infested plant debris at the end of the season and destroy either by burning or burying. Composting old, diseased plant debris should kill any surviving pathogens; however, if the compost is not turned properly, inoculum may build up. Burying old plant debris deeply works for some foliar and fruit pathogens that do not survive in the soil, but burning is best for stem and root pathogens, if burning is allowed in your area.

Remove Affected Plants

It is important to remove diseased plants right away to prevent the spread of a disease to unaffected plants. This is often recommended for viral diseases.

Use Registered Pesticides

Use a pesticide (either fungicide, bactericide, insecticide, or herbicide) according to the label. The name of the plant to be treated must be on the label for legal use. Be sure to pay attention to how soon fruits or vegetables can be safely eaten after they have been sprayed. Remember that most fungicides act as a physical barrier to infection and must be applied on a regular basis to be effective. They should be applied more often during rainy periods both because rain washes the chemical off and because

pathogens are more active during rainy weather.

Resistant varieties are ones that have been bred for resistance to certain diseases. A resistant variety is not resistant to all diseases, but only to those for which it has been developed. Also, one must understand that a variety sold as "resistant" is not immune, and can, under certain circumstances, become infected with the pathogen to which it is resistant.

Tolerant varieties are ones that yield or grow relatively well in spite of infection. Consult Extension publications for information on which varieties are resistant to which diseases. Resistant varieties have not been developed for every disease.

Pruning

Cut out affected plant parts. This is used as a control measure for cankers or galls on trees. Pruning tools should be disinfected between cuts. Products such as 'Lysol', (diluted to 1 part per 10 parts water, or undiluted), 'Listerine', (full strength), and rubbing alcohol (at least 70% concentration), are good disinfectants. Do not use 'Pine Sol' or chlorine bleach, as these are highly corrosive to tools. Cuts should be made back to live tissue. Pruned branches should be buried or burned, if burning is allowed in your area.

Soil Fumigation

Apply a registered fumigant or soil sterilant (soil drench) to the soil before replanting. The chemical acts as a biocide and will kill nematodes, fungi, and bacteria. Of course, it can kill beneficial microorganisms as well as pathogens, and should only be used if rotation or other cultural practices are not effective in controlling the disease. Few soil fumigants are available for use by homeowners. Soil fumigants can only be used as a preplant treatment. Professional applicators may be hired to apply soil fumigants.

Soil Test

Submit a soil sample for analysis. Most soil analysis laboratories will test for pH, potassium, phosphorous, calcium, and magnesium. Unfortunately, there is no accurate soil test for available nitrogen. Soluble salts and tests for minor elements, such as zinc and manganese, must usually be requested as special tests. Remember that nutrient unavailability is often caused by improper pH (soil acidity) and not actually a low level of nutrients in the soil. Apply lime or sulfur and fertilizer as recommended.

Weed Control

Weed control is important for controlling virus diseases. Weeds can be asymptomatic carriers of certain viruses and the viruses can be spread by insects from weeds to garden plants. Weeds can be controlled by hand pulling, cultivating, mulching, or by registered herbicides. For home gardens, mulching is the best method, with hand pulling for the few that will grow.

Insect Control

Insect control can also be important for controlling some plant diseases. Viruses, viroids (virus-like particles), mycoplasmas, bacteria, and even fungi can be spread by insects.

Mulching

Mulching is a good control for diseases that are brought on by lack of adequate moisture in the soil or for diseases brought on by plant contact with the soil. Mulch keeps moisture in the soil and prevents leaves and fruits from being in direct contact with soil pathogens; however, improper application of mulch can damage trees and shrubs. It should not be placed directly against the bark of the trunk as this can lead to decay. Mulch should be placed in a doughnut-shaped ring around the plant, not contacting the trunk or main stem, and should not be more than 2-3 inches deep.

Submit a Sample For Laboratory Diagnosis

The disease is difficult to diagnose from symptoms or information alone and more sophisticated techniques, such as microscopy or culturing, are necessary to diagnose the problem. The diagnostician will provide a diagnosis and control recommendation to the Extension agent whenever possible. The agent must then relay, interpret, or modify the results as necessary. A "Plant Disease Diagnostic Form" **must accompany each sample.** The accurate diagnosis of plant disease depends upon receiving a fresh sample. All specimens should be fresh when collected and shipped immediately. If the sample is in good condition, the disease will be diagnosed and acknowledged within a few days. If specimens arrive unidentified, wilted, crushed, or in advanced stages of decay, accurate diagnosis is usually impossible. When

submitting specimens, follow these guidelines (also found on the back of the Virginia Tech "Plant Disease Diagnostic Form" available through your Extension agent):

Collecting Specimens-- Where possible, collect the whole diseased plant, including roots and at least one pint of moist soil. Dig (don't pull) plants with a shovel or trowel. Collect more than one plant if various stages of decline are evident. Dead or dry plant material is of no value to the diagnostician. When possible, include healthy plants or plant parts for comparison.

Packaging Plant Specimens-- Immediately after digging small plants, place the moist root ball in a plastic bag and tie the top around the stem just above the soil line. This will prevent the soil from drying during transit. Enclose the tops of the plants in a ventilated plastic bag. Do not wet the tops before packaging. When distinct spots on the leaves are the only symptoms, include several twigs with leaves still attached wrapped between dry strips of cardboard or a thin magazine. Do not wrap leaves in wet paper towels. However, enclose a crumpled wet paper towel in the plastic bag. Do not pack your diagnostic form in contact with soil. Specimens should be packed in a sturdy container to prevent damage in transit. Avoid exposure to high temperatures. Whenever possible, avoid weekend lay-overs in the post office.

A final note on the control recommendations is that not all the controls listed need be used to control a given disease. You should recommend all possible controls; then the gardener can decide which ones he or she would like to use. For example, both fungicides and resistant varieties may be listed in the key for one particular disease; however, if resistant varieties are used, fungicides should not be necessary. You may want to suggest a fungicide treatment for the current season and resistant varieties for the following season.

You will certainly learn from working with plant problem diagnosis that experience is the best teacher. The key should be of use to you as you are gaining experience.

Study Questions

37. _____ involves planting a crop in a different area every few years.

38. _____ varieties are ones that yield or grow relatively well in spite of infection.

39. Soil fumigants can only be applied:
a) before planting; b) during plant dormancy; c) during bloom; d) in June

40. Mulch can cause damage to plants by:
a) drying out soil; b) preventing leaves and fruit from contacting soil; c) causing decay if piled to closely to the trunk; d) all of the above

41. When submitting specimens for laboratory diagnosis, try to: a) remove all soil; b) dry out plant material before sending c) include healthy plants for comparison; d) thoroughly moisten the plant before placing it in an airtight bag

Answers:
37 - rotation; 38 - tolerant; 39 - a; 40 - c; 41 - c

Diagnostic Key

Vegetables

Symptoms	Possible Causes	Controls & Comments
All Vegetables		
Poor fruit yield; fruit may be small and have poor taste	Uneven moisture	Supply water during dry periods
	Poor soil fertility	Soil test
Plants grow slowly; leaves light green	Insufficient light	Thin plants; do not plant in shade
	Cool weather	
	Poor soil fertility	Soil test
	Improper soil pH	Soil test
	Excess water	Do not overwater; improve drainage
	Seed corn maggot	Replant with insecticidal seed treatment
	Insufficient water	Supply water
Seedlings don't emerge	Dry soil	Supply water
	Seeds washed away	
	Damping-off (fungal problem)	Do not overwater; treat seed with registered fungicide
	Incorrect planting depth	
	Slow germination due to cool weather	Plant when ground is warm
	Root maggots	Use registered soil insecticide
Wilted seedlings; seedlings fall over	Dry soil	Supply water
	Damping off (fungal diseases)	Do not overwater; treat seed with registered fungicide
	Cutworms	Use registered soil insecticide; collars
	Root maggots	Use registered soil insecticide
Chewed seedlings	Rodents, rabbits, or birds	Fence or netting
	Slugs	Use slug bait (beer or commercial slug bait)
	Various insects	Use registered insecticide
Wilted plants; bottom leaves may turn yellow	Dry soil	Water
	Root rot (fungal disease)	Do not overwater; remove old plant debris; rotate
	Vascular wilt (fungal disease: mainly affecting tomato, potato, eggplant, pepper)	Use resistant varieties; rotate
	Root knot (nematode problem)	Use resistant varieties; rotate; soil fumigation
	Various root-feeding nematodes	Submit soil sample for nematode analysis; soil fumigation
	Walnut wilt (mainly affecting tomato)	Do not plant near walnut or butternut trees; sever tree roots bordering garden and place barrier between tree and garden
	Waterlogged soil	Improve drainage
	Insects with sucking mouth parts such as aphids and true bugs	Insecticide
General leaf yellowing; no wilting	Nutrient or mineral deficiency	Soil test
	Insufficient light	Thin plants

Diagnostic Key: Vegetables

Symptoms	Possible Causes	Controls & Comments
Leaves stippled with tiny white spots	Spider mites	Treat with registered miticide
	Air pollution (ozone)	
	Leaf hoppers, thrips, or aphids	Insecticide
Leaf margins turn brown and shrivel	Dry soil	Supply water
	Salt damage	Do not place garden where de-icing salt may have been applied on nearby concrete
	Fertilizer burn	Soil test for soluble salts level; do not over-apply fertilizer; flush soil with water
	Potassium deficiency	Soil test
	Cold injury	
	Thrips or mites	Insecticide or miticide
Discrete brown spots on leaves; some spots may coalesce	Fungal or bacterial leaf spot disease	See controls under specific disease in PMG; submit sample for laboratory diagnosis if necessary
	Chemical injury	Do not apply chemicals that are not registered for use on the plant; apply chemicals at registered rates; some chemical injury occurs from drift
	Plant bugs	Insecticide
White powdery growth on upper leaf surfaces	Powdery mildew (fungal disease)	Use registered fungicide
Leaves shredded or stripped from plant	Hail damage	
	Rodents	Place fence around garden
	Slugs	Use slug bait
	Dead tissue dropping out	Use registered fungicide before problem fungal infection reaches this stage
	Various insects	Identify insect then use appropriate control (see PMG)
Leaves with yellow and green mosaic or mottle pattern; leaves may be puckered and plant stunted	Viral disease	Use resistant varieties if available; weed control; remove affected plants; remove old plant debris; insect control
Leaves curled, puckered, or distorted	Herbicide injury (common on tomato, cucumber)	If lawn herbicides are used, apply after wind has died down and do not apply in heat of day
	Viral disease	Same controls as above
	Aphids, leaf hoppers, or thrips (insects)	Treat undersides of leaves with registered insecticide
Asparagus		
Tops turn yellow, brown, and die back; reddish-brown, orange or black pustules appear on stems and leaves	Rust	Cut tops close to ground in fall and destroy cuttings; use registered fungicide; use resistant varieties
Shoot wilt, turn yellow, then brown; roots are reddish color	Fusarium wilt (fungal disease)	Destroy infected plants; rotate for 2-4 years; soil fumigation
	Root rot (fungal disease)	Rotate; remove old plant debris; plant in well-drained area

Symptoms	Possible Causes	Controls & Comments
Small spears	Immature plants	Asparagus produces small spears for the first 2-3 years after planting
	Overharvested plants	Do not harvest late into the season; plants cannot store enough food for following season
	Poor fertility	Soil test
	Poor drainage	Do not overwater; plant in well-drained area
Spears crooked	Mechanical injury from windblown sand or mishandling	
	Insect injury	Control asparagus beetles with registered insecticide
Spears turn brown and soft	Frost injury	Protect spears with mulch on nights when cold temperatures are expected
	Root rot (fungal disease)	Remove old plant debris; rotate; plant in well-drained area
Leaves chewed; slime may be present on leaves; no evidence of insects	Slugs (emerge at night and hide during the day)	Sue slug bait
Spears and leaves chewed or scarred	Asparagus beetles	Use registered insecticide
Beans		
Plants wilted or are stunted; leaves may turn yellow	Dry soil	Supply water
	Root rot (fungal disease)	Remove old plant debris; rotate; plant in well-drained area
	Root knot (nematode problem)	Rotate; soil fumigation
	Poor fertility	Soil test
	Root maggots	Use registered insecticide
Failure to set pods	High temperatures; causing blossoms to drop	
	Dry soil	Supply water
	Wet soil; causing lack of oxygen to roots	Do not overwater; plant in well-drained soil
	Mature pods left on vines, causing seed production rather than pod set	Pick pods regularly
Rust-colored powdery spots surrounded by yellow haloes form on leaves, stems, and pods	Rust (fungal disease)	Use resistant varieties; use registered fungicide; remove old plant debris
Soft, watery spots on leaves, stems, and pods; white moldy growth on these plant parts; plants wilt and die	White mold (fungal disease)	Use registered fungicide; rotate; remove old plant debris
Thin, white powdery growth on leaves and pods	Powdery mildew (fungal disease)	Use resistant varieties; use registered fungicide; rotate; remove old plant debris
Small, brown spots surrounded by yellow haloes on leaves; leaves wither	Bacterial blight	Avoid overhead watering which spreads the disease; use fixed copper bactericide if available; rotate
Brown spots without yellow haloes appear on leaves, pods and seeds; leave wither	Fungal disease (any of several)	Submit sample for laboratory diagnosis
	Stink bugs	Use registered insecticide
Leaves skeletonized; copper colored beetles with black spots or yellow grubs present	Mexican bean beetle	Hand pick beetles and grubs or use registered insecticide
Leaves with shiny white flecks	Spider mites	Use registered miticide
Young leaves curled, distorted, and yellow; clusters of tiny insects on leaves and stems	Aphids	Use registered insecticide

Diagnostic Key: Vegetables

Symptoms	Possible Causes	Controls & Comments
Beets		
Small, circular spots with light centers and dark borders on leaves	Cercospora leaf spot (fungal disease)	Pick off and destroy affected leaves, fungicides are not warranted
Roots cracked; black areas on surface and inside root; plants stunted	Boron deficiency	Soil test; maintain pH between 6 and 7; apply solution of household borax if necessary (1 T household borax per 12 gal water per 100 ft row)
Leaf margins rolled upward; leaves brittle and puckered along veins; plants stunted	Viral disease	Control leafhoppers that spread the disease; weed control
Misshapen roots	Overcrowding	Thin beets early
	Lumpy soil	
Leaves with many small holes	Flea beetles	Treat early with registered insecticide
Irregular, tan blotches on leaves	Leafminer (insect)	Use registered insecticide; root is still edible
Root scarred or tunneled	Carrot weevil, carrot rustfly, or wireworms	Destroy infected plants; next year work in a soil insecticide at planting

Study Questions

42. A possible cause of wilted vegetable seedlings would NOT be: a) dry soil; b) damping off; c) root maggots; d) spider mites

43. Controls for root rot (fungal disease) do NOT include: a) rotation; b) removing plant debris; c) a thorough watering; d) avoiding overwatering

44. White, powdery growth on the upper surfaces of leaves is a sign of: a) spider mites; b) powdery mildew; c) slugs; d) any/all of the above

45. Small asparagus spears are NOT caused by: a) a virus; b) overharvested plants; c) poor fertility; d) poor drainage

46. The cause of curled, distorted, yellow leaves with clusters of tiny insects on leaves and stems is _____.

47. A virus of beets that causes rolled leaf margins, brittle leaves, and puckered veins is spread by _____.

Answers:
42 - d; 43 - c; 44 - b; 45 - a; 46 - aphids; 47 - leafhoppers

Symptoms	Possible Causes	Controls & Comments
Carrots		
Brown spots on leaves; spots may appear on carrots also	Fungal or bacterial disease (any of several)	Submit a sample for laboratory diagnosis
Inner leaves yellowed, outer leaves reddish purple; roots stunted and bitter	Aster yellows (mycoplasma disease)	Remove affects plants; weed control; leafhopper control with registered insecticide
Root tops green	Root tops exposed to sunlight	Cover exposed roots with soil or mulch
Roots misshapen	Overcrowding	Thin carrots early
	Lumpy soil	
	Root knot (nematode problem)	Submit soil sample for nematode analysis; rotate; soil fumigation if necessary
Plants stunted and yellowed; roots misshapen; small knots on fibrous roots	Root knot (nematode problem)	Submit soil sample for nematode analysis; rotate; soil fumigation if necessary
Tiny holes on leaves	Flea beetles	Use registered insecticide
Light brown blotches or tunnels in leaves	Leafminer	Use registered insecticide

Symptoms	Possible Causes	Controls & Comments
Celery		
Stalks tough and bitter	High temperatures	
	Dry soil	Celery requires high moisture
	Poor fertility	Soil test
	Overmaturity	Harvest when tender
Plants stunted and yellowed; stalks twisted and brittle	Aster yellows (mycoplasma disease)	See control under carrots
Plants wilted; soft, watery rot on leaves and stalks; heart of plant may be black	Fungal or bacterial crown rot	No adequate controls; rotate and remove old plant debris
	Black heart (due to calcium deficiency)	Calcium deficiency results from uneven water supply or improper pH; water during dry periods; soil test; maintain soil pH between 6.5 and 8
Brown or gray spots on leaves and stalks	Fungal or bacterial leaf spot	Submit sample for laboratory diagnosis
Cole Crops (Broccoli, Brussels Sprouts, Cabbage, Cauliflower, Turnip)		
Cracking of cabbage heads	Excess water taken up by the plant causes head to burst	Harvest heads as soon as mature
Poor heading	Overcrowding	Thin plants early
	Dry soil	Supply water
	High temperatures	
	Poor fertility	Soil test
	Root knot (nematode problem)	Check roots for knots; rotate; soil fumigation
	Clubroot (fungal disease)	Check roots for large swellings (larger than root knots); rotate cole crops out of affected area for 7 years
	Root rot (fungal disease)	Rotate; remove old plant debris; plant in well-drained soil
Discolored cauliflower heads	Exposure to sun	Tie leaves over head when heads form
Brown spots on leaves	Fungal or bacterial disease (any of several)	Submit sample for laboratory diagnosis
Plants wilt and turn yellow; roots have large swellings (not to be confuse with smaller root knots)	Clubroot (fungal disease)	7-year rotation
Plants wilt and turn yellow; roots are discolored and poorly developed; roots may be hard and brittle	Blackleg (fungal disease)	Use western-grown hot-water-treated seed; rotate; remove old plant debris
	Cabbage maggot	Work in a registered soil insecticide at planting time
Plants stunted and yellowed (esp. cabbage), roots not discolored	Dry soil	Supply water
	Poor fertility	Soil test
	Fusarium yellows (fungal disease)	Use resistant varieties; rotate
	Cabbage maggot	Work in a registered soil insecticide at planting time
Heads soft and rotted	Soft rot of broccoli (bacterial water disease)	Grow broccoli varieties that shed (conical head)
	Bottom rot of cabbage (fungal disease)	Rotate; plant in well-drained soil
Rough, brown, raised areas on undersurface of leaves	Oedema, physical problem due to uneven water supply	Water during dry periods
Leaves riddled with shotholes	Flea beetles	Use registered insecticide
Leaves chewed	Imported cabbage worm, cabbage looper, diamondback moth, cross-striped cabbage worm, or flea beetle	Identify insect; use registered insecticide

Diagnostic Key: Vegetables

Symptoms	Possible Causes	Controls & Comments
Some leaves curled yellowed; clusters of small gray or green insects	Aphids	Use registered insecticide
Corn		
Ears not completely filled with kernels	Poor pollination	Plant in blocks of at least 3-4 short rows instead of 1 long row; hand pollinate
	Birds	Put paper bag over ear after pollination
	Western corn rootworm	Rotate crops
White smooth or black powdery galls on stalk, leaves, ears, or tassels	Smut (fungal disease)	Cut off galls before they turn black; remove old plant debris; use tolerant varieties
Brown lesions on stalks near joints; stalks rotted inside; kernels pink or brown and moldy	Fungal stalk and ear rot (any of several)	No adequate controls; remove old plant debris
Plants wilted and stunted; long, irregular brown streaks on leaves; brown cavities in stalks near soil line	Bacterial wilt	Control flea beetles and cucumber beetles; remove affected plants; use tolerant varieties
Yellowish or tan elliptical spots on lower leaves first and older leaves later	Fungal leaf spot (any of several)	Submit sample for laboratory diagnosis
Plants stunted with yellow and green stripe or mosaic pattern, older leaves pale yellow	Maize dwarf mosaic (viral disease)	Weed control; esp. Johnsongrass; aphid control; destroy affected plants; do not handle healthy plants after handling affected ones
Small pustules containing rust colored powdery substance on leaves	Rust (fungal disease)	Use resistant varieties; remove old plant debris
Plants fall down after rain	Western corn rootworm	Plant root crops next year
Numerous tiny brown spots on leaves	Fungal leaf spot (any of several)	Submit sample for laboratory diagnosis
Leaves reddish on margins	Phosphorus deficiency	Soil test
	Viral disease	Weed control before corn emerges; aphid control; remove affected plants
Distorted leaf or stalk: leaves may fail to unfurl or stalk may be bent	Herbicide injury	
Caterpillar feeding on the tip of the ear	Corn earworm	Apply registered insecticide during silking to prevent infestation
Young plants chewed off at ground level	Cutworms	Use registered insecticide
Cucurbits (Cantaloupe, Cucumber, Pumpkin, Squash, Watermelon)		
No fruit produced	Poor pollination	Be patient; male and female flowers are not produced at the same time at first; bee activity may be low due to cool weather or use of insecticides; spray insecticides in late afternoon when pollinators are not active
Misshapen or bitter fruit	Poor pollination	See above for no fruit produced
	Dry soil	Supply water
	Poor soil fertility	Soil test
Watersoaked, sunken, brown or black spot at blossom end of fruit only	Calcium deficiency usually caused by uneven soil moisture and poor supply of calcium to fruit during early development	Water during dry periods; calcium foliar spray
Watersoaked, sunken, brown or black spot on fruit not restricted to blossom end	Fungal or bacterial fruit rot	Submit sample for laboratory diagnosis

Symptoms	Possible Causes	Controls & Comments
Wilted plants	Dry soil	Supply water
	Bacterial wilt	Control cucumber beetles
	Root rot (fungal disease)	Improve drainage; rotate; remove old plant debris
	Fusarium wilt (fungal disease)	Use tolerant varieties if available; rotate
	Root knot (nematode problem)	Soil fumigation; rotate
	Squash vine borer	Destroy vine or use insecticide
Wilted plants; if a cut stem piece is propped up in a glass of water so that the cut end remains suspended in the water (not touching bottom), a white, milky substance streams out within 15 minutes (make sure what you see is not debris or soil)	Bacterial wilt	Control cucumber beetles; remove affected plants
Circular or irregular brown spots on leaves and/or fruit	Fungal or bacterial disease (any of several)	Submit sample for laboratory diagnosis
White, powdery growth on leaves; may be on both leave surfaces	Powdery mildew (fungal disease)	Use resistant varieties; use registered fungicide; remove old plant debris
Yellow spots on upper leaf surfaces; grayish fuzzy growth on underside of spots (visible with hand lens)	Downy mildew (fungal disease)	Use resistant varieties; use registered fungicide; remove old plant debris
Yellow and green mottled pattern on leaves; leaves have strapped appearance i.e. abnormally narrow with leaf veins stretched out at leaf margins so leaves appear feathery	Viral disease	Weed control before plants emerge; aphid control; remove affected plants
	Herbicide injury	Do not spray lawn herbicides on hot days; spray after wind has died down
Holes chewed in leaves and stalks; yellow-green beetles with black stripes or spots	Cucumber beetles	Use registered insecticide
Squash and pumpkin leaves wilt, eventually become black and crisp; dark gray bugs 1/2 inch long present	Squash bug	Use registered insecticide

Study Questions

48. A recommendation to control a fungal or bacterial disease that causes brown spots on carrot leaves and roots is to: a) submit a sample for laboratory diagnosis; b) use registered pesticide; c) transplant; d) mulch

49. Black heart of celery is caused by a _____ deficiency.

50. Poor heading of cole crops can be due to: a) overcrowding; b) dry soil; c) clubroot; d) any/all of the above

51. Rough, brown, raised areas on undersides of leaves of cole crops is caused by: a) slugs; b) an uneven water supply; c) too much sun; d) excess fertilizer

52. Corn smut appears as: a) white smooth or black powdery galls on stalks, leaves, ears, or tassels; b) ears not completely filled with kernels; c) small pustules containing rust colored powdery substance on leaves; d) blue corn kernels

53. Effective ways to control a corn virus that causes reddish leaf margins would NOT be to: a) control weeds; b) control aphids; c) soil test; d) remove affected plants

54. In cucurbits, dry soil, bacterial wilt, root rot, fusarium wilt, root knot, and squash vine borer all show the symptom of _____.

55. To control squash bugs on cucurbits: a) rotate crops; b) use a registered insecticide; c) control weeds; d) use resistant varieties

Answers: 48 - a; 49 - calcium; 50 - d; 51 - b; 52 - a; 53 - c; 54 - wilting; 55 - b

Diagnostic Key: Vegetables

Symptoms	Possible Causes	Controls & Comments
Eggplant		
Blossoms drop; no fruit develops	Poor pollination due to unfavorable temperatures	Be patient, fruit will set when temperatures become more favorable
Plants wilt; bottom leaves may turn yellow	Dry soil	Supply water
	Verticillium wilt (fungal disease)	Rotate; remove old plant debris; do not plant tomatoes, strawberries, potatoes, or brambles in the same area
	Waterlogged soil	Improve drainage
	Root knot (nematode problem)	Check roots for knots; rotate; remove old plant debris; soil fumigation
Plants wilt; bottom leaves may turn yellow, brown discoloration inside stem	Verticillium wilt (fungal disease)	Rotate; remove old plant debris
	Waterlogged soil	Improve drainage
	Walnut wilt	Do not plant garden near walnut or butternut trees; sever roots between garden and tree and put in barrier
Circular or irregular brown spots on leaves and/or fruit	Fungal or bacterial disease (any of several)	Submit sample for laboratory analysis
Leaves riddled with tiny holes	Flea beetles	Use registered insecticide
Lettuce		
Bolting; may taste bitter	Weather too hot	Lettuce is a cool season crop; plant early or late
Sunken, water-soaked spots appear on lower leaves, which turn brown and slimy; heads turn brown	Rhizoctonia bottom rot (fungal disease)	Rotate; remove old plant debris; plant in well-drained area
	Sclerotinia drop (fungal disease)	Sample cultural controls as for bottom rot; fungicides are available for Sclerotinia drop
Sunken, water-soaked spots appear on lower leaves, which turn brown and slimy; head turns brown and slimy; hard, black, pea-sized pellets found in mold between dead leaves	Sclerotinia drop (fungal disease)	See above
Stem and lower leaves rotted; dense, fuzzy gray mold on affected areas	Botrytis gray mold (fungal disease)	Rotate; remove old plant debris; plant in well-drained area
Yellow or light green blotches on upper leaf surfaces; white, fuzzy mold on underside of blotches (visible with hand lens); spots eventually turn brown	Downy mildew (fungal disease)	Rotate; use registered fungicide
Plants stunted; yellowed; youngest leaves curled; head soft	Aster yellows (mycoplasma disease)	Remove affected plants; weed control; insect control
	Mosaic virus	Remove affected plants; weed control; insect control
	Nutrient deficiency	Soil test
Leaf veins and area adjacent to veins turns light yellow causing a “big vein” effect	Big vein (viroid disease)	Plant in well-drained soil: viroid (virus-like particle) is spread by a soil fungus; remove affected plants; rotate out of area for 10 years
Onion		
Watersoaked spots appear on the leaves and rapidly turn brown; spots become purplish with a dark margin and surrounded with a yellow zone; spots become covered with brown, dusty mold in moist weather	Purple blotch (fungal disease)	Use registered fungicide
Numerous small white flecks on leaves; leaves die from tips back and turn brown	Botrytis blast (fungal disease)	Use registered fungicide
	Downy mildew (fungal disease)	Use registered fungicide
	Onion thrips (insect)	Use registered insecticide

Symptoms	Possible Causes	Controls & Comments
White flecks form on leaves and expand into elongated leaf lesions; white to purplish mold (visible with hand lens), develops on spots during moist weather; leaves drop and dry up	Downy mildew (fungal disease)	Rotate; Use registered fungicide
Leaves yellow and die back from tips; bulbs are soft and rotted	Fungal or bacterial bulb rot (any of several)	Rotate; remove old plant debris; tips; plant in well-drained soil
Dark green or black smudge up to 1 inch in diameter on bulb or neck; dark smudge is covered with stiff bristles (visible with hand lens)	Smudge (fungal disease)	Rotate; remove old plant debris; plant in well-drained soil
Plants grow slowly, wilt, and die; white maggots inside bulb	Onion maggot	Work registered insecticide into soil; destroy infested onions
White streaks or blotches on leaves	Onion thrips	Use registered insecticide
Peas		
Plants stop producing pods; leaves turn yellow , then brown and die	Hot weather	Peas are cool season vegetables; plant early in spring; plant heat tolerant varieties
	Root rot (several fungi)	Rotate; plant in well-drained soil; remove old plant debris
	Fusarium wilt (fungal disease)	Use resistant varieties; rotate; remove old plant debris
Plants stunted; lower leaves yellowed; internal stem tissue discolored brown	Fusarium wilt (fungal disease)	Use resistant varieties; rotate; remove old plant debris
	Waterlogged soil	Improve drainage
White, powdery mold develops on upper and then lower surfaces of leaves; leaves and pods may be distorted	Powdery mildew (fungal disease)	Rotate; remove old plant debris
Brown or white spots on leaves, pods, and/or stems	Fungal or bacterial disease (any of several)	Submit sample for laboratory analysis
	Thrips, aphids, or leafhoppers	Identify insect, use registered insecticide
Yellowish areas on leaves; blister-like ridges on undersides of leaves and on pods; pod distortion	Pea enation mosaic virus	Use resistant varieties; weed control; insect control; remove affected plants
Light-colored leaf veins; rosetting of shoot tips; plants stunted with poor pod set	Pea stunt virus	Weed control; insect control; remove affected plants
Yellow and green mottle or mosaic pattern on leaves; plants stunted	Viral disease (any of several)	Use resistant varieties; weed control; insect control
Peppers		
Large, sunken, tan, watersoaked spot develops on blossom end of fruit; spot turns black and mold may grow on surface	Blossom end rot, caused by calcium deficiency to developing fruits	Calcium deficiency is a problem when developing fruits receive uneven moisture; supply water during dry periods; mulch
Thin, wrinkled tan areas develop on fruit and become white and papery	Sunscald	Control leaf diseases with registered pesticides to prevent leaf drop which exposes fruit to sun
Brown frass filled tunnels in fruit	European corn borer	Insecticide or discard fruit
Dark brown, sunken spots develop on fruit (not restricted to blossom end) and leaves	Fungal or bacterial disease (any of several)	Submit a sample for laboratory diagnosis
Small tan to dark brown spots develop on leaves; small brown, dry raised spots appear on fruit	Bacterial spot	Use fixed copper bactericide (e.g. Kocide) if available; use bleach-treated or western grown, hot-water-treated seed; avoid overhead watering
Tiny, brown specks with pale white haloes develop on fruit; fruit may be distorted around specks	Stink bug injury	Submit sample for laboratory diagnosis

Diagnostic Key: Vegetables

Symptoms	Possible Causes	Controls & Comments
Brown spots on leaves	Fungal or bacterial disease (any of several)	Submit sample for laboratory diagnosis
Plants stunted; leaves curled yellow and green with mottle; fruit misshapen with brown streaks; rings; yellow, green, and red mottle	Viral disease (any of several)	Resistant varieties are available for some viral disease of pepper; weed control; insect control; remove old plant debris
Plants wilted; dark brown canker at base of stem	Fungal or bacterial disease (any of several)	Submit sample for laboratory diagnosis
Plants wilted; dark brown canker at base of stem; small, hard, brown pellets form on soil and rotted plant tissue	Southern blight (fungal disease)	Rotate; remove old plant debris
Plants wilt; lower leaves may turn yellow	Fungal or bacterial vascular wilt disease	Rotate; remove old plant debris
	Dry soil	Supply water
	Waterlogged soil	Improve drainage
	Root rot (fungal disease)	Rotate; remove old plant debris; plant in well-drained soil

Study Questions

56. Blossom drop with no fruit development of eggplant is due to _____.

57. Aster yellows of lettuce appear as:
a) a dense, fuzzy grey mold; b) bolting and bitter taste; c) sunken, water-soaked spots; d) stunted, yellow plants with curled leaves

58. A recommended control of onion smudge does NOT include: a) using a registered insecticide; b) plant rotation; c) removing plant debris; d) planting in well-drained soil

59. In peas, light colored leaf veins, rosetting of shoot tips, stunting, and poor pod set are caused by:
a) aphids; b) a virus; c) a bacteria; d) cold weather

60. _____ of peppers is caused by calcium deficiency, which is a problem when plants receive uneven moisture.

61. Viral diseases of peppers cause:
a) stunting; b) mottled, curled leaves;
c) misshapen fruit; d) any/all of the above

Answers:
56 - unfavorable temperatures; 57 - d; 58 - a; 59 - b; 60 - blossom end rot; 61 - d

Symptoms	Possible Causes	Controls & Comments
Potato		
Potato tuber is green	Exposure to sun	Mound soil up around plants; do not eat green parts of potatoes
Tubers with tunneling white worms present	Potato tuberworm	
Brown spots on leaves and/or stems	Various fungal diseases	Submit sample for laboratory diagnosis
Plants wilt; bottom leaves may turn yellow	Dry soil	Supply water
	Vascular wilt (fungal disease)	Rotate; remove old plant debris
	Root rot (fungal disease)	Rotate; remove old plant debris; plant in well-drained soil
	Root knot (nematode problem)	Check roots for knots; rotate; soil fumigation if necessary
	Waterlogged soil	Improve drainage
Plants wilt; dark brown or black canker at base of stem	Fungal or bacterial disease (any of several)	Submit sample for laboratory diagnosis

	Symptoms	Possible Causes	Controls & Comments
	Brown, corky scabs or pits on tubers; plants do not wilt	Scab (bacterial disease)	Soil test; acidify soil with aluminum sulfate if necessary to maintain pH of 5.0-5.5; rotate out of area for 3-4 years; use tolerant varieties; use certified seed pieces
	Plants stunted; leaves turn bronze to yellow color; plants wilt; tubers have raised, knotty areas	Root knot (nematode problem)	Rotate; soil fumigation
	Tubers show irregular white or brown cavities when cut open	Hollow heart, caused by plants growing too rapidly	Do not overfertilize or plant too far apart
	Shoot tips stunted, forming rosette; leaves turn yellow, then brown between veins; leaf margins curl upward; individual shoots may wilt; tubers show dark brown discolored ring internally when cut open	Ring rot (bacterial disease)	Submit sample for laboratory diagnosis; these two diseases are difficult to distinguish; discard infected tubers; plant certified seed pieces
		Brown rot (bacterial disease)	Submit sample for laboratory diagnosis; these two diseases are difficult to distinguish; discard infected tubers; plant certified seed pieces
	Irregular brown discoloration	Early frost inside tubers	
		Drought	Supply water
		Viral disease (any of several)	Use tolerant varieties; weed control; insect control
	Leaves stippled with dark specks; have bronzed appearance; die starting with lowest leaves	Ozone injury	
	Deformed tubers, e.g. dumbbell or other shapes	Second growth due to extremes in moisture and/or temperature	Maintain uniform moisture by watering and mulching
	Tubers have slimy, smelly rot	Soft rot (bacterial disease)	Plant in well-drained soil; hill plants to encourage water runoff; wait until vines turn yellow and die to dig; store properly
	Leaves roll upward, turn light green to yellow and leathery; plants stunted	Leaf roll (viral disease)	Plant certified seed pieces; insect control; weed control
	Leaves roll upward, turn purple or yellow; plants stunted; aerial tubers form	Aster yellows (mycoplasma disease)	Leafhopper control; weed control
	Tunnels bored into tubers	Wireworm	Use a soil insecticide at planting time
	Leaves chewed; fat, red, humpbacked grubs or orange beetles with black stripes present	Colorado potato beetle	Hand pick beetles or use registered insecticide
Radish			
	Yellow spots develop on upper leave surfaces and later turn brown with bluish-black lace-like markings; white mold develops on undersurface of spots (visible with hand lens); inner root tissue may be discolored	Downy mildew (fungal disease)	Remove old plant debris; rotate
	Purple to black spots develop on root surface; black discoloration extends inward in radial streaks; roots remain firm	Black root (fungal disease)	Plant in well-drained soil; rotate; remove old plant debris
	Leaves riddled with tiny holes	Flea beetles	Use registered insecticide
Spinach			
	Bolting	Hot weather and long days	Spinach is a cool-season crop; plant in early spring

Symptoms	Possible Causes	Controls & Comments
Pale yellow spots appear on upper leaf surfaces; grayish purple mold develops on underside of spots (visible with hand lens); whole leaves may wither	Downey mildew (fungal disease)	Fungicides are registered but usually not practical; remove affected leaves and old plant debris
White, blister-like spots with a yellow border appear on undersides of leaves; upper surfaces are pale green to yellow	White rust (fungal disease)	Fungicides are registered but usually not practical; remove old plant debris; 3-year rotation
Irregular tan blotches or tunnels appear on leaves; tunnels are translucent when held up to light	Leafminer	Use registered insecticide before leaves become infected

Study Questions

62. _____ causes potato tubers to turn green.

63. Hollow heart of potato is caused by: a) rapid growth; b) squash bugs; c) a virus; d) nematodes

64. Fat, red, humpback grubs on potatoes are: a) wireworms; b) beneficial insects; c) Colorado potato beetle larvae; d) butterfly larvae

65. On radishes, _____ cause leaves riddled with tiny holes.

66. To avoid bolting of spinach: a) use a pesticide; b) plant in early spring; c) plant in shade; d) rotate crops every 3-4 years

Answers: 62 - exposure to sun; 63 - a; 64 - c; 65 - flea beetles; 66 - b

Symptoms	Possible Causes	Controls & Comments
Sweet Potato		
Large cracks in potato skin	Growth cracks, caused by moisture extremes	Supply water during dry periods
Brown or black spots on potato skin; discoloration extends beneath skin	Various fungal diseases	Submit sample for laboratory analysis
Brown, irregular blotches on potato skin; discoloration dose not extend beneath surface	Scurf (fungal disease)	3-4 year rotation; use disease-free slips; eat infected potatoes soon since they will dry out rapidly
Tomato		
Uniformly small (1/8") chocolate brown spots or dark spots with tan centers develop on leaves from bottom of plant to top; spots sometimes form on stems but never on fruits; leaves shrivel	Septoria leaf spot (fungal disease)	Use registered fungicide; remove old plant debris
	Bacterial spot	Not as common as Septoria leaf spot; use bleach-treated seed and Kocide spray if available. It is very important to distinguish bacterial spot from Septoria in commercial operations
Dark brown irregular spots with target rings and yellow haloes develop on leaves, stems, and fruit; spots on fruit are often at stem end and are sunken	Early blight (fungal disease)	Use resistant varieties; use registered fungicide; remove old plant debris
	Phoma rot (fungal disease)	Phoma rot is not as common as early blight
Light tan spots on upper leave surfaces; dense olive green moldy growth on undersurface of spot	Gray leaf mold (fungal disease)	Mainly a greenhouse problem: provide adequate ventilation to avoid high humidity; fungicides used to control other diseases will control this disease in the garden
Small (1/8") chocolate brown spots on leaves and fruit; spots on fruit are raised	Bacterial spot	Use bleach-treated seed; avoid overhead watering; used fixed copper bactericide (e.g. Kocide) if available; remove old plant debris; rotate
Very tiny raised specks on fruit; no white haloes around spots	Bacterial speck	Same controls as for bacterial spot

Symptoms	Possible Causes	Controls & Comments
Very tiny raised specks surrounded by white haloes on fruit; plants wilt; center of stem appears discolored brown when cut longitudinally; marginal leaf scorch with a band of chlorosis inside the brown scorched edge	Bacterial canker	Difficult to diagnose without fruit spots; same controls as for bacterial spot and speck
Brown spots on leaves that do not fit above descriptions	Various fungal leaf spots	Submit sample for laboratory analysis
Dark brown, leathery spot on blossom end of fruit only; mold may grow on spot	Blossom end rot, caused by calcium deficiency to developing fruits during dry periods	Calcium deficiency is a problem when fruits receive uneven moisture during early development; supply water; apply calcium foliar sprays; mulch
Dark brown sunken spots on fruits	Various fungal fruit rots	Submit sample for laboratory analysis
General browning of tomato skin; brown speckling of walls between seed cavities apparent when fruit is cut open	Internal browning (viral disease)	Use resistant varieties (to tobacco mosaic virus); weed control; do not handle healthy plants after diseased ones; remove affected plants
Extreme malformation and scarring of fruit during fruit formation	Catfacing, caused by cool weather or herbicide injury	
Yellow-orange blotches that do not ripen at stem end of fruit or white, papery spot on side of fruit facing sun	Sunscald	Prevent foliar diseases that cause leaf drop and exposed fruits to sun
Leaves distorted with “strapped: or feathery look (leaves narrower than normal, tips stretched out into thin projection, veins very close together)	Herbicide injury	Do not spray lawn herbicides during hot weather; spray after wind has died down in late afternoon
	Cucumber mosaic (viral disease)	It is impossible to distinguish these two problems based on symptoms alone; however, if samples comes during spring when lawn herbicides are being sprayed, strongly suspect herbicide injury; virus is controlled by removing affected plants, weed control and aphid control
Leaves roll upward, feel leathery, but remain green; plants are not stunted	Excess water	Common physiological disorder after wet periods; varieties Big Boy, Floramerica, and Beefsteak are especially susceptible
Plants wilted; bottom leaves may turn yellow; brown discoloration inside stem (in vascular ring)	Fungal or bacterial vascular wilt	Submit sample for laboratory analysis; resistent varieties are available for some fungal and viral diseases
	Walnut wilt, caused by toxin from walnut tree	Do not plant tomatoes near walnut or butternut trees; sever roots bordering garden and place barrier between tree and garden
Plants stunted, wilted, and yellow; nodules on roots	Root knot (nematode problem)	Rotate; remove old plant debris; soil fumigation if necessary
Young plants cut off at ground level	Cutworms	Use cutworm collars or registered insecticide
Young plants with many tiny holes in leaves	Flea beetles	Tomatoes will tolerate a lot of flea beetle damage if they are healthy; when necessary, use a registered insecticide
Tiny white-winged insects on undersides of leaves	Whiteflies	Yellow sticky boards (smeared with grease) will attract and trap adults or use registered insecticide

Study Questions

67. Brown, irregular blotches on the skin that don't extend below the surface of a sweet potato are caused by: a) scurf; b) moisture extremes; c) bacteria; d) aphids

68. Early blight of tomatoes can be controlled by: a) using resistant varieties; b) planting in cold weather; c) mulching heavily; d) rotating crops every 3-4 years

69. _____ of tomato is extreme malformation caused by cool weather or herbicide injury.

70. Do not plant tomatoes under _____ trees, as they can be toxic to tomato plants.

71. Yellow, sticky boards smeared with grease can be used to attract and trap _____.

Answers: 67 - a; 68 - a; 69 - catfacing; 70 - walnut/butternut; 71 - whiteflies

Tree Fruits & Nuts

Symptoms	Possible Causes	Controls & Comments
Problems Common to Many Trees Bearing Fruits and Nuts		
Premature fruit drop	Natural thinning	Many trees produce more fruit than they need and thin themselves naturally
	Spring frost	Frost often kills developing fruits or buds
	Poor pollination	Tree may require other trees nearby to pollinate it; be careful not to kill bees with insecticides
	Environmental stress	Drought, cold, or hear can cause fruit to drop
	Disease stress	See controls under specific diseases
	Use of Sevin insecticide	Sevin causes some fruit thinning; do not misuse
	Various insects	Submit insect for laboratory identification
Poor fruit development (small number of fruit on tree)	Poor pollination	Tree may require other trees nearby to pollinate it; be careful not to kill bees with insecticides
	Biennial bearing	Apples and pears naturally near a heavy crop one year and few fruits the following year
	Improper pruning	Do not prune off fruit-bearing wood during the dormant season; consult pruning chapter for proper pruning timings
	Frost injury	
Fruits too small	Failure to prune	Peaches, nectarines, plums, and apples tend to produce many small fruits if not pruned; consult pruning chapter for proper instructions
	Poor soil fertility	Soil test
Fruit misshapen; "cat faces"	Tarnished plant bug	Follow spray schedule
Many small twigs broken off	Squirrel damage	Squirrels prune twigs for nest-building and often prune more than they need
	Wind damage	

Symptoms	Possible Causes	Controls & Comments
Oozing sap on branches or trunk	Natural gummosis	Cherries, plums, apricots, and peaches naturally ooze sap
	Environmental stress	Drought or waterlogging can cause fruit trees to ooze excessively
	Mechanical injury	
	Disease or insect damage	See section on specific diseases and insects
	Shothole borer	Promote vigorous growth
Large areas of split bark; no decay evident	Frost cracks	Frost can split tree trunks if sap in trunk expands; use tree-wrap to protect bark from sun to prevent extremes in temperature
	Sunscald	Thin-barked trees, e.g. young ones, split when exposed to intense sunlight; use tree wrap or block sun with board on bright days
	Mechanical injury, e.g. lawn mower	Dig up grass around trunk and replace with mulch to avoid mowing too closely to base of tree
	Lightning injury	
Large areas of split bark; decay evident in wood	Secondary decay of any of the wounds described above	No adequate controls; remove loose bark; water and fertilize tree when necessary
	Fungal or bacterial (any of several)	Same as for secondary decay canker
Gray or white powdery growth on leaves or flowers; leaves and fruit may be distorted	Powdery mildew (fungal disease)	Use registered fungicide
Black, sooty growth on leaves, stems, and/or fruit	Sooty mold (fungus that grows on honeydew substance secreted by aphids and other insects)	Identify insect then control as warranted
Brown dead areas on leaf margins	Leaf scorch, caused by insufficient transport of water to leaves	Water tree deeply during dry periods; scorch is usually caused by hot, dry weather, but root rots or other root damage may also be involved
	Cold injury	
	Bacterial scorch (bacterial disease)	No control; bacteria are thought to be transmitted by insects. Consult with certified arborist
Trees wilted/may have poor color	Dry soil	Water deeply during drought
	Root rot (fungal disease)	Improve drainage
	Root knot or root-feeding nematodes	Submit soil sample for nematode assay
	Various fungal, bacterial, or viral diseases	Submit for laboratory analysis
	Waterlogged soil	Improve drainage
Interveinal yellowing of leaves; no wilting	Nutrient or mineral deficiency; incorrect soil pH	Soil test
	Waterlogged soil, resulting in poor transport of nutrients to leaves	Improve drainage
Large, corky galls at base of tree and on roots	Crown gall (bacterial disease)	Some galls can be pruned out, but it is best to consult with a certified arborist; trees may live for many years in spite of galls
Young leaves curled and distorted; clusters of insects on undersides of leaves	Aphids	Use registered insecticide; thoroughly cover undersides of leaves
Silk tents in branch crotches in spring	Eastern tent caterpillar	Physically remove tents or use registered insecticide when caterpillars are small
Silk tents on ends of branches in mid or late summer	Fall webworm	Same as for Eastern tent caterpillar

Diagnostic Key: Tree Fruits & Nuts

Symptoms	Possible Causes	Controls & Comments
Crescent-shaped scars on fruit; whitish legless grubs with brown heads present	Plum curculio	Use registered insecticide on a regular schedule
Leaves with tiny white spots, often dirty with webbing	Spider mites	Use registered miticide
Bark encrusted with tiny, slightly raised bumps; apples may have red spots with white centers	San Jose scale	Use a dormant oil spray or treat with registered insecticide when eggs are hatching; consult PMG for timing

Study Questions

72. Spring frost, poor pollination, and environmental stress can all result in _____ of fruit trees.

73. Oozing sap on branches or trunks of fruit trees is NOT caused by:
a) natural gummosis; b) environmental stress; c) shothole borer; d) warm weather

74. The best control for sooty mold would be:
a) controlling insects that secrete honeydew; b) watering during warm weather; c) using a viricide; d) controlling squirrels, which spread the fungus

75. Silk tents on ends of branches in mid or late summer are a sign of _____.

76. San Jose scale can be controlled by:
a) using a dormant oil spray; b) physical removal; c) controlling the insect vectors that spread it; d) tree removal

Answers:
72 - premature fruit drop; 73 - d; 74 - a; 75 - fall webworm; 76 - a

Symptoms	Possible Causes	Controls & Comments
Apple and Pear		
Leaf spots with light tan centers and brown borders; large rotted spots with black pimply structures appear on fruit; cankers with black pimply structures may appear on twigs	Frogeye leaf spot, also called black rot (fungal disease)	Control fire blight disease since black rot often invades fire blight cankers; use apple/pear fungicide spray program
Leaf spots similar to those described above but no fruit or stem symptoms; defoliation	Alternaria blotch (fungal disease)	Submit sample for laboratory analysis
Olive-brown velvety spots on leaves and young fruit; fruit spots develop onto brown corky lesions and mature fruit is distorted	Scab (fungal disease)	Choose scab resistant varieties; use apple/pear fungicide spray program
Bright yellow spots with orange or black centers on upper surface of leaves; cuplike pustules on lower leaf surface, with cup-like structures on fruit	Cedar Apple Rust (fungal disease)	Use apple/pear fungicide program; do not plant red cedar trees, which are the alternate hosts of the fungus, in the area
Brown, roughly circular leaf spots not fitting above descriptions	Fungal leaf spot (any of several)	Submit sample for laboratory analysis
	Chemical injury	Some fungicides can cause spotting on certain varieties of fruit trees
Sunken, light brown circular spots with salmon colored specks (spore masses) on fruit; apple tastes bitter; sunken lesions may appear on branches	Bitter rot (fungal disease)	Use apple/pear fungicide spray program; prune out branches with sunken lesions
Circular clusters of tiny black specks and small sooty smudges on fruit	Fly speck and sooty blotch (two fungal diseases that commonly occur together)	Use apple/pear fungicide spray program; fruit is still edible; specks can be rubbed off
Sunken, dark green lesions with a feathery edge on fruit	Quince rust (fungal disease)	Use apple/pear fungicide spray program

Symptoms	Possible Causes	Controls & Comments
Spots on fruit that do not fit above descriptions	Fungal disease	Submit sample for laboratory analysis
	Corking, a physiological problem associated with certain varieties	Grimes Golden and York apple varieties are susceptible
	Various insects	Use apple/pear insecticide program
Bark on young branches is rough and pimply; tissue beneath bark has brown spots	Measles, believes to be a nutrient imbalance	Soil test
Sunken, black or wine-colored cankers on young twigs, larger branches, or trunk; leaves wilt, curl, and cling to twigs; shoot tip may be curved into “shepherd’s crook”	Fire blight (bacterial disease)	Prune out affected branches; in late summer remove young suckers as they appear since they are very susceptible to fire blight; do not plant apples near pears which are highly susceptible
	Sooty mold (fungus that grows on honeydew secreted by aphids and other insects)	Usually this can be easily distinguished from fire blight; sooty mold can be rubbed off but fire blight cannot
Tree breaks off at graft union during strong winds	Poorly constructed graft	Purchase young transplants from reliable dealer
	Virus infection at graft union	Submit soil sample for nematode analysis; some of these viruses are transmitted by nematodes in the soil
Pink-white worms bore into blossom end of apple; clusters of round, brown frass pellets inside fruit	Codling moth	Use registered insecticide on a regular schedule
Apples dimpled with faint brown areas in flesh	Apple maggot (“railroad streaks in the flesh worm”)	Use registered insecticide on a regular spray schedule
Stone fruits (Apricot, cherry, peach, plum, and nectarine)		
Small, angular leaf spots (1/16” - 1/8” long) confined between veins’ spots are green, then purple, then brown; small circular, depressed spots with watersoaked margins on fruit; sunken cankers may appear on twigs	Bacterial spot	No adequate controls; spraying with basic copper sulfate may reduce spread; however, basic copper sprays may cause severe toxic effects on fruit and leaves and are usually too toxic to use; prune out affected twigs
Small, circular, olive-green spots on young fruit; spots eventually turn brown and velvety; similar spots on leaves	Scab (fungal disease)	Use fungicidal spray program recommended for stone fruits; prune properly so that sprays penetrate the canopy
Purple spots appear on upper surfaces of cherry leaves; leaf spots drop out leaving holes, and turn yellow; fruit may also be spotted	Cherry leaf spot (fungal disease)	Plant resistant cherry varieties (Meteor and Northstar); use fungicidal spray program recommended for stone fruits
Peach or nectarine leaves puckered, thickened, and curled from the time they first appear in the spring; leaves red or orange at first but turn yellow; shoots swollen and stunted	Peach leaf curl (fungal disease on peaches and nectarines)	Use registered dormant spray fungicide before buds begin to swell; do not use this on anything but peach and nectarine
Blossoms and young twigs wilt and decay during bloom; sunken cankers with gummy ooze develop on twigs; circular brown spots which develop tufts of gray spores during moist weather form on fruit; rot may cover large portion of fruit	Brown rot (fungal disease common to all stone fruit)	Use stone fruit fungicidal spray program; remove all affected fruit from tree and on ground: decayed fruit turns into a “mummy” on which the fungus overwinters
Sunken cankers on twigs, larger branches and/or trunk; leaves above canker wilt	Fungal or bacterial disease (any of several)	Submit sample for laboratory analysis
Swellings that split the bark appear on plum or cherry branches and later turn coal-black; leaves may wilt above swellings	Black knot (fungal disease of plum and cherry only)	Use registered fungicide; prune out affected twigs at least 4” below knots; destroy wild plum and wild cherry trees in the area

Diagnostic Key: Tree Fruits & Nuts

Symptoms	Possible Causes	Controls & Comments
Shoot tips stunted; leaves yellow and curled upward; severe defoliation; trees tend to break off near ground in strong winds; base of trunk may be swelled	Stem pitting (viral disease; primarily of peach)	Submit soil sample for nematode analysis; nematodes can transmit the virus or it can come in on the transplants; remove and destroy the affected trees
	Nutrient or mineral deficiency	Soil test
	Various other viral diseases	Submit sample for laboratory analysis
New growth at tip of twig wilts and dies; resin at tip of twig; maturing fruit may contain 1/2 long pinkish worms	Oriental fruit moth	Use registered insecticide to prevent damage; peach will tolerate a lot of natural pruning by this insect, so insecticides may not be necessary
Gum oozes from holes at base of trunk or lower branch crotches; sawdust may be evident	Peach tree borers	Use registered insecticide on bark only
Many small round holes in twigs and branches	Shothole borer	Remove and destroy all dead or dying wood; use registered insecticide to protect healthy trees
Tiny white, flat insects encrusting bark	White peach scale	Use a dormant oil or treat with registered insecticide; refer to PMG for application timings
Pecan		
Small, olive-colored spots on twigs and undersides of leaves; tiny black dots on shucks enlarge to form black lesions; nuts drop prematurely	Scab (fungal disease)	Use pecan fungicide spray program
Downy or frosty looking spots appear on lower leaf surfaces; later greenish-yellow spots are evident on both leaf surfaces	Downy spot (fungal disease)	Use pecan fungicide spray program
Reddish-brown, irregular spots with grayish concentric rings form on leaves	Brown leaf spot (fungal leaf spot)	Use pecan fungicide spray program
Brown leaf spots; no spots on nuts	Fungal or bacterial disease (any of several)	Submit sample for laboratory analysis
	Chemical injury	
Empty nut shells	"Pops" - a problem of unknown cause	Environmental stress or poor pollination are though to be causes; no controls are known
Nutmeats (kernels) have brown or black blotches and may be distorted	Feeding punctures (several species of plant bugs and stink bugs)	Remove any nearby weed growth; treat with insecticide if insects found
Small, cream-colored worms in immature nuts or in the green shucks after shells have hardened	Hickory shuckworm	Clean up and destroy fallen nuts to eliminate overwintering larvae
Walnut		
See section on general problems. Most walnut diseases are difficult to diagnose without consulting a diagnostic laboratory.		

Study Questions

77. _____ are the alternate hosts of a rust fungus that affects apples and pears.

78. Sunken, light brown circular spots with salmon colored specks on fruit, and a bitter taste are caused by _____.

79. Although they have similar symptoms, fire blight can be distinguished from sooty mold because: a) fire blight only attacks apples; b) sooty mold can be rubbed off; c) sooty mold only appear in cold weather; d) fire blight only occurs on grafted trees

80. _____ appears on upper surfaces of cherry leaves, with leaf spots dropping out to leave holes.

81. Black knot fungal disease only appears on: a) apples; b) plums and cherries; c) pears; d) peaches and nectarines

82. A recommended control for hickory shuckworm, which attacks pecans, would be: a) crop rotation; b) insecticidal soap; c) cleaning up and destroying fallen nuts; d) controlling weeds

Answers:
77 - Red cedar trees; 78 - bitter rot; 79 - b; 80 - cherry leaf spot; 81 - b; 82 - c

Small Fruits

Symptoms	Possible Causes	Controls & Comments
Problems common to many small fruits		
Grayish or white moldy growth on leaves	Powdery mildew (fungal disease)	Use fungicide program
Galls at base of plant, on roots, and on canes; plants stunted	Crown gall (bacterial disease)	Prune out galled canes; no chemicals will control this disease
Plants wilt; leaves may turn yellow	Dry soil	Supply water
	Waterlogged soil	Plant in well-drained area
	Verticillium wilt (fungal disease)	Use resistant varieties; plant new transplants in another area; soil fumigation
	Root rot (fungal disease)	Plant in well-drained soil
	Root knot (nematode problem)	Check roots for knots; submit soil sample for nematode analysis; soil fumigation; rotate
Green and yellow mosaic or mottle pattern on leaves; plants may be stunted	Viral disease (any of several)	Purchase certified virus-free plants; prune out affected canes; if more than 20% of canes are infected, remove entire planting; control aphids with registered insecticide; remove nearby related wild plants (e.g. brambles)
Tip dies; rows of punctures around twig	Raspberry cane borer	Prune and destroy dead tips
Leaves rolled or tied together; small caterpillars feeding inside	Leafrollers	Use registered insecticide
Blueberry		
Plants stunted and discolored	Soil pH too high	Blueberries require acid pH; soil test
	Nutrient deficiency	Soil test
	Viral disease (any of several)	Submit sample for laboratory analysis
Berries turn reddish or tan color as they ripen and become shriveled and hard; blossoms turn brown and wither; center of new leaves are black	Mummy berry (fungal disease)	Use blueberry fungicide program; destroy all old mummies
Brown blotches appear on flowers and stems; fuzzy grayish mold forms on infected plant parts	Gray mold (fungal disease)	Do not plant too closely; use blueberry fungicide program
Branches die back; no cankers evident externally; reddish-brown discoloration deep into wood	Phomopsis dieback (fungal disease)	Prune out affected branches; use wettable sulfur spray after harvest
Branches die back; cankers may be evident externally; internal discoloration not reddish-brown	Fungal canker (any of several)	Submit sample for laboratory analysis
	Winter injury	Common in spring
Ripening berries soft and mushy	Blueberry maggot	Use registered insecticide on a regular schedule

Diagnostic Key: Small Fruits

Symptoms	Possible Causes	Controls & Comments
Brambles		
Plants wilt; leaves turn yellow at bottom of plant first; stem turns dark blue color at base; internal stem tissue may be discolored	Verticillium wilt (fungal disease)	Use certified disease-free plants; use resistant varieties, 3-4 year rotation
Plants wilt with symptoms above but blue stem symptom not evident	Dry soil	Supply water
	Waterlogged soil	Improve drainage
	Verticillium wilt (fungal disease)	Use certified disease-free plants; use resistant varieties, 3-4 year rotation
	Root rot (fungal disease)	Improve drainage
	Root knot (nematode problem)	Check roots for knots; rotate; soil fumigation
Plant wilts and dies back; roots rotted	Phytophthora root rot (fungal disease)	Improve drainage; use a soil drench fungicide
	Planted too deeply (brambles do not tolerate deep planting)	
Ripening berries covered with tufts of gray, green, white, or black moldy growth	Fungal fruit rot (any of several)	Use bramble fungicide program; pick berries regularly and cool immediately
White or tan spots with purple borders appear on canes; spots may be sunken; canes die back	Anthracnose (fungal disease)	Submit sample for laboratory analysis; plant red raspberries far away from black raspberries since black ones are more susceptible
	Fungal canker (any of several)	Submit sample for laboratory analysis; prune out cankered canes; prune out old canes at the end of the season
Leaves curl downward; leaves smaller than usual; internodes shorter than normal	Leaf curl (viral disease)	Do not plant Cuthbert or Cumberland varieties which are very susceptible; plant certified virus-free stock; prune out affected canes; if more than 20% of canes are affected, remove entire planting; control aphids with registered insecticide; remove nearby wild brambles
	Aphids or blackberry psyllid	Look for clusters of small gray insects on undersides of leaves; control with registered insecticide
	Herbicide injury	
Blister-like reddish-orange pustules develop on lower leaf surfaces	Rust (any of several fungal diseases)	Use resistant varieties; remove and destroy affected plants immediately; fungicides are not effective; remove nearby wild brambles
Leaf spots with a brown whitish center and a brown or purplish margin	Septoria leaf spot (fungal disease)	Use registered fungicide; space plants to allow proper air circulations on blackberry
Currant		
Orange-brown blisters containing yellow spores appear on undersides of leaves; leaves turn yellow	White pine blister rust (fungal disease which has white pine as alternate host)	Use resistant varieties (Viking and Red Dutch); plant certified disease-free stock
Stems die back; cankers with tiny black pimple-like structures appear on stems	Fungal dieback (any of several)	Prune out affected stems
Brown leaf spots with tiny black pimply structures	Septoria leaf spot (fungal disease)	Use registered fungicide
Brown leaf spots without tiny black pimply structures	Fungal leaf spot (any of several)	Submit sample for laboratory analysis

Study Questions

83. On small fruits, the best control for gall would be: a) registered chemicals; b) pruning; c) irrigation; d) sanitation

84. On blueberries, _____ cause(s) ripening berries to be soft and mushy.

85. A dark blue color at the base of stems of bramble fruits is a symptom of: a) Verticillium wilt; b) dry soil; c) root rot; d) anthracnose

86. _____ should not be planted near red raspberries, as they are highly susceptible to anthracnose.

87. Currants are susceptible to a rust disease which is alternately hosted on _____ trees.

Answers:
83 - b; 84 - blueberry maggots; 85 - a; 86 - black raspberries; 87 - white pine

Symptoms	Possible Causes	Controls & Comments
Grape		
Brown spots with dark borders on leaves; grapes turn black, shrivel up like raisins; and remain attached to stem	Black rot (fungal disease)	Use grape fungicide spray program; remove mummified berries since fungus overwinters on them
Brown leaf spots	Fungal leaf spot (any of several)	Submit sample for laboratory analysis
Small yellow spots appear on upper leaf surfaces; white cottony growth forms on undersides of spots; do not confuse white leaf hairs of some varieties with fungus	Downy mildew (fungal disease)	Use grape fungicide spray program; Concord grape is resistant
Fruit rot not resembling black rot	Fungal fruit rot (any of several)	Submit sample for laboratory analysis
Canes die back; dark lesions on canes; tiny black lesions on leaves	Fungal dieback (most common one is Phomopsis dieback)	Prune well below cankers; use grape fungicide program
Leaf resembles a fan: main veins are drawn together and teeth along margins are elongated; plants stunted	Fan leaf (viral disease)	Purchase certified virus-free stock; submit soil sample for nematode analysis; remove affected plants
	Herbicide injury	Fan leaf and herbicide injury symptoms are identical: if symptoms occur in spring when lawn herbicides are being applied, herbicide injury is a good bet; do not apply lawn herbicides in hot weather; wait to apply herbicides until wind has died down
Small, green, seedless grapes are intermingled with ripe grapes in the cluster	Shot berry, caused by environmental stress or poor pollination	No control
Grapes and/or leaves webbed together; some grapes collapsed	Grape berry moth	Use registered insecticide on regular schedule
Green or red irregular swellings on leaves, canes, or tendrils	Grape tomato gall (insect problem	Prune out and destroy heavily infested leaves and canes before the insects inside have matured
Small, rough galls the size of a small pea on the undersides of leaves; swellings on roots	Grape phylloxera (insect)	Use resistant varieties; no chemical controls
Strawberry		
Small spots with white or tan centers and reddish brown borders on leaves	Mycosphaerella leaf spot (fungal disease)	Use resistant varieties; use strawberry fungicide spray program
Purplish or brown spots on leaves not fitting above description	Fungal or bacterial leaf spot (any of several)	Submit sample for laboratory analysis
White or gray crusty material covering leaves, stems, and/or fruits	Slime mold (fungus)	Slime molds grow on plant surfaces during wet weather and disappear again in dry weather; no need for control
Gray, fuzzy mold on fruit, especially during wet periods	Gray mold (fungal disease)	Do not crowd plants; do not apply fertilizer in spring since dense foliage delays drying of berries after rains; mulch; use strawberry fungicide program

Diagnostic Key: Small Fruits

Symptoms	Possible Causes	Controls & Comments
Plants wilt; leaves may turn brown at margins; roots and crown appear discolored when cut open	Root and/or crown rot (fungal disease)	If many plants show symptoms, replant in another area; plant in well-drained area
	Nematode injury	Submit soil sample for nematode analysis; soil fumigation
Fruit is hard and leathery with brown spots	Leather rot (fungal disease)	Mulch; rotate if infection is severe
	Environmental stress	Poor growing conditions can cause berries to become dry and hard
Fruit is soft with brown spots	Fungal or bacterial fruit rot (any of several)	Mulch; use strawberry fungicide if fungal disease is diagnosed
Malformed berries: look like several berries have grown together	Fasciation; a response to environmental conditions	Common in certain varieties in fall and spring
Berries seedy at tips	Insect injury	Use strawberry insecticide spray program
	Mites	Use registered miticide
	Frost injury	Protect plants from frost by mulching
	Nutrient deficiency	Soil test
	Green petal (mycoplasma disease)	Use strawberry insecticide spray program
Flower buds droop, turn brown and may drop to ground	Strawberry bud weevil	Use registered insecticide during the bud stage
Small holes in leaves; poor growth	Strawberry rootworm	Rotate to new area

Study Questions

88. _____ grapes are resistant to downy mildew.

89. On grapes, herbicide injury has symptoms identical to: a) fan leaf; b) shot borer; c) grape berry moth; d) phylloxera root rot

90. _____ molds grow on strawberries during wet weather and disappear again in dry weather.

91. _____, a response to environmental conditions that cause malformed berries, is common on certain varieties of strawberry in fall and spring.

Answers:
88 - Concord; 89 - a; 90 - slime; 91 - fasciation

Ornamental Trees & Shrubs

Most ornamental tree and shrub problems can be diagnosed from the general problems category; only very common problems specific to certain trees or shrubs are listed in the specific categories.

Symptoms	Possible Causes	Controls & Comments
Problems common to many ornamental trees and shrubs		
Many small twigs broken off	Squirrel damage	Squirrels prune twigs for nest-building and often prune more than they need
	Wind breakage	
	Twig pruner, twig girdler (insects)	Rake up and destroy fallen twigs
Large areas of split bark; no decay evident	Frost cracks or SW injury	Frost can split trunks; use tree-wrap to protect back from the sun to prevent extremes in temperature
	Sunscald	Thin-barked trees, e.g., young ones, split when exposed to intense sunlight; use tree-wrap or block sun with board on bright days; avoid heavy fertilization in late summer and in fall
	Mechanical injury, e.g. lawn mower injury	Dig up grass around trunk and replace with mulch to avoid mowing too close to the base of the tree
	Lightning injury	Use lightning rod
Large areas of split bark; decay evident in wood	Secondary decay of any of the wounds described above	No adequate controls; remove loose bark; water and fertilize tree at appropriate times
	Fungal or bacterial canker (any of several)	Submit sample for laboratory analysis
Gray or white powdery growth on leaves; leaves may be distorted	Powdery mildew (fungal disease) (see photo 1C)	Use registered fungicide
Black, sooty growth on leaves and/or stems	Sooty mold (fungus that grows on honeydew substance secreted by aphids and other insects) (see photo 1D and 1E)	Identify the insect pest, then control with registered insecticide(s)
Brown dead areas on leaf margins	Leaf scorch, caused by insufficient transport of water to leaves	Water tree deeply during dry periods' scorch is usually caused by hot, dry weather, but root rots or other root damage can also be involved
	Cold injury	
	Chemical injury	Chemical injury to trees is not common on home lawns but it does occur on shrubs where herbicides are used too closely
	Improper mulching	Placing mulch against trunk of tree leads to bark decay; mulch should be only 2-3" deep and in a doughnut-shaped ring around the tree

Diagnostic Key: Ornamental Trees & Shrubs

Symptoms	Possible Causes	Controls & Comments
Tree wilted and may have poor color	Dry soil	Water deeply during drought
	Root rot (fungal disease)	Improve drainage
	Root knot or root-feeding nematodes	Submit soil sample for nematode analysis
	Various fungal, bacterial, or viral diseases	Submit sample for laboratory analysis
	Waterlogged soil	Improve drainage
	Plant is rootbound	Cut rootball in several places before transplanting so roots will grow out into soil
	Girdling roots	Plant's own roots have grown around base of trunk and strangled plant; take care to plant properly (most common in container-grown plants)
	Girdling by tag wires or wire baskets not removed	Remove tag wires at planting; cut tops of wire baskets around roots at planting
	Transplant shock (on young transplants)	Water regularly after transplanting
	Bark beetles	Prune out and destroy dead or dying wood; protect nearby trees of same species with registered insecticide; keep trees healthy and growing vigorously
Interveinal yellowing of leaves; no wilting	Nutrient or mineral deficiency	Soil test
	Waterlogged soil, resulting in poor transport of nutrients to leaves	Improve drainage
Large, corky galls at base of tree and on roots	Crown gall (bacterial disease) (see photo 1F)	Some galls can be pruned out, but it is best to consult an arborist; trees may live for many years in spite of galls
Few or no flowers	Cold injury	
	Improper pruning	Some plants flower only on old wood
	Overfertilization with nitrogen	This stimulates leaf production and reduces flower production
	Shade	Grow plants in proper amount of light for the species
	Incorrect fertility	Soil test
Galls on upper branches	Fungal disease (any of several)	Submit sample for laboratory analysis; prune out galled branches
	Various insects	Most are harmless; prune out galled branches
Proliferation of branches at specific points on the plant, forming a "witches' broom" disease effect	Insect injury	For all of theses, only control is to prune out affected branches
	Fungal, viral, or mycoplasma	
	Mistletoe	
Pustules containing yellow, orange, or black powdery substance on leaves; may be on both leaf surfaces	Rust (fungal disease)	Use registered fungicide
Brown, gray, green, or yellow crusty, leaf-like growths on trunk and branches	Lichens	Lichens are a combination of algae and fungi; they grow on bark and do not harm the plant; lichens tend to grow on dead or dying trees where the lack of a canopy exposes them to sunlight
Early leaf drop	Environmental stress, such as drought, compacted soil, or transplant shock	
	Various insects or disease	Submit sample for laboratory analysis
Browning of tips of conifer needles; faint yellow bands about 1/8" wide at the same location across groups of needles	Ozone injury	No controls; white pine is especially sensitive but individual trees vary in sensitivity

Diagnostic Key: Ornamental Trees & Shrubs

Symptoms	Possible Causes	Controls & Comments
General browning of conifer needles	Drought	Water deeply during drought
	Salt injury	De not use de-icing salt on sidewalks or roads near trees or shrubs; flush soil with water
	Gas leak	Check soul around roots for gray, crumbly appearance and foul smell indicative of gas leak
	Pine wood nematode	Submit lower branches for nematode analysis; remove and destroy affected trees; control longhorn beetles which transmit the nematode
	Root-feeding nematodes	Submit soil sample for nematode analysis
	Waterlogged soil	Improve drainage
	Transplant shock	Water regularly after transplanting
	Girdling roots	Be sure main roots are not encircling plant when transplanting
	Plant is rootbound	Cut rootball in several places before transplanting or scrape outside of rootball to loosen roots
	Fungal canker	Check trunk and branches for cankers; prune out affected branches
	Mites	Use miticide
	Dog urine injury	
Sour-smelling sap oozes from cracks	Slime flux (bacterial disease)	Avoid wounding the tree, protect tree from other stresses such as soil compaction, and promote tree vigor. The old recommendation of drilling the tree to reduce pressure is no longer recommended
Yellow and green mottle or mosaic pattern on leaves; leaves may be distorted	Viral disease	No controls; removal of plant may be necessary if virus is easily spread
Sunken cankers on trunk or branches; plant may wilt or have poor growth	Fungal or bacterial canker	Submit sample for laboratory analysis; prune out affected branches well below canker
Oozing sap on trunk	Natural gummosis	Some trees naturally ooze sap
	Environmental stress	Drought or waterlogging can cause trees to ooze excessively
	Mechanical injury	Prevent lawn mower injury, other wounds
	Disease or insect damage	See section on specific diseases
Brown leaf spots	Fungal or bacterial disease (any of several)	See section on specific diseases or submit sample for laboratory analysis
	Chemical injury	
Leaves chewed or completely eaten	Various caterpillars, sawflies, leaf beetles, etc.	Use registered insecticide while insects are small and before damage is extensive; consult PMG
Fish scale-like structures tightly attached to leaves, twigs, or branches	Various scale insects	Submit sample for laboratory analysis; use dormant oil
Young leaves puckered, curled, or distorted; clear, sticky substance on leaves; clusters of small insects on undersides of leaves	Aphids	Use registered insecticide
Leaves off-color with tiny white or yellow spots; may appear dirty due to fine webbing and dust that leaves collect	Spider mites	Use registered miticide

Symptoms	Possible Causes	Controls & Comments
Galls (abnormal growths on leaves, stems, or other tissues)	Various insects or mites	There are no chemical controls for gall insects, but the plants will not be seriously harmed

Study Questions

92. Large areas of split bark can result from: a) frost cracks; b) sunscald; c) lightning; d) all of the above

93. A method of controlling leaf scorch is: a) watering deeply during dry periods; b) controlling the insect pest that causes it; c) applying fertilizer; d) using trunk wrap in winter

94. Waterlogged soil can result in: a) scorched leaves; b) large, corky galls; c) interveinal yellowing of leaves; d) few or no flowers

95. The best method to control witches' broom is: a) to use an insecticide; b) to use a fungicide; c) to use a viricide; d) pruning

96. Brown, gray, green, or yellow crusty or leaf-like growths on tree trunks and branches are _____.

97. A sour smelling sap that oozes from cracks in bark is caused by _____.

98. _____ are fishscale-like pests tightly attached to leaves, twigs, or branches.

Answers: 92 - d; 93 - a; 94 - c; 95 - d; 96 - lichens; 97 - slime flux (bacterial disease); 98 - scale insects

Symptoms	Possible Causes	Controls & Comments
Birch		
Leaves sparse, especially at top of tree; swollen ridges in bark	Bronze birch borer	Use registered insecticide on bark in mid-May, early, mid, and late June
Boxwood		
Large portions of shrub turn yellow or brown; on some leaves, the browning may only occur at leaf margins	Winter injury	This is the most common problem the Plant Clinic receives in the spring; always suspect this if problem occurred during the winter; prune out dead branches but wait until June to be sure branches are dead; water and fertilize
	Phytophthora root rot (fungal disease) (see photo 1G)	Check for brown discoloration in roots; improve drainage; plant in another area
	English boxwood decline (fungal disease) (see photo 1H)	Submit sample for laboratory analysis; only a problem on English boxwood; replace shrub with American boxwood or other species
	Volutella blight (fungal disease) (see photo 1I)	Prune out affected branches
	Root-feeding nematodes (see photo 1J)	Submit soil sample for nematode analysis
Large portions of shrub turn yellow or brown; brown discoloration evident in wood when base of trunk is cut open	Phytophthora root rot (fungal disease)	Improve drainage; plant in another area
	English boxwood decline (fungal disease) (see photo 1K)	Submit sample for laboratory analysis; only a problem on English boxwood; replace shrub with American boxwood or other species
Leaves are brown and have tiny black specks on them	Macrophoma leaf spot (fungal disease) (see photo 1K)	Secondary problem; prune out branches damaged by winter injury or disease
Leaves blistered; small yellowish maggots inside	Boxwood leafminer	Use registered insecticide in early June

Symptoms	Possible Causes	Controls & Comments
Leaves at stem tips cupped	Boxwood psyllid	Use registered insecticide just as new growth starts appearing
Tiny white or yellow flecks on leaves	Boxwood mite	Use registered miticide as soon as damage is noticed
Cotoneaster		
Individual twigs die back, turn black, and have curved tips; sunken cankers may be evident on wood	Fire blight (bacterial disease) (see photo 1L)	Prune out affected branches or remove plant if you do not observe the blackening or curved tips; problem could be drought or root rot; black that can be rubbed off is sooty mold
Dogwood		
Purplish brown spots on leaves; leaves may be distorted	Various fungal leaf spots (see photos 1M & 1N)	Most common ones are anthracnose, discula anthracnose, and Septoria leaf spot; submit sample for laboratory analysis
Brown leaf and bract spots with purple margins; spots vary widely in size and may blight entire leaves; lower branches die back and whole tree may eventually die; leaves cling to tree in winter	Discula anthracnose (fungal disease) (see photos 1O & 1P)	
Brown, wrinkled patches form on flowers; gray fuzzy mold develops on flowers	Gray mold (fungal disease)	Use registered fungicide
Leaves wilt and leaf margins turn brown	Scorch, due to hot, dry weather	Dogwood should be planted in reduced sunlight; it is very susceptible to scorch
	Fungal canker	No controls; water and fertilize
	Dogwood borer, dogwood twig borer	Use registered insecticide to protect trees; prune out dead and dying branches
	Lawn mower injury	
Elm		
Leaves wilt, curl, turn yellow, and drop off; branches die back	Dutch elm disease (fungal disease transmitted by beetles)	Submit sample of many medium-sized affected twigs for laboratory analysis
	Various other fungal wilt disease	Submit sample for laboratory analysis
	Phloem necrosis (mycoplasma disease)	Submit sample for laboratory analysis
Leaves eaten between veins and appear lacy; may turn brown and drop off	Elm leaf beetle	Use registered insecticide
Hemlock		
Resinous bleeding near base of trunk on young (3-7 year old) trees; browning under bark	Bleeding canker	No controls known; cause has not been determined
Needles with brown specks, especially near base; fine webbing between needles; foliage gray and dirty	Spruce mite	Use registered insecticide
Holly		
Dieback of part or all of foliage; blackened roots	Black root rot (fungal disease) (see photos 2B & 2C)	Only a problem on Japanese hollies; use soil drench fungicide
Tan winding trails or blotches on leaves; tiny brown dots on undersides of leaves	Leafminers	Use registered insecticide in early June
Leaves with tiny yellow spots; leaves small and off-color	Southern red mite	Use registered miticide

Study Questions

99. Winter injury on boxwood appears as: a) leaf drop; b) yellowing/browning of leaves; c) twig drop; d) sparse flowering in spring

100. Cupped leaves at stem tips are a symptom of: a) boxwood leaf miner; b) boxwood mite; c) boxwood psyllid; d) English boxwood decline

101. On dogwood, gray mold signs appear on: a) flowers; b) leaves; c) twigs; d) roots

102. Dutch elm disease is transmitted by _____.

103. On hemlock trees, bleeding canker mostly appears on: a) young trees; b) old trees; c) dead trees; d) seedlings

104. Black root rot is only a problem on _____ hollies.

Answers: 99 - b; 100 - c; 101 - a; 102 - beetles; 103 - a; 104 - Japanese

Symptoms	Possible Causes	Controls & Comments
Juniper		
Tips of branches turn brown; black pimple-like structures can be seen on brown needles or stems	Various fungal tip blights (see photos 2D & 2E)	Submit sample for laboratory analysis; fungicides are registered for some of these tip blights
Browning of parts or all of plant	Root rot (fungal disease)	Submit sample for laboratory analysis; fungicides are registered for Phytophthora root rot
	Winter injury	Prune out dead branches
	Drought	Water deeply during dry periods
Brick-red or brown galls form on branches; in spring, orange jelly-like horns form on the galls; galls turn brown with age	Cedar-apple rust (fungal disease)	Pick off galls; the fungus spreads to apple trees
Needles gray, dirty-looking, and covered with tiny yellow specks	Spruce mite	Use registered miticide
Lilac		
Brown spots appear on leaves in early spring; leaves are distorted, turn black and die; flowers die	Bacterial blight	Prune out affected branches
	Frost injury	Prune out affected branches
Stems swollen and cracked near ground; sawdust may be present	Lilac borer	Use registered insecticide on bark in early May and mid-June
Bark chewed off	European hornet	Carefully destroy the hornet's nest
Magnolia		
Twigs with powdery white or tan bumps the size of half a bean	Magnolia scale	Use registered insecticide in early September or dormant oil
Marginal browning of older leaves or sometimes all leaves	Winter injury	Water deeply in fall before ground freezes; apply anti-desiccant before winter
Maple		
Large, irregular grayish blotches on leaves; concentric ring pattern in spots are evident when leaves are held up to light	Zonate leaf spot (fungal disease)	No fungicides registered; rake up and burn or bury fallen leaves; this is a late season disease; fungicides are not warranted
Irregular, shiny black, tar-like spots, about 1/2" in diameter on upper leaf surfaces	Tar spot (fungal disease)	Use registered fungicide; rake up and destroy fallen leaves
Irregular, brown spots on leaves; on Norway maple, brown areas follow leaf veins; tree otherwise healthy	Anthracnose (fungal disease)	Use registered fungicide; rake up and destroy fallen leaves
	Scorch, caused by hot, dry weather	Water tree deeply; Anthracnose can be confused with scorch if the leaf spots have enlarged and coalesced; in early stages, it should be possible to distinguish between the two; scorch is mainly at the leaf margins
Brown, dry areas on margins of leaves only;	Scorch, caused by hot, dry weather	Water tree deeply

Symptoms	Possible Causes	Controls & Comments
Leaves on tree suddenly wilt and may turn yellow and drop off; wilt may occur on one side of tree only; tree may die suddenly or decline over a period of years; no external trunk or branch damage evident; some branches may have brown streaks in wood	Verticillium wilt (fungal disease) (see photos 2F & 2G)	Fertilizing heavily with nitrogen sometimes helps the tree to recover: distribute nitrogen in holes rather than on soil surface or grass may die; if tree dies, do not replant in the spot or replant with a species immune to Verticillium wilt; water tree deeply
	Drought	Water tree deeply
Tree shows "stagheading", i.e., top branches die back; leaves discolored and small	Poor site	Maple is a shallow-rooted tree and cannot withstand stresses such as soil compaction, being planted near roads and sidewalks, etc.
	Maple decline, a disease thought to be associated with several pathogens and environmental stresses	Watering and fertilizing may help
	Fungal or bacterial canker	Prune out cankered branches; water fertilize
Cottony egg sacs on twigs and leaves	Cottony maple scale, cottony maple leaf scale	Use registered insecticide when egg sacs first appear
Small red, green, or black globular growths on upper leaf surfaces	Gall mites	No control, but the tree will not be harmed

Study Questions

105. Brick red or brown galls on branches of Juniper which form orange, jelly-like horns in spring are a sign of _____.

106. Swollen stems cracked near the ground and the presence of sawdust on lilacs is a symptom of: a) bacterial blight; b) frost injury; c) European hornet; d) lilac borer

107. A method of controlling winter injury on Magnolias is: a) fertilizing in fall; b) mulching 1' deep over root spread; c) watering deeply in fall before ground freezes; d) all of the above

108. On maple trees, a difference between scorch and anthracnose is: a) anthracnose only appears on stems; b) scorch only appears in winter; c) scorch mainly occurs on leaf margins; d) anthracnose can be rubbed off

109. "Stag heading" of maples is due to: a) poor site selection; b) maple decline; c) fungal or bacterial canker; d) all/any of the above

110. _____ cause(s) small red, green, or black globular growths on upper surfaces of maples.

Answers:
105 - cedar apple rust; 106 - d; 107 - c; 108 - c; 109 - d; 110 - gall mites

Symptoms	Possible Causes	Controls & Comments
Oak		
General yellowing of tree or yellowing sections of tree; no wilting	Iron chlorosis, especially on pin and willow oak	Soil test; iron deficiency can usually be corrected by adjusting soil pH to 6.0; in severe cases, injections of iron can be made
Puckered, circular areas 1/2" in diameter on leaves; blisters are yellowing at first, then turn brown; leaves may drop	Oak leaf blister (fungal disease)	Rake up and destroy affected leaves

Diagnostic Key: Ornamental Trees & Shrubs

Symptoms	Possible Causes	Controls & Comments
Brown, dead areas on leaves, extending out to leaf margins; no trunk damage evident	Anthracnose (fungal disease)	Use registered fungicide; rake up and destroy fallen leaves
	Scorch, caused by hot, dry weather	Anthracnose can be confused with scorch if leaf lesions have enlarged and coalesced; if browning is mainly at leaf margins, it is probably scorch or the disease bacterial scorch
	Various other fungal leaf spots (anthracnose is probably the most common	Submit sample for laboratory analysis; rake up and destroy fallen leaves
	Bacterial scorch	No control
Leaves wilt, turn bronze color, and drop off; no trunk damage evident	Dry soil	Water tree deeply
	Oak wilt (fungal disease)	Submit sample for laboratory analysis
	Soil compaction	Relieve compaction; consult certified arborist
Galls on leaves or branches	Gall wasps	Oaks are subject to attack by dozens of species of gall wasps. The tree is not harmed even by heavy infestations
Photinia		
Circular, gray leaf spots with purplish borders; tiny black specks in centers of spots; defoliation	Entomosporium leaf spot (fungal disease) (see photo 2H)	Use registered fungicide on a regular basis throughout the season; avoid pruning and fertilizing plants in summer
Pine		
Cream-colored pustules containing bright orange or yellow spores form on needles; sides of pustules are papery in appearance; needles may drop	Needle rust (fungal disease)	Fungicides usually not necessary; remove goldenrods and asters around pines: these are alternate hosts of the fungus
Rough, elongated, swollen areas with yellowish orange color develop on trunk and branches; sap may flow from these cankers; needles turn brown	White pine blister rust (fungal disease)	Submit sample for laboratory analysis; remove all currant and gooseberry bushes in a 1000-foot radius of tree (alternate hosts); prune out cankers
	Various other fungal cankers	Submit sample for laboratory analysis
Black, sooty substance covers needles and stems	Sooty mold, fungus very common on pine, grows on honeydew excreted by aphids and other insects	Not a disease; control aphids with registered insecticide
Small, circular spots or bands on needles; some needles may be brown from a spot all the way out to the tip	Brown spot or other needle cast	Submit sample for laboratory analysis; time of fungicide application depends on which disease it is
Needles turn reddish brown and remain attached to tree	Pine wood nematode, especially on Japanese black pine	Submit sample of lower branches for nematode analysis; remove and destroy affected trees immediately; control longhorn beetles with registered insecticide
	Dry soil	Water tree deeply
	Other environmental stress; e.g. soil compaction, gas leak	
	Fungal canker	Prune out cankers
	Fungal tip blight (any of several)	Submit sample for laboratory analysis
	Root-feeding nematodes	Submit soil sample for nematode analysis
	Mites	Use registered miticide
Needles turn brown from tips of branches back	Fungal tip blight (any of several)	Submit sample for laboratory analysis
	Dry soil	Water tree deeply
Tips of needles turn brown; two yellow bands about 1/8-1/4” wide appear across groups of needles; tree is otherwise healthy	Ozone injury, especially on white pine	Tree will recover if damage is not severe

Symptoms	Possible Causes	Controls & Comments
Clusters of caterpillar-like insects feeding on needles in groups	Sawflies	Use registered insecticide
Leader wilts, droops, and dies	White pine weevil	Prune out infested terminals; spray leader with registered insecticide in early April

Study Questions

111. Adjusting soil pH to 6.0 can correct problems of _____ deficiency in oak, which appear as general yellowing of the tree or tree sections.

112. Galls on leaves or branches of oaks are a symptom of _____.

113. Needle rust of pine can be controlled by removing: a) goldenrods and asters; b) apple trees; c) cedar trees; d) currants and gooseberries

114. Brown needle tips with yellow bands 1/8 to 1/4" wide across groups of needles on otherwise healthy trees are a symptom of: a) dry soil; b) mites; c) ozone injury; d) sawflies

115. When a pine leader branch wilts, droops, and dies, it is a symptom of _____.

Answers: 111 - iron; 112 - gall wasps; 113 - a; 114 - c; 115 - white pine weevil

Symptoms	Possible Causes	Controls & Comments
Rhododendron and Azalea		
Fleshy, thick, white galls form on leaves and/or flowers	Azalea leaf and petal gall (fungal disease) (see photo 2I)	Pick off and destroy galls
General leaf yellowing on all or part of plant	Improper soil pH	Soil test; rhododendron and azalea require acid soil
	Nutrient deficiency	Soil test
Small, pale, circular spots appear on undersides of flower petals; spots enlarge and appear white on colored flowers and brown on white flowers; flowers become limp and covered with white, fuzzy spore mass	Ovulinia petal blight (fungal disease), mainly on azalea	Use registered fungicide
Marginal leaf browning; leaves curl downward on rhododendron	Winter injury	Very common on rhododendron; always suspect this on samples submitted in early spring
	Scorch, caused by hot, dry weather	Supply water
	Salt injury	Do not overapply de-icing salt on sidewalks or drives near shrubs or trees
	Phytophthora root rot (fungal disease) (see photos 2J & 2K)	Submit sample (include roots) for laboratory analysis
	Phytophthora dieback (fungal disease that attacks from stem tips)	Submit sample for laboratory analysis
	Botryosphaeria dieback (fungal disease)	Submit sample for laboratory analysis; prune out dead branches; consult pruning manual for proper technique when doing routine pruning; the fungus often invades pruning wounds or stressed tissue; protect plants from winter injury
Brown spots on leaves	Various fungal leaf spots	Submit sample for laboratory analysis
	Physiological leaf spot, cause unknown	Easily confused with fungal leaf spot
	Foliar nematodes	Submit sample for laboratory analysis

Diagnostic Key: Ornamental Trees & Shrubs

	Symptoms	Possible Causes	Controls & Comments
	Leaves with yellow specks on upper surface; black, shiny spots on undersurface	Lace bugs	Use registered insecticide
Rose			
	Black, circular lea spots with feathery edges surrounded by yellow halo; leaves drop	Black spot (fungal disease) (see photo 2L)	Use registered fungicide; plant resistant cultivars
	Spots of various colors on leaves that do not fit above descriptions	Various fungal leaf spots	Submit sample for laboratory analysis
	Various patterns of yellow and green on leaves, including streaks, rings, vein clearing (yellow veins), or blotches	Viral disease	Common on roses; these viruses mainly enter through grafts and are not transmitted from plant to plant; purchase healthy stock; maintain shrub vigor by watering and fertilizing; not necessary to remove shrub
	General or interveinal chlorosis	Nutrient deficiency	Soil test
		Waterlogged soil	Improve drainage
	Branches die back; sunken or swollen discolored areas which may be covered with tiny black specks appear on branches	Various fungal cankers	Very common problem on rose; prune out cankers; no fungicides are registered; prevents stress from other diseases and environmental problems; prune near side shoot or bud; do not leave long pruning stubs
	Plants wilt; lower leaves may turn yellow	Dry soil	Supply water
		Verticillium wilt (fungal disease)	Use resistant varieties; do not replant in same area
		Root knot (nematode problem)	Check roots for knots; soil fumigation; plant in another area
		Waterlogged soil	Improve drainage
		Transplant shock	Water regularly after transplanting
	Flowers wilt, develop spots, or fail to open and become covered with fuzzy, grayish mold	Botrytis blight (fungal disease)	Remove and destroy affected flowers; fungicides for black spot should control this disease
	Flower buds fail to open; blooms are deformed with brown streaks or spots on petals	Thrips	Use registered insecticide
	Shoots and foliage have an abnormal red color; stems appear thick and succulent; rapidly elongating shoots; shoots with shortened internodes; stems with an overabundance of pliable thorns; new growth may have many branches that create a witch's broom (similar to glyphosate injury); distorted or dwarfed leaves (similar to 2,4-D injury); deformed buds and flowers; abnormal flower color; lack of winter hardiness; spiral cane growth	Rose rosette (viral disease)	Virus is spread by eriophyid mites; choose healthy nursery stock without any of the symptoms mentioned here; remove any wild multiflora roses within 100 yards of the landscape; space plants well to allow for mature growth to slow potential of mites from spreading from plant to plant
Spruce			
	Needles on branches near ground turn brown; branches die back; needles may drop or remain attached; dried, white pitch may ooze from bark	Cytospora canker (fungal disease) especially on Colorado and Norway spruce	Prune dead branches back to trunk
	Older, inner needles of branches appear speckled with dull yellowish blotches; later needles turn brown or purple from tips back and drop; tiny black specks in rows on needles can be seen with a hand lens	Rhizosphaera needle blight (fungal disease)	Use registered fungicide
		Other fungal needle blights	If you don't see the black specks, you may have a different fungal needle blight; submit sample for laboratory diagnosis

Symptoms	Possible Causes	Controls & Comments
Willow		
Willow is very susceptible to a number of different fungal cankers. See general section for description of canker symptoms. Prune out and destroy cankered branches.		

Study Questions

116. Improper soil pH for rhododendrons and azaleas results in: a) fleshy, thick white galls; b) profuse flowering; c) brown, dead patches; d) general leaf yellowing on all or part of the plant

117. Symptoms of _____ on azaleas are leaves with yellow specks on the upper surface and black, shiny spots on the undersurface.

118. Black, circular leaf spots with feathery edges surrounded by a yellow halo on roses are a symptom of: a) black spot; b) virus disease; c) dry soil; d) underfertilization

119. Deformed roses with brown streaks or spots on petals and failure of buds to open are signs of _____.

120. Cytospora canker of spruce can be controlled by: a) pruning; b) watering; c) transplanting; d) all of the above

Answers:
116 - d; 117 - lace bugs; 118 - a; 119 - thrips; 120 - a

Annual & Perennial Flowers

Most flower problems can be diagnosed from the general problems category. Only very common problems or those with very striking symptoms are listed in the specific categories.

Symptoms	Possible Causes	Controls & Comments
Problems common to many annual and perennial flowers		
Plants wilt; flowers may drop and leaves may turn yellow	Dry soil	Supply water
	Waterlogged soil	Improve drainage
	Transplant shock	Do not transplant in heat of day; water regularly after transplanting
	Verticillium wilt (fungal disease)	Submit sample for laboratory analysis; replant in another area
	Root and stem or corm rot (fungal disease or bacterial disease)	Plant in well-drained soil; destroy affected plants
Seedlings wilt, stems turn brown and soft and may be constricted at the soil line	Damping-off (fungal disease)	Plant in well-drained soil; destroy affected plants
	Wrong season	Plants have specific day length requirements for flowering
	Cool weather	
	Insufficient light	Do not plant sun-loving plants in shade
	Too much nitrogen	Do not overfertilize; nitrogen stimulates foliage, not flowers
	Immature plants	Biennials and perennials often do not flower in the first year
	Undersized bulbs	

Diagnostic Key: Annual & Perennial Flowers

Symptoms	Possible Causes	Controls & Comments
Too many small flowers	Plants not disbudded	Some flowers; e.g. chrysanthemum, need to have some buds removed to produce large flowers
Tall, “leggy” plant; stem and foliage pale or yellow	Insufficient light	Plant in location where plant species will receive adequate light
General yellowing of leaves; yellowing may be interveinal; plants may be stunted; no wilting	Nutrient deficiency	Soil test
Grayish white powdery growth on leaves	Powdery mildew (fungal disease)	Use registered fungicide
Pustules containing orange, yellow, or brown powdery substance	Rust (fungal disease)	Use resistant varieties if available; use registered fungicide on leaves
Brown, dead spots on leaves	Fungal, bacterial, or foliar nematode disease (any of several)	Submit sample for laboratory analysis
Brown, dead areas on margins of leaves	Scorch, due to hot, dry weather	Supply water
	Salt injury	Do not plant near sidewalks or drives that were de-iced in winter
	Chemical injury	Not common in home gardens
Flowers wilt or fail to open; grayish mold appears on flowers in moist weather	Gray mold (fungal disease)	Pick off and destroy affected flowers; use registered fungicide
Yellow and green mottle or mosaic pattern on leaves	Viral disease (any of several)	Remove affected plants; do not touch healthy plants after diseased ones; control insects
Tiny white flecks on leaves	Ozone injury	
	Spider mites	Use registered miticide
Clusters of insects on stems or undersides of leave; leaves may be curled or distorted	Aphids	Use registered insecticide
Leaves chews or completely eaten	Various insects	Submit insect for laboratory identification
	Slugs	Use slug bait
Light-colored tunnels or blotches in leaves	Leafminers	Use registered insecticide
Tiny, white-winged insects on undersides of leaves	Whiteflies	Use yellow sticky boards (smeared with grease) to trap insects or use registered insecticide
White, cottony masses on leaves or stem	Mealybugs	Use registered insecticide
Chrysanthemum		
Flowers distorted and abnormally colored; rosetting of florets may occur; yellow and green mosaic, mottle, or ring pattern may appear on leaves	Viral disease (any of several)	Destroy affected plants; insect control

Study Questions

121. Bacterial stem rot and leaf spot of geranium can be controlled by: a) planting in well-drained soil; b) picking off affected leaves; c) avoiding overhead watering; d) all of the above

122. On gladiolus flowers, aster yellows can be differentiated from poor growing conditions because: a) aster yellows cause large flowers; b) poor growing conditions cause twisted flower spikes; c) aster yellows cause twisted foliage; d) poor growing conditions also cause wilting

123. A control for penicillium corm rot of gladiolus does NOT include: a) destroying affected corms; b) rotation; c) dipping corms in a fungicide; d) storing bulbs in a cool, wet location

124. Rust disease of hollyhock is different from rust diseases of other plants because: a) it doesn’t have an alternate host; b) it has an alternate host; c) the symptoms can not be seen with a hand lens;

d) the rust attacks the flowers only

125. _____ is spread by the iris borer.

126. Alternaria blight of marigold appears as: a) round, corky galls on lower stems; b) numerous small brown spots on leaves, stems, and flowers; c) wilted plants; d) green flowers

127. Bands of bleached, dead tissue on upper and lower leaf surfaces of petunias with pinched or twisted leaf edges are caused by _____.

128. Streaked, spotted or irregular tulip flowers are infected with _____.

129. Wilt of zinnia plants is NOT caused by: a) waterlogged soil; b) dry soil; c) virus disease; d) bacterial wilt.

Answers:
121 - d; 122 - c; 123 - d; 124 - a; 125 - bacterial soft rot; 126 - b; 127 - smog; 128 - viruses; 129 - c

Symptoms	Possible Causes	Controls & Comments
Green-colored flowers instead of normal color; upper branches of flowering stem are yellowish and upright	Aster yellows (mycoplasma disease)	Destroy affected plants; control insects
Brown, dead flowers	Thrips	Prune off flowers or use insecticide
Daylily		
Greenish yellow spots that enlarge and turn orange-brown on leaves; flowers are normal	Russet spot, cause unknown	Common to certain varieties
	Fungal or bacterial leaf spot (any of several)	Submit sample for laboratory analysis
Geranium		
Corky, raises spots on lower leaf surfaces	Oedema, a physiological program associated with overwatering	Do not overwater; ivy geraniums are especially prone to oedema
Plants wilt; brown or black rotted area evident at base of stem; brown spots may be present on leaves	Fungal or bacterial root and stem rot (any of several)	Plant in well-drained soil; remove dead plants
Pie-shaped brown areas or small brown spots on leaves; rot may be present on lower stems	Bacterial stem rot and leaf spot	Plant in well-drained soil; pick off affected leaves; avoid overhead watering; remove and destroy affected plant debris
Gladiolus		
White streaked flowers	Viral disease	Destroy affected plants; control insects; do not plant near vegetable garden since two major gladiolus viruses also infect plants in bean and cucumber family
Plants are thin with weak leaves that turn yellowish green; flower spikes are twisted and distorted and may be green	Aster yellows (mycoplasma disease)	Destroy affected plants; weed control; insect control
	Poor growing conditions	Aster yellows could be confused with poor growing conditions, but twisted flowers are an indication of disease
Plants stunted; flowers small and faded; leaves yellow from tips back; corm may be rotted; corm discolored internally	Fusarium yellows (fungal disease)	Destroy affected plants; rotate; soak corms in registered fungicide before planting
	Various fungal corm rots	Same as above
	Waterlogged soil	Improve drainage
Plant stunted and yellowed; corm rotted with blue-green powdery mold on surface	Penicillium corm rot (fungal disease)	Destroy all affected corms; store corms in cool, dry place before planting; dip corms in registered fungicide before planting; rotate

Diagnostic Key: Annual & Perennial Flowers

Symptoms	Possible Causes	Controls & Comments
Sunken, black lesions covered with shiny, varnish-like substance surrounded by raised, brittle rims on corms; after planting, tiny, raised reddish-brown specks appear on leaf bases; leaf specks become soft	Scab (bacterial disease)	Destroy affected corms; rotate
Whitish streaks on leaves; flowers deformed and discolored	Gladiolus thrips	Use registered fungicide
Hollyhock		
Yellow to orange spots on upper leaf surfaces; small, brown pustules on corresponding lower leaf surfaces	Rust (fungal disease)	Pick off and destroy affected leaves; use registered fungicide; rust is mentioned here because symptoms are slightly different from those on other plants; symptoms on other plants are described in the general section. This rust does not have an alternate host. Destroy all diseased plant tissue in the fall
Iris		
Leaves turn yellow and wilt; if pulled gently, leaves detach from plant; soft, slimy, smelly rot at base of plant; rhizomes may have holes	Bacterial soft rot, spread by iris borer	Dispose of infested plants in fall; use registered insecticide to control iris borer when plants are 5-6” tall
Oval, watersoaked leaf spots that later turn tan and blight the entire leaf	Heterosporium leaf spot	Remove all debris in the fall: use a registered fungicide when leaves are 4-6” tall
Marigold		
Plants wilt; leaves wither; lower stem discolored inside and out	Fungal stem rot	Destroy affected plants; rotate; plant in well-drained soil
	Fusarium wilt (fungal disease)	Same as for stem rot
Round, corky galls on lower stem and roots	Crown gall (bacterial disease)	Destroy affected plants; rotate
Numerous small brown spots on leaves, stems, and flowers	Alternaria blight	Use registered fungicide
Peony		
New shoots wilt and turn black; flowers, buds, leave, and stems turn brown and leathery; gray fuzzy mold may appear in wet weather	Gray mold (fungal disease)	Prune out affected plant parts; use registered fungicide
	Phytophthora blight (fungal disease)	Same as for gray mold except severely affected plants should be destroyed and new peonies should not be planted in same spot
	Cold injury	
Petunia		
Bands of bleached, dead tissue appear on upper and lower leaf surfaces; leaf edges are pinches or twisted	Smog injury	No control
Snapdragon		
Pale, yellow spots appear on upper leaf surfaces; reddish pustules of spores appear on upper leaf surfaces in concentric rings	Rust (fungal disease)	This is mentioned here because it is slightly different from other brown rusts in that the pustules form concentric rings; used registered fungicide
Tulip		
Stems are very short and flowers bloom at ground level	Warm spring and/or inadequate winter cooling	Place tulip bulbs in paper bags in fall and chill in refrigerator before replanting

Symptoms	Possible Causes	Controls & Comments
Light or dark colored spots on leaves and flowers; spots enlarge to form large, gray blotches; fuzzy brown or gray growth appears on spots during wet weather; leaves and stems are distorted	Botrytis blight (fungal disease)	Destroy affected plants; rotate; do not plant spotted bulbs; use registered fungicide
Flowers streaked, spotted, or mottled in an irregular pattern; leaves may also be streaked or mottled	Viral disease (any of several)	Destroy affected plants; insect control; do not plant variety Rembrandt near other tulips: its showy streak patterns are caused by a virus which may infect other plants; Parrot tulips also streak but this is genetic and not caused by a virus
Zinnia		
Small, dark brown, angular spots on leaves and flowers; flowers may be completely blighted	Bacterial spot	Submit sample for laboratory analysis; use bleach-treated seed
	Various fungal diseases	Submit sample for laboratory analysis
Reddish-brown, circular spots with grayish white centers; flowers may also have spots	Alternaria blight (fungal disease)	Use registered fungicide
Plants wilt; no sign of root rot	Dry soil	Supply water
	Waterlogged soil	Improve drainage
	Bacterial wilt	Submit sample for laboratory analysis

Study Questions

130. One way to avoid transplant shock of annuals and perennials is to: a) not transplant in spring; b) reduce watering; c) not transplant in the heat of day; d) not apply mulch

131. Too much nitrogen can result in: a) pale, leggy plants b) failure to flower; c) too many small flowers; d) general yellowing of leaves

132. Grayish-white powdery growth on leaves of annuals and perennials is a sign of _____.

133. Light colored tunnels on perennial leaves are caused by _____.

134. Mealybugs appear as: a) clusters of red insects on undersides of leaves; b) white, cottony masses on leaves and stems; c) brown, dead flowers; d) tiny, white winged insects on undersides of leaves

135. Green colored chrysanthemum flowers are a symptom of _____.

Answers:
130 - c; 131 - b; 132 - powdery mildew; 133 - leaf miners; 134 - b; 135 - aster yellows

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Chapter 9
Pesticide Use & Safety

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Revised by *Stephanie Blevins, Consumer Education Project Coordinator, Virginia Tech Pesticide Programs (2015)*

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Pesticides are chemicals used to control pests. In most state and federal laws, they are defined as 'economic poisons' -- substances used to prevent, kill, repel, or mitigate the harmful effects of pests. Pesticides may be useful when nonchemical methods fail to provide adequate pest control. Pesticides are valuable gardening tools, but they must be selected and used with personal and environmental safety in mind. As with all tools, it is important to use the right pesticide for the job. Pesticides must be used properly to be effective. Safe use requires careful management.

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Introduction

Pests

Most organisms are not considered pests. However, certain situations may occur that prompt an organism to be termed a pest. Organisms are considered pests when they:

* Compete with desirable plants or animals;
* Damage food, fiber, structures, or other materials that humans need or value;
* Cause or spread disease; and
* Annoy humans by stinging or biting.

People want to control pests that can harm them, damage property, or lower their quality of life. It is important to correctly define an organism as a pest, and verify the identity of the pest, before making any pest management decisions.

Pest Management and Decision Making

Before using any pesticide, there are important questions to ask and decisions to make. Start by identifying or describing the problem. Then ask yourself:

* Is the problem actually caused by a pest?
* If so, what kind of pest?
* Is the problem severe enough to require action?
* Can the pest be controlled at this stage of its life or growth cycle?
* What control options are available? Is pesticide use the best management option?
* Are there effective, legal, and manageable chemical control options for this site and situation?
* Is pesticide use cost-effective? Is the plant or damage observed worth the control effort?

In general, here are some factors to consider when making pest management decisions:

* Pest life cycle and habits,
* Pest population size and distribution,
* Factors that attracted the pest to the site,
* Management options, both chemical and nonchemical, and
* Ways to prevent future problems.

Safe use Precautions

Following safety precautions and using common sense can prevent pesticides from causing unintended and unnecessary harm. Before buying a pesticide, identify the pest to be controlled. Then read the label of each product you consider buying. Choose a product that is both labeled for the site you wish to treat and effective against the pest you want to control. Consider only those products you have the equipment and expertise to handle. If there is a choice of several products, select the least hazardous one. Contact your local Extension office or consult the Pest Management Guide for Home Grounds and Animals (VCE Publication 456-018: http://pubs.ext.vt.edu/456/456-018/456-018.html) for pest management recommendations.

Some pesticides are intended specifically for use in the home garden. These products are packaged in small quantities, i.e., pints, quarts, and ounces. Their label directions are less technical than those intended for occupational users. Although they are still dangerous if used improperly, pesticides intended for home grounds and pets are seldom highly toxic. Most are either ready-to-use or contain relatively low concentrations of the active ingredient(s).

Products packaged for agricultural and professional/commercial use may appear to be less expensive, ounce per ounce, than 'homeowner' products. However, home gardeners should not buy them. These products are often more toxic than comparable products intended for home use. This is because they are highly concentrated, and/or contain highly toxic active ingredients. Most require special protective clothing and application equipment. These products are usually in large containers, which means the homeowner will have more material than he or she can use in a reasonable time or store safely. In addition, they are difficult to mix correctly, since rates are usually given on a per-acre basis.

Read the label before purchasing a pesticide to be sure you can use it according to the label directions. Before using a pesticide, read the label again. Be sure you have the proper handling and measuring devices, application equipment, and protective clothing. Read the mixing instructions and application directions. Note any special handling instructions, specific warnings, and precautions.

Note days to harvest (preharvest intervals) for food crops, sites that may (and may not) be treated, and any other special instructions. For example, some pesticides labeled for use on home garden fruits and vegetables may have limits on the frequency of applications or the number of treatments that can be applied in a season.

Pesticide Terminology

The words "insecticides" and "pesticides" are often incorrectly interchanged or used as though they had the same meaning. However, as you can see from the information below, an insecticide is just one type of pesticide.

Type of Pesticide	Pesticide Function
Acaricides	Control mites, ticks, and spiders
Attractants	Lure pests (to a trap or bait)
Avicides	Control birds
Bactericides	Control bacteria
Disinfectants (antimicrobials)	Control microorganisms
Fungicides	Control fungi
Growth Regulators	Stop, speed up, or otherwise change normal development processes
Herbicides	Control plants
Insecticides	Control insects
Miticides	Control mites
Nematicides	Control nematodes
Repellents	Keep pests away
Rodenticides	Control rodents

Terms which describe how to use pesticides	
Band	Application to a strip over or between each crop row
Broadcast	Uniform application to an entire area
Dip	Immersion in a pesticide
Directed	Aiming the pesticide at a target, for example, at a specific plant or part of a plant
Drench	Saturating the soil with a pesticide
In-furrow	Application to or in the furrow in which a plant is growing
Spot treatment	Application of a pesticide to a small section or area of a crop
Sidedress	Application along the side of a crop row

Pesticide Modes of Action - How Pesticides Work (many work in more than one way)	
Contact insecticides and fungicide -	Kill pests simply by touching them
Stomach poison insecticides -	Kill pests when swallowed, or when treated materials are eaten
Systemic pesticides -	Are absorbed or ingested and circulate in the body (for example, in the blood of an animal or sap of a plant)
Contact herbicides -	Affect only the plant parts that are sprayed
Translocated herbicides -	Are absorbed and move from the point of initial application to circulate throughout the plant
Selective pesticides -	Affect only certain kinds of plants or animals. For example, 2,4-D is used for lawn weed control because it kills many broadleaf plants but does not harm most grasses
Nonselective pesticides -	Kill many pests in a category. For example, the herbicide gylphosate kills many/most plants
Protectant fungicides -	Are a preventative measure against certain diseases. You must apply protectants to the plant host before the fungus has a chance to invade
Curative/Eradicant fungicides -	Cure fungal disease

The Pesticide Label

In order for a pesticide to be sold, purchased, or used in the United States, the pesticide must be registered by the Environmental Protection Agency (EPA). Registration decisions are based on the agency's examination of: the ingredients of the pesticide; the intended application site; the amount, frequency, and timing of use; and storage and disposal practices.

The EPA assesses both risks and benefits of a product. They only register those pesticides the agency has determined – that when used in accordance with label directions – will not have unreasonable adverse effects on humans, the environment, and non-target species. A product cannot be legally sold, purchased, or used as a pesticide until it is registered with the EPA's Office of Pesticide Programs. The agency must review each application submitted by the manufacturer for active ingredient registration and product labeling.

Federal law defines pesticide labeling as all of the print information and graphics (label, booklet) attached to or sold with the product. The pesticide label is a binding legal agreement between: the product registrant (manufacturer), the EPA, and the end user.

No pesticide may be sold in the U.S. until the EPA has reviewed the manufacturer's application for active ingredient registration and each pesticide label to make sure it meets their required criteria for approval. The pesticide label must provide the user with all the necessary information on how to safely and effectively use the pesticide, properly store the pesticide, and properly dispose of the pesticide and it's container. Pesticide users are required to follow all label directions. Using a pesticide in any manner that is inconsistent with the labeling is against the law.

The pesticide label gives the user instructions on how to use the product safety and correctly. Everything you need to know to use a product legally, safely, and effectively is on the label. Pesticide users are required by law to follow all label directions.

Specific parts of the label identify the product, its hazards and precautions for handlers, and directions for proper use, storage, and disposal.

Brand name: Each company uses brand names to identify its products. The brand name is displayed plainly on the front panel of the label.

Ingredient statement: The ingredient statement must list the chemical name* and amount (as a percentage by weight of the total product) of active and inert ingredients. The label must also show what percent of the total contents are inert ingredients.

** Pesticides have complex 'official' chemical names describing their chemical composition. Some have also been given a shorter name, or common chemical name, to make them easier to identify. A product label may use either the chemical name or the common name to identify the active ingredient(s).*

EPA registration number: A registration number must be on every pesticide label. It shows that the product has been registered with the EPA for the uses listed on the label. A specific EPA registration number identifies each pesticide product.

EPA establishment number: The establishment number identifies the facility where the pesticide was made.

Name and address of manufacturer: The law requires the maker or distributor of a product to print the name and address of the company on the label.

Net contents: The front panel of the pesticide tells you how much product is in the container. This can be expressed in gallons, pints, pounds, quarts, or other units of measure.

Type of pesticide: The front panel usually indicates in general terms what the pesticide will control. This statement may also indicate how the product may be used.

Type of formulation: The same pesticide may be available in more than one formulation. Sometimes the

formulation of a specific product is written on the label or is part of the product name (ex. Liquid concentrate, Granule, Dust.)

Restricted-use designation: When a pesticide is classified as restricted, the label will state "Restricted-Use Pesticide" in a box at the top of the front panel. Below this heading may be a statement describing the reason for the restricted-use classification. Restricted-use products are not for home and garden use.

Precautionary statements: Precautionary statements identify hazards associated with use of the product, how to avoid them, and first aid for exposures. The product's toxicity is described by the signal word. All pesticide products carry a child hazard warning statement. The Precautionary Statements section of a label may also include personal protective equipment (PPE) requirements, user safety requirements and recommendations, environmental hazards, and physical or chemical hazards.

Signal words and symbols: Pesticides may be poisonous to humans or animals. You can tell how toxic a product is by the Signal Word on the label.

Signal Word	Approximate Human Toxicity	Lethal Dosage
Danger	High	A drop to a tea-spoonful
Warning	Moderate	A teaspoonful to a tablespoonful
Caution	Low, or relatively nontoxic	More than an ounce

Pesticides with the "Danger-Poison" signal word (skull and crossbones symbol) are restricted-use, and only available to trained and state-certified applicators. Pesticides with a "Danger" label are generally not sold in the lawn and garden trade. Many products may bear the child-hazard warning statement "Keep Out of Reach of Children."

First Aid (Statement of practical treatment): The label provides emergency first aid instructions and describes the types of exposure requiring medical attention. Four routes of exposure that can be harmful include ingestion (swallowing), inhalation (inhaling vapors), ocular (eyes) exposure, and dermal (skin) exposure.

Personal protective equipment: The protective clothing and equipment you must use when handling the product are listed here.

Engineering controls: If there are any special handling devices required for use of a product, they will be described/discussed here.

Hazards to humans and domestic animals: This section must be included if a product is hazardous to humans or domestic animals. It will tell you if and how a product may harm people and animals. It will also describe any special steps necessary to avoid exposures.

Environmental hazards: The label tells how to avoid harm to the environment--- including water, soil, air, and beneficial insects, plants, and/or wildlife. Some examples are: "This product is highly toxic to bees exposed to direct treatment on blooming crops or weeds. Do not apply this product -or expose it to- blooming crops or weeds when bees are actively visiting the treatment area;" and "Do not apply directly to water. Exercise caution when disposing of waste as groundwater contamination may result from careless handling or spills."

Physical and chemical hazards: This section lists any specific fire, explosive, or chemical hazards the product may have.

Directions for use: This section describes where, when, and how to apply the product, how much to use, and how to handle from start to finish. These instructions will:

* Identify the crops, animals, or locations that can be treated legally and safely with the product.
* Describe anything you must do - or not do - to prevent contamination to sensitive areas of exposure of nontarget species.
* List the pests the product will control.
* Explain how the product should be applied (application equipment or methods to use).
* Tell you when to apply this product (season, pest or host growth stage; restrictions based on temperature, weather, or time of day, if any).
* Tell you how often this product may/should be applied.
* List the pre-harvest interval(s) and how long to stay out of treated areas, if applicable.
* Tell you how much to use (how much to mix).
* Give you instructions regarding storage and disposal.

Pesticides labeled for use on food crops usually have a preharvest interval. The preharvest interval is a period between the time of application and the time it is safe to pick and use the crop. A preharvest interval is usually expressed as "days to harvest". It is often listed as a number in parentheses following the crop name. This is the time required for a pesticide residue to drop to a safe level. It is a mistake to assume that a residue can be washed off.

Some "homeowner" pesticide products instruct you to keep people or pets out of treated areas for a short period of time, or until certain conditions are met. For example, the label of some granular products say that children and pets may re-enter after the treated area has been watered and allowed to dry. Others instruct you to keep people and pets out of treated areas until sprays have dried or dusts have settled.

Misuse statement: This section will remind you that it is a violation of federal law to use a product in a manner inconsistent with its labeling.

Emergency assistance: Instructions for how to contact the company for emergency information are listed here.

In Summary:

Pesticide product labels provide instructions for all steps of pesticide use. Applicators must read, understand, and follow label directions carefully.

* Pesticides may not be applied to any plant, animal, or site not listed on the product label.
* Materials may not be applied at higher rates or more frequently than the label directs.
* Pesticide applicators are required to follow label directions for transport, mixing, loading, application, storage, and disposal of pesticides and pesticide containers.

READ THE LABEL:

* Before purchase, and
* Before, during, and after each use.

PESTICIDE LABEL DIRECTIONS ARE NOT ADVICE; THEY ARE LEGAL REQUIREMENTS. THE LABEL IS THE LAW!

Pesticide Formulations

The formulation describes the physical state of a pesticide. Pesticides are usually formulated as a mixture of active and inert ingredients. They are rarely sold or applied at full strength. The chemical in the pesticide formulation that actually kills the pest(s) is called the active ingredient. The added chemical(s), which dilute the pesticide and make it easier and safer to handle, are the inert (inactive) ingredients.

Pesticide active ingredients are often available in several formulations. You should choose a formulation that is right for the job. Common pesticide formulations are listed below.

Aerosols (A)

These are very low-concentrate solutions, usually applied as a fine spray or mist. They are generally sold in pressurized cans or pump-style atomizer bottles.

Baits (B)

A bait formulation is made by adding the active ingredient to an edible or attractive substance. Baits are often used to control ground-dwelling foraging insects and rodents.

Dusts (D)

Dusts are made by adding the active ingredient(s) to a fine, inert powder or talc. Dusts are ready-to-use and do not require further dilution or mixing.

Granules (G) or Pellet (P)

Granular formulations are similar to dust formulations, except the particles are larger and heavier. These coarse particles are made from an absorptive material such as clay. The active ingredient either coats the outside of the granules or is absorbed into the particles. The amount of

active ingredient is usually low. Granular pesticides are ready-to-use.

Emulsifiable Concentrates (EC or E)

In an EC, the active ingredient is mixed with an organic solvent (often petroleum derivatives), forming an emulsion. They are made to be diluted with water and applied - as a spray or soil drench, for example. ECs are common in the home garden trade. They should be protected from excessive heat and cold which can break down the emulsifier. Because they contain organic solvents, ECs may damage some materials or surfaces and may be phytotoxic.

Concentrates (C) / Liquid Concentrates (LC)

This is a liquid that will form a true aqueous solution when mixed. Like an EC, it is diluted with water for application.

Ready to Use Solutions (RTU)

These liquid formulations contain the correct amount of active ingredient, solvent, and adjuvant when you buy them. No further dilution or mixing is required. Often, they are packaged in a spray bottle applicator.

Wettable Powders (WP)

Wettable powder formulations are made by combining the active ingredient with a fine powder. A WP may look like a dust, but it is made to be mixed with water and applied as a spray, with its particles suspended in water. WPs need continuous agitation to maintain the particles in suspension. This feature makes them difficult for home gardeners to use. When mixing and loading a WP, first mix the quantity needed with a small amount of water, forming a slurry. Add some water to the spray tank, then add the pesticide slurry, and finally the remainder of the water. The spray tank must be shaken frequently to keep the particles from settling.

Water-Dispersible Granules (WDG)/ Dry Flowables (DF)

A pesticide formulated as a water-dispersible granule (also called a dry flowable) is like a wettable powder, but compacted into small granules. Once in water, the granules break apart into a fine powder. WDG/DF formulations have a lower inhalation hazard compared to wettable powders. They are also easier to measure and mix since they are measured by volume rather than by weight. Each batch is sold with a specially calibrated measuring device. Like wettable powders, they form a suspension, instead of a solution or emulsion, when mixed with water. They must be agitated to prevent them from settling in the spray tank during the application process.

Adjuvants & Pesticide Compatibility

An adjuvant is a chemical that is added to a pesticide formulation or mix that affects how the pesticide works. Adjuvants do not have pesticidal properties, therefore are not registered with the EPA. However, they are listed on the label as part of the formulation. If adjuvant is not already present in the formulation, recommendations for adding adjuvants will appear on the label as necessary. They are sold separately from pesticides unless already included in a formulation.

Adjuvants are incorporated into pesticide formulations or mixes to improve the action of the pesticide, or to modify the properties of the formulation or mix for better application. There are many types of adjuvants. They include: wetting agents, emulsifiers, invert emulsifiers, plant penetrants, drift control additives, thickeners, safeners, compatibility agents, buffers or pH modifiers, antifoaming agents, spreaders, stickers, and extenders. Some of these common adjuvants, like wetting agents and spreaders, are considered surfactants.

Surfactants contain surface-active ingredients that affect the dispersing, spreading, and wetting properties of spray droplets. When added to a pesticide, a surfactant reduces the surface tension between two unlike materials, such as a spray film and a solid surface. For example, by adding a surfactant to a sprayer, oil and water will mix and can be sprayed on plant surfaces. With increasing emphasis on safe application of pesticides, such factors as droplet size, spray pattern, and pesticide drift have focused more attention on surfactants to give ideal coverage for pesticides.

Surfactants that act as spreading, sticking, and wetting agents are most useful when spraying the hard-to-wet foliage of such plants as azalea, boxwood, camellia, carnation, conifer, euonymus, gardenia, gladiolus, holly, iris, narcissus, peony, rose, and yew. Whether a spray rolls off or sticks to a plant surface depends on the physical and chemical properties of the spray mixture and the physical properties of the surface itself. If the surface tension of the mixture is high or if the plant surface is waxy, the spray droplets will roll off.

A spreader or film extender (spreader-activator) is a substance that, when added to a pesticide mix, increases the area that a given volume of spray will cover and improves the contact between the pesticide and the plant surface. A spreading agent builds spray deposits and improves weatherability. Most wettable powder insecticides benefit from the addition of a spreader.

A sticker or adhesive is a material that, when added to a spray mix or dust, improves the adherence (tenacity) to a plant surface rather than increasing the initial deposit. Commercial sticking agents are oily in consistency and increase the amount of suspended solids retained on plant surfaces by coating the particles with a resin or varnish-like film. Most fungicides, especially wettable powders, benefit greatly from the use of stickers.

A wetting agent is a material that, when added to a pesticide, lowers the interfacial tension between a liquid and a solid, in this case, a plant surface. Effectiveness is measured by the increase in spread of a liquid over a solid surface and the ability of the spray film to make complete contact with it. When a wetting agent reduces surface tension, spreading naturally occurs.

All commercial spreading, sticking, and wetting agents should be mixed strictly according to label directions. Adding more surfactant than recommended may cause excessive runoff, resulting in a poor spray deposit and reduced pest control. Make sure to follow all label directions and recommendations concerning surfactants and adjuvants exactly.

Compatibility occurs when two or more pesticides can be mixed together without reducing their effectiveness or harming the target. Not all pesticides are compatible. Synergism occurs when two materials used together produce a greater effect than the sum of the materials used alone. Example: Chemical A kills 60%, Chemical B kills 20%, Chemical A and B together kill 98% of the pests. Synergism may increase control or reduce the amount of pesticide needed to do a job. It may also be harmful because it causes injury to the plant or animal that the pesticides were intended to protect. Chemicals should not be mixed and applied together unless the label specifically says they are compatible and gives instructions for tank mixing.

Study Questions

1. When choosing pesticides, always look for one that: a) contains adjuvants; b) contains the most potent active ingredients; c) contains the least hazardous active ingredients; d) is least expensive

2. The pesticides that are absorbed or ingested and circulate in the body are called _____.

3. Which signal word would be found on a highly-toxic pesticide?:
a) Danger; b) Warning; c) Caution; d) Poison

4. The pesticide formulation(s) that requires constant agitation to maintain particle suspension is/are:
a) emulsifiable concentrate; b) granules; c) dry flowable; d) wettable powders

5. An _____ is a chemical added to a pesticide formulation or mix to increase their effectiveness or safety.

6. What are the most logical FIRST steps in pest management decision-making?
a) Calibrate your application equipment and study the site before making an application; b) Choose a product suited for the site, situation, and pest. Be sure you have the equipment and expertise to use it as directed; c) Evaluate the problem. Identify the pest causing it; d) Learn about this pests's life cycle, and when chemical control measures are most likely to be successful

7. Which pesticide formulation is NOT ready-to-use?
a) bait; b) dust; c) emulsifiable concentrate; d) granule

8. You should read a pesticide product's label BEFORE you purchase it, even if you have used the product in the past, so you can: a) compare prices; b) ensure that you can use the product on the site (place, plant, etc.) you want to treat; c) identify the pest; d) review the mixing directions and compute the application rate

9. Where can you find out what protective clothing you need to wear and what equipment you should use when handling a pesticide? a) compatibility chart; b) the pesticide label; c) the EPA's website; d) Virginia Cooperative Extension's Pest Management Guide (PMG)

10. If you want to control broadleaf perennial weed in a lawn, the BEST choice would be a product that contains an active ingredient that is a) contact; b) non-selective; c) stomach poison; d) selective

Answers:
1 - c; 2 - systemic; 3 - a; 4 - c and d; 5 - adjuvant; 6 - c; 7 - c; 8 - b; 9 - b; 10 - d

Personal Safety

For pesticide handlers, risk management = pesticide management!

In general, two factors determine your risk when handling a pesticide: your exposure to it and its inherent toxicity. The best way to manage risk is by reducing exposure through quality decision-making and proper pesticide use. Using a combination of integrated pest management (IPM) methods can help minimize pest issues. IPM is a mixture of nonchemical and chemical control strategies. If the decision is made to use a chemical control, careful product selection, such as picking the least toxic chemical, can help minimize exposure. Safe work habits, using engineering controls, and using personal protective equipment (PPE) can also help minimize exposure. PPE provides an additional line of defense to prevent accidental exposure. Select ready-to-use products that are sold in an application device whenever possible to minimize or eliminate the need to handle during measuring, mixing, and loading. There is no substitute for working safely. Be prepared. Read the label before you buy or apply any pesticide, and follow label directions to the letter.

Personal Protective Equipment

The product label lists the minimum personal protective equipment (PPE) required for handling the pesticide. Requirements and recommendations for PPE vary, and depend on the toxicity and formulation of the product. Protective clothing items are often the minimum amount of PPE required for pesticide application.

Minimum protective clothing items for pesticide users are: a long-sleeved shirt, long-legged pants (or a cotton coverall garment), socks, and shoes. Use of unlined chemical-resistant (ex: neoprene or nitrile) gloves, an apron, and goggles or a face shield is recommended for mixing and loading. A wide-brimmed waterproof hat protects the head and the back of the neck.

Consider using additional PPE for "high hazard" situations, such as:

* Mixing concentrate and loading an application device
* Making a broadcast spray application with hand-held equipment (if you must walk through areas where sprays have not dried)
* Application with hand-carried equipment (excluding "spot spraying")
* Walking into a recently-treated area
* Treating an enclosed space
* Using an aerosol (especially indoors)
* High-exposure applications such as powder dusters, aerosols (especially indoors)
* Making an application directed upwards and overhead.

After using any pesticide, wash your hands and arms thoroughly with soap and water. Never eat, drink, or smoke while handling pesticides or before washing your hands after you've finished.

If you have been doing a lot of spraying or dusting, remove your clothes, take a shower, and put on clean clothes. Protective clothing should be laundered separately from the family wash. The washer should be run through one wash cycle with only detergent and water -- no clothes -- after cleaning pesticide-contaminated clothing.

If you spill pesticide on yourself or your clothing, shower immediately. Use first aid procedures if necessary.

Safety Precautions

Pesticides can cause severe illness or even death if misused. Eating or drinking the product causes many accidental pesticide poisonings. In theory, this should never happen. However, it can occur if pesticides are stored where young children can get into them, or if they are transferred to an unlabeled container. Some applicators are injured when they breathe a pesticide vapor or when a pesticide comes into contact with their skin. Always use safety precautions, and treat all pesticides with respect. To prevent accidents with pesticides, use and store them properly in their original containers. Take care to follow all label directions.

Symptoms of Pesticide Poisoning

Awareness of the early symptoms and signs of pesticide poisoning is important. Unfortunately, all pesticide poisoning symptoms are not the same. Each chemical family affects the human body in a different way. Common insecticides like organophosphates and carbamates injure the nervous system. The symptoms develop in stages, usually occurring in this order:

Mild Poisoning or Early Symptoms of Acute Poisoning: Fatigue, headache, dizziness, blurred vision, excessive sweating and salivation, nausea and vomiting, stomach cramps, or diarrhea.

Moderate Poisoning or Intermediate Symptoms of Acute Poisoning: Symptoms described above become more severe. In addition, new symptoms may include: inability to walk, weakness, chest discomfort, muscle twitches, or constriction of pupil of the eye.

Severe or Acute Poisoning: Unconsciousness, severe constriction of pupil of the eye, muscle twitches, convulsions, secretions from mouth and nose, breathing difficulty. Death may occur if the person is not treated.

In cases of acute poisoning, ill effects appear soon after exposure-- usually within 24 hours. Acute effects are usually obvious and often reversible if the appropriate medical care is given promptly. If you begin to feel ill more than 12 hours after exposure to a pesticide, you may have some other problem. Check with your physician to be sure.

Emergency Procedures

Read the First Aid section (which may be called the "Statement of Practical Treatment") on each label. The directions can save lives. In pesticide emergencies, the best first aid is to stop the exposure as soon as possible.

If a pesticide gets on the skin, wash it off as quickly as possible. Remove all contaminated clothing. Prompt action may prevent sickness even when the spill affects a large area of the body. Detergents work better than soap in removing pesticides. Don't forget to wash hair and fingernails.

If you get pesticide in your eye, flush the eye quickly but gently. If you have an eyewash, use it. If not, hold the eyelid open and wash the eye with a gentle drip of clean running water. Position yourself or the victim so the stream of water flows across the eye rather than directly into it. Rinse for at least 15 minutes.

In case of acute poisoning, seek medical attention immediately. If you call a physician, give the victim's name, age, and sex. Identify yourself and your relationship to the victim. As with any poisoning incident, have the pesticide packaging on hand. Tell the physician what chemical was involved (and how much) and how the victim was exposed. Describe the incident to the best of your ability. If you take a victim to a hospital, take the pesticide container or the labeling with you. However, transport it safely. Never carry a pesticide container in the passenger space of a car or truck.

In the case of a poisoning emergency, assistance is available from Virginia's Poison Control Centers. The telephone number of the nearest Poison Control Center, along with other emergency information, is listed in the Introduction section of the Virginia Cooperative Extension Pest Management Guides. To purchase one of these guides or to ask about emergency information in advance, contact your local Extension agent.

Protecting the Environment

Protecting Insect Pollinators

Gardeners should give special consideration to protecting insect pollinators and other beneficial insects from insecticide poisoning. There is detailed information

about pollinator protection in the Home Grounds and Animals Pest Management Guide. Often, insecticide labels recommend restricted application times to protect pollinators. Bees are not active in late evening and early morning. In general, evening applications are least hazardous to bees. Do not apply insecticides to plants in bloom. Do not apply insecticides when temperatures are unusually low because residues will remain toxic much longer. If possible, choose an active ingredient that is relatively non-toxic to bees. Also, if possible, use products formulated as granules, liquid concentrates that are diluted and sprayed, or ready-to-use spray solutions rather than dusts or sprays made from wettable powders or water-dispersible granules/dry-flowables.

Persistence and Accumulation

Most pesticides break down quickly, remaining in the environment only a short time before being changed into harmless products. However, some pesticides break down slowly and stay in the environment for a long time. These are called persistent pesticides. Some persistent pesticides can build up in the bodies of animals, including humans. These pesticides are called accumulative. Most persistent pesticides have very limited usage or have been removed from the market.

Pesticide Movement

Pesticides cause problems when they move off target. This may mean drifting in the form of airborne dust or fine mist, moving with soil particles by erosion, leaching through the soil, being carried out as residues on crops or livestock, or evaporating and moving with air currents.

Pesticides should be directed to the target. To minimize drift, do not apply them on hot or windy days. Applications can be managed in a light, steady breeze. However, if strong or gusty winds come up while you are working, stop immediately. Reduce drift by using low pressure and a nozzle with a large opening (orifice), which will produce large spray droplets. Generally, the safest time of day to spray to reduce the hazard of drift is early morning or late in the evening.

Vaporization (or volatilization) is the evaporation of an active ingredient during or after application. Pesticide vapors can cause injury. High temperatures increase vaporization. Choose pesticide formulations that do not evaporate easily, if possible. If the pesticide label has temperature restrictions, observe them. Some products and formulations, like 2,4-D ester formulations, are very volatile and can move for miles under favorable conditions. They should not be used near highly sensitive plants like grapes and tomatoes.

Do not mix or load where a spill will contaminate water. Do not apply pesticides close to a well, creek, pond, or other water supply.

Sources of Information

You can access information about pesticide properties by reading the product label and its Material Safety Data Sheet. You can also find science-based, referenced information about pesticide active ingredients from the Extension Toxicology Network (EXTOXNET): http://extoxnet.orst.edu/

The EXTOXNET website includes a list of active ingredient properties (including toxicological effects, ecological effects, environmental fate, physical properties, and exposure guidelines) which may be accessed directly from this page: http://extoxnet.orst.edu/pips/ghindex.html

Integrated Pest Management

Integrated Pest Management, or IPM, is a well-rounded management approach to pest control that can reduce the need for pesticides. Damage to plants by pests is minimized by prevention and control techniques that get at the root causes of the problem. Prevention is achieved through good cultural practices, choosing pest-resistant plant varieties, encouraging beneficial insects, and close monitoring of pest population levels. Once a pest problem has developed, control may be achieved through physical removal of the pests, biological controls, use of a pesticide, or other means. Often, control is as simple as pruning out an infested branch.

IPM does not mean forgoing chemical pesticide use altogether. It does mean understanding your pest problem before applying pesticide so you can use the proper chemical at the proper time for your particular insect or disease. This not only can greatly reduce the amount of pesticide you use, but also can result in fewer serious insect infestations because the natural predators of pests are able to survive and keep pests in check. Furthermore, using less pesticide reduces potential harm to our water resources. Always carefully diagnose plant problems before deciding to treat plants with pesticides.

Application Equipment

Using the same spray equipment for weed and insect control is neither safe nor desirable. No matter how well a tank is rinsed after using some herbicides, a residue may be left in the tank, gaskets, hoses, and other parts. If the same equipment is then used to spray a plant with insecticide or fungicide, the herbicide residue may kill or injure the plant. The wisest policy is to maintain two sprayers, one for herbicides and another for insecticides and fungicides. Have them clearly labeled according to use pattern.

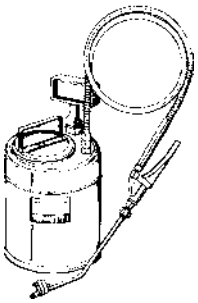
Sprayers should be rinsed after each use. Don't forget to flush hoses and nozzles. Proper rinsing will keep sprayers clean and in good working order. Also, replace nozzles when they begin to show signs of wear and tear.

Pesticide application equipment comes in all shapes, sizes, types, and prices. Select equipment that best suits your application needs.

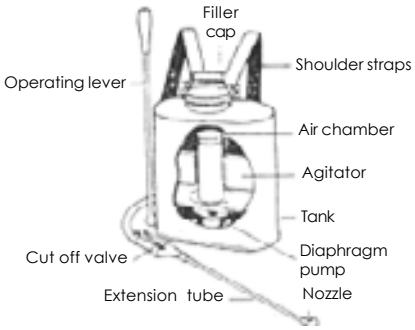
Compressed Air Sprayer

(Backpack or tank sprayer) Spray is mixed in a small tank (generally one to four gallons). The tank is carried like a backpack, over the shoulders. A hand-operated pump supplies pressure during application. A single nozzle releases the spray at the end of a hand-held wand. Most do not have in-tank agitation. As a result, it is difficult to apply a wettable powder with this type of equipment because such a spray mixture requires agitation. The applicator has excellent control over coverage, making this sprayer a good choice for treating dwarf fruit trees, vegetables, and ornamentals. Spray will not reach into tall trees. Water weighs more than 8 lbs. per gallon. Therefore, small tanks are easier to carry than large tanks.

Compressed Air Sprayer

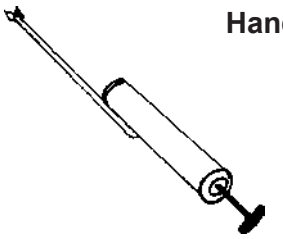


Two-gallon Hand Held Sprayer



Details of Backpack Sprayer

Five-gallon Backpack Sprayer



Hand Duster

Hand Duster

The duster may consist of a squeeze tube or shaker, a plunger that slides through a tube, or a fan powered by a hand crank. Uniform coverage of foliage is difficult to achieve with many dusters. Dusts are more subject to

drift than liquid formulations due to their light weight and poor sticking qualities. Many dust formulations are sold in dispenser canisters.

Sprayer Calibration & Application Techniques

All pesticide labels have mixing and application instructions. Some pesticides give application rates in teaspoons, tablespoons, or ounces per gallon. For example, a herbicide label may direct the user to make a 1% solution by mixing three tablespoons per gallon, and to use this mixture to "spot-spray"--- wet the foliage of the weeds to be controlled. In this instance, there is no need to calibrate application equipment. However, the spray must be directed to the target, and coverage instructions must be followed.

Other labels give rates of application in volume per unit area, for example, teaspoons per 100 square feet or ounces per 1000 square feet. This is often true for lawn herbicides and insecticides. Pesticides with rates given in volume per area must be delivered by properly calibrated equipment. Unfortunately, some consumers solve this problem by guessing how much to use. This can be dangerous and wasteful. Too concentrated may be phytotoxic; too little may be ineffective. It is irresponsible to apply chemicals at improper rates. It is dangerous to the applicator, his or her neighbors, and the environment.

The calibration of a backpack sprayer is relatively easy. Sprayers should be calibrated regularly by the applicator who will use them.

Calibration procedure is as follows:

Start with a clean sprayer, set up exactly as it will be used.

Calculate the area to be treated. Multiply length times width to determine the area of a rectangle. The area of a triangle is calculated by multiplying the base times the height and dividing by 2. Most areas can be calculated by combining rectangles and triangles or subtracting triangles from rectangles.

Choose and mark off a test area.

For small applications, a calibration test area between 1/5 and 1/4 the size of the actual area to be treated is recommended. For example, if you plan to treat 1000 square feet, you should calibrate using a test area of 200 to 250 square feet.

You can either determine the swath width of the sprayer and set up a linear course, or simply mark off an area.

Ex: 5 x 50 or 2.5 x 100 = 250 square feet;

Ex: 4 x 50 or 2 x 100 = 200 square feet.

Fill your sprayer (about ½ full), and pump it to the normal operating pressure.

Time yourself as you spray the test area with water at your normal walking speed.

Spray into a bucket for the same amount of time it took you to spray the test area.

Pour the water from the bucket into a graduated container. This will allow you to measure the volume you would apply to the test area accurately.

Calculate the volume of water and pesticide you need to treat the target area. For example, if you used one gallon to treat 200 square feet, you will need five gallons to treat 1000 square feet. If the pesticide label instructs you to apply it at a rate of one quart per 1000 square feet, you dilute one quart in five gallons and spray the five gallons uniformly over the target area.

Area spray applications should be continuous and uninterrupted. If a herbicide is being applied, the sprayer should not be slowed down or stopped at each weed. If the herbicide has been mixed correctly and the sprayer is properly calibrated, the continuous uninterrupted flow of chemical will be sufficient for good weed control.

If possible, direct spray applications so you will not walk through just-treated, wetted areas while spraying. If you must apply a broadcast spray to a wide area, use a pattern that forms an arc no more than 3 to 4 feet on either side of the operator. The sprayed area should have a small amount of overlap to ensure proper coverage. A good method for ensuring proper coverage when applying granules is to cut the application rate in half and apply the pesticide first in an east-west pattern, then in a north-south direction.

When applying pesticides, wear the protective clothing and equipment that the label requires. To prevent spillage of chemicals, always check spray application equipment for leaking hoses or connections, plugged, worn, or dripping nozzles before adding pesticide. Check openings/gates of granular application devices (rotary or drop spreaders). Before applying a pesticide, clear all people, pets, and livestock from the area.

Diagrams: Broadcast Spray Pattern for a Single Application (A) and a Double/Split Granular Application (B)

Storage & Disposal

Storage

Always read the pesticide label for specific storage requirements. The chemical and the container in which it is purchased must be maintained in good condition. This is necessary to ensure that the material remains useful, and to avoid environmental or human health hazards.

Design or designate a pesticide storage area that meets the following requirements:

* Secure
* Well-ventilated
* Properly lit when in use
* Dry
* Protected from temperature extremes
* Spacious enough to hold all materials and allow for separation of herbicides, fungicides, insecticides, and fertilizers
* Constructed in such a manner that leaks and/or spills may be contained.

A good storage area is safe from unwanted visitors - especially children and animals. Good lighting and ventilation are important to protect the health of anyone using the storage area. Proper ventilation can also prevent chemicals from affecting other materials in storage. It is essential to store pesticides where their fumes cannot invade areas used by people or pets. Group stored chemicals by type as a precaution against cross-contamination. Dampness is a serious problem, as it reduces the shelf life of many chemicals and causes metal and paper containers to decompose. It is imperative that storage areas be designed so that there is no danger of chemicals being washed into our water by flooding or by accidental spills into water drains. Freezing or high heat are dangerous because temperature extremes may cause containers to rupture. Extreme heat and cold may also cause physical or chemical changes in some pesticide formulations. Such changes may make the product ineffective and/or cause plant injury. If specific temperature ranges are required for proper storage, they will be printed on the product label. Finally, the storage area should be set up so that leaks and spills are contained. Contained spills can be cleaned up without compromising the soil and water quality in the vicinity.

Locate your storage area where cleanup materials (absorbent, broom, dustpan, water, etc.) are near at hand. Keep pesticides in their original containers. Do not store pesticides with or near food, medicine, cleaning supplies, seed, or animal feed. Do not store flammable materials with pesticides.

Organize the materials in storage so they are accessible and visible. Place opened containers in clear plastic bags or see-through plastic containers. This will allow for easy identification of products while containing leaks and helping to avoid accidental spills. Mark all containers with the date of purchase. Keep a written inventory of materials on hand, and use older chemicals first. A storage inventory helps in planning purchases next season. Useful records may include product name, active ingredient, date of purchase, record of use, and date and volume stored. Routinely inspect your storage area. Check containers for damage or leaks.

Disposal

Waste minimization and careful planning can reduce or eliminate disposal problems. Buy only the amount of pesticide you need for a job or for the growing season. Consider small volume containers, even if you pay more for the active ingredient. Look for pesticides packaged in ways that reduce or eliminate container waste. Choose products formulated to simplify measuring and mixing. Often ready-to-use products are the best choice for small pest management jobs.

Disposal options for pesticide concentrates depend on the legal status of the product. If it is legal to use, the best way to dispose of a pesticide is by proper use. You may use it yourself or give it to another gardener. Consult your local Extension agent if in doubt. Other methods for disposal of unmixed product include:

* Following label disposal directions,
* Returning it to the point of sale or manufacturer, and
* Participating in a household hazardous waste collection program.

Earth 911 (1-800-CLEANUP or www.earth911.com) is another source of information about disposal and waste collection programs.

Never pour pesticides down the sink, into the toilet, or down a sewer or street drain.

If no community waste collection program or guidance exists, EPA's Citizen's Guide to Pest Control and Pesticide Safety (2005) directs the following:

"In general, to dispose of less than a full container of a liquid pesticide, leave it in the original container with the cap tightly in place to prevent spills or leaks. Wrap the container in several layers of newspapers and tie it securely. Put the package in a covered trash can for routine collection with municipal trash. If you do not have a regular trash collection service, take the package to a permitted landfill (unless your town has other requirements).

Wrap individual packages of dry pesticides in a tight carton or bag and tape or tie the package closed. Put the package in a covered trash can for routine collection."

Note: EPA recommends that no more than one gallon of liquid or 5 pounds of dry pesticide should be disposed of in this manner at one time. Homeowners should use this disposal method only for small quantities of household, lawn, or garden pesticides and only as a last resort!

Careful planning should prevent the problem of dealing with excess mixed pesticide. Pesticide mixes should NOT be stored. Excess mix has only one good disposal option: application to a legal site according to label directions. This means that the site (plant, place) must be listed on the product label, and the amount applied in this and any other application does not exceed label rates. The best way to deal with leftover pesticide mixes is to avoid having any.

Take care that rinse water does not become a pollutant. Water collected from cleaning equipment can be used for another 'batch' or applied to a properly labeled site.

Empty, rinsed, and drained pesticide containers should be disposed of according to label directions. In most cases, these can be placed in household trash. Empty product containers made of plastic or metal should be punctured to prevent re-use before discarding. However, do not puncture (or burn) a pressurized container - it may explode!

If you have questions about proper pesticide disposal, contact your local solid waste management agency, Virginia Department of Agriculture and Consumer Services (Office of Pesticide Services), or your local Extension office.

Spill Management

The best defense is to work carefully, but be prepared to deal with splashes or spills. Keep PPE and spill cleanup materials handy, close to the place where you

mix concentrates and load application equipment. In case of an accident, refer to the product label for directions for spill management. If there are no specific directions regarding spill remediation, remember the three C's: Control, Contain, then Cleanup.

Control the spill by first taking steps to protect yourself and others. Put on PPE if you will need to handle a leaking container or may be exposed when controlling a spill. Stop the source. This may be as simple as placing a leaking container into a larger, chemical-resistant one or setting a fallen container upright. Do not leave a spill unattended until it is cleaned up.

Contain the spill by confining it...use dirt, kitty litter, newspaper, vermiculite, sand, or absorbent pads, "pillows", or "snakes" to contain (and absorb) a liquid spill. You can protect dusts, granules, or powders by covering them up or by misting them lightly with water. Do not apply water---that will just spread the material over a wider area and make clean-up more difficult.

Clean up the spill by first sweeping up the spilled solid or absorbed liquid + sorbent. Apply the spilled material (and sorbent if any) to a legal site. If this is not possible, place it in a heavy-duty plastic bag and dispose of it as you would unwanted product (see previous section). Decontaminate the spill area (ex. remove soil and apply to legal site, neutralize solid surfaces with vinegar or household ammonia and wash the affected spot with heavy-duty detergent, treat soil with activated charcoal). Clean all PPE and the equipment used to contain the spill as directly by the pesticide label.

Things to keep on hand in case you need to handle a small spill include: chemical-resistant gloves; absorbent materials for containing/absorbing liquid spills (such as sawdust, pet litter, vermiculite, or paper); a shovel, broom, and dustpan; vinegar or ammonia and heavy-duty detergent; any other spill cleanup materials specified on the labels of products you use; and a sturdy plastic bag.

Pesticides and the Law

The United States Environmental Protection Agency (EPA) and the Virginia Department of Agriculture and Consumer Services (VDACS) are the regulatory agencies charged with enforcing pesticide laws and regulations. Under the Federal Insecticide, Fungicide, and Rodenticide Act, it is illegal to use a pesticide on a site unless that site (plant, animal, place) is listed on the label. You may not exceed the rate of application or number of applications directed by the label.

You are liable for misuse of pesticides on your property. Recent court rulings extend your liability to include misuse by commercial applicators you hire. Serious misuse by home gardeners may result in drift on to other people's property, leaching of a pesticide into water supplies, or other problems related to application of a pesticide contrary to label directions.

Some pesticide products are extremely hazardous to humans and/or to the environment. The EPA classifies these products as RESTRICTED USE PESTICIDES (RUP). A certificate issued by the Virginia Department of Agriculture and Consumer Services is required to purchase a RUP product. Only qualified applicants may sit for the examination(s) that lead to certification in Virginia. Private Applicator certification is intended for commercial growers producing agricultural commodities on their farms or on land they lease. Commercial Applicator and Registered Technician certification is required for all others who use pesticides as part of their job duties. The certification system and RUP products are NOT intended for the home gardener.

Choosing the Right Pesticide

Avoid problems by taking the time to study your pesticide needs carefully. Your local Extension agent or certified nursery employee can help with pesticide recommendations, as well as help you tailor the application to the site intended. Personal and environmental safety are prime concerns.

Consider the Site: Read the label of each product under consideration to be sure that it can be used in the place and the manner you intend. For example, if the label indicates that the material is toxic to fish, do not use it on plants along the border of a pond. If the label requires that you wait two weeks from the time that you spray until you harvest, it should not be used on vegetables or fruit that are almost ripe. Similarly, if the product label lists only ornamental uses, do NOT apply it to fruits or vegetables; if a specific product gives application instructions for some types of vegetables but not others, use it ONLY on the crops discussed in the Directions for Use section of the label. Consider all uses of the site to which the

pesticide will be applied and protect children, pets, and wildlife by careful pesticide selection and use.

What application equipment and personal protective equipment does the label require? Do you have the gear? If not, are you willing to purchase, use, and maintain it? Do you want a pesticide that must be mixed and loaded into a sprayer, or will a pre-mixed, "ready-to-use" product in a spray bottle be more appropriate for your needs?

Minimize Waste: You should purchase only the amount of pesticide you anticipate using in one season. Most pesticides have a limited shelf life. If pesticides are stored, they must be protected from extreme heat and cold, and must be kept in a secure, locked place. Read the storage section of the product label prior to purchase, and do not buy a product that you can't store as directed. Also, remember that pesticides must be kept in their original container with the label intact.

Choose the Least Toxic Product: Compare pesticides based on how hazardous they are. The signal word on the label indicates a product's toxicity. For example, products marked CAUTION are less toxic than products marked WARNING, and should be considered first.

Environmental Hazards are Reported on the Label: Be especially cautious with pesticides containing warnings regarding impacts on water.

Carefully Read the Disposal Directions: Be sure you can properly dispose of any unused or unwanted pesticide and the pesticide's container according to the manufacturer's recommended method.

If all else is equal, compare the cost per unit of active ingredient before making your final selection. Pesticides can be valuable gardening tools, but they must be selected with personal and environmental safety in mind. As with other tools, it is important to use the right pesticide for the job. Care and planning before pesticides are purchased can ensure safe and proper use.

Study Questions

11. Mild poisoning or early symptoms of acute poisoning include: a) vertigo, hot flashes, nausea; b) fatigue, headache, sweating, and salivation; c) inability to walk, chest discomfort, muscle twitches; d) unconsciousness, constriction of pupil of the eye, convulsions

12. A method of reducing pesticide spray drift would be to: a) spray on hot days; b) spray in the morning; c) spray at noon; d) water plants after applying pesticides

13. A pesticide storage area should be: a) well-ventilated; b) dry; c) protected from temperature extremes; d) all of the above

14. A method for reducing pesticide disposal problems would NOT include: a) buying small volume containers; b) buying ready-to-use containers; c) mixing unused product before storage; d) choosing products that simplify measuring and mixing

15. Pesticide products that are extremely hazardous to humans and/or the environment are classified as _____, and can only be purchased by Virginia-certified applicators.

Answers: 11 - b; 12 - b; 13 - d; 14 - c; 15 - restricted-use-pesticides

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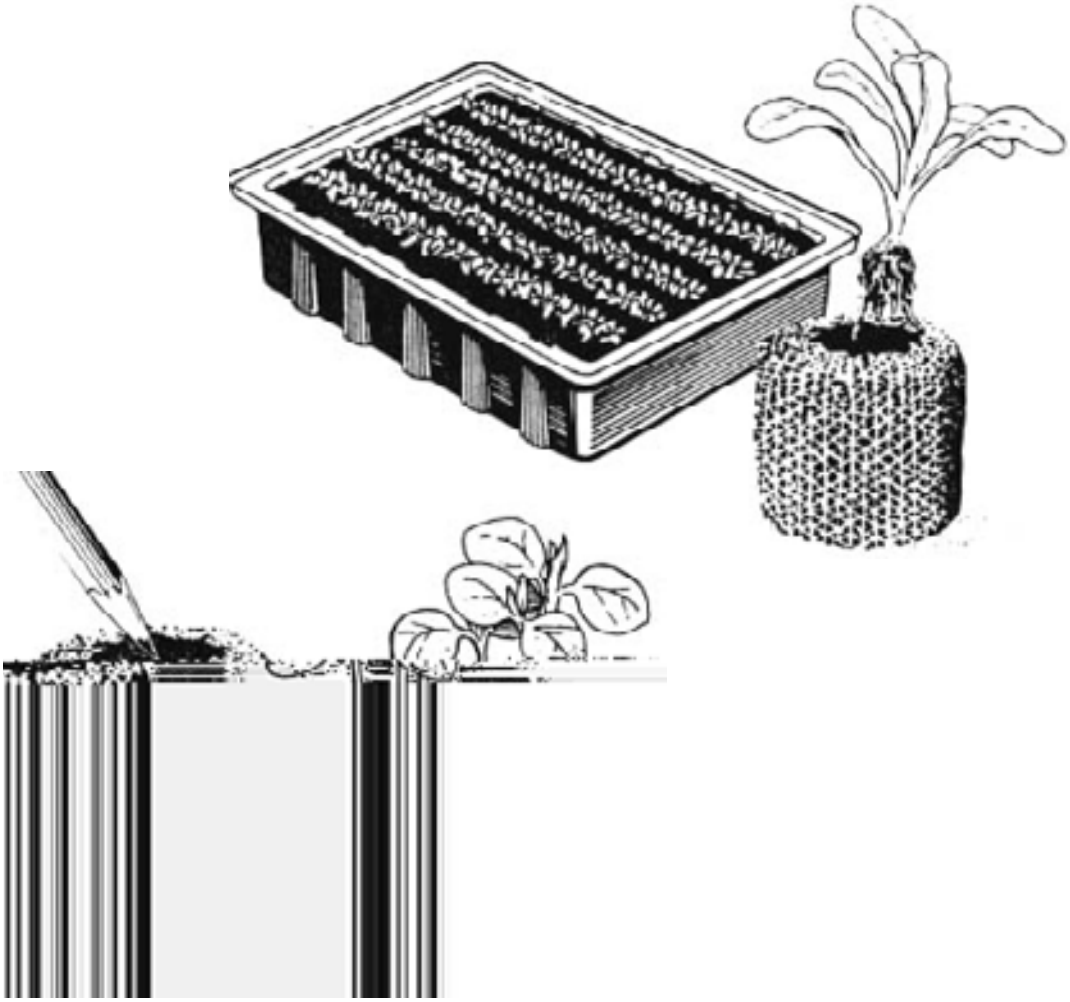
Plant Propagation

Chapter 10



Plant Propagation

Chapter 10

Revised by *Pamela H. Smith, Fairfax County Local Master Gardener Coordinator (2015)*
Diane Relf, Extension Specialist, Horticulture (2009)

Reviewed by *J. Roger Harris, Professor and Department Head, Department of Horticulture, Virginia Tech (2015)*

Plant propagation is the process of multiplying the numbers of or perpetuating a species or a specific individual plant. There are two types of propagation: sexual and asexual. Sexual reproduction requires the union of the sperm and egg and results in a plant with a new combination of genes. It involves the floral parts of a plant. Asexual propagation involves taking a part of one plant and causing it to regenerate itself into a new plant. Genetically it is identical to its "parent." Asexual propagation involves the vegetative parts of a plant: stems, roots, or leaves. The advantages of sexual propagation are that it may be cheaper and quicker than other methods; it may be the only way to obtain new varieties and hybrid vigor; in certain species, it is the only viable method for propagation, and it is a way to avoid transmission of certain diseases. Asexual propagation has advantages, too. It may be easier and faster in some species; it may be the only way to perpetuate some cultivars; and it bypasses the juvenile characteristics of certain species.

Contents

Sexual Propagation

Sexual propagation involves the union of the sperm (male) with the egg (female) to produce a seed. The seed is made up of three parts: the outer seed coat, which protects the seed; the a food reserve (usually the endosperm); and the embryo, which is the young plant itself (refer to Chapter 2: *Botany*). When a seed is mature, not in dormancy, and placed in a favorable environment, it will germinate, or begin active growth. In the following section, seed germination and transplanting of seeds will be discussed.

Seed

To obtain quality plants, start with good quality seed from a reliable dealer. Select varieties to provide the size, color, and habit of growth desired. Choose varieties adapted to your area which will reach maturity before an early frost. Many new vegetable and flower varieties are hybrids, which cost a little more than open pollinated types. However, hybrid plants usually have more vigor, more uniformity, and better production than non-hybrids and sometimes have specific disease resistance or other unique cultural characteristics.

Although some seeds will keep for several years if stored properly, it is advisable to purchase only enough seed for the current year's use. Good seed will not contain seed of any other crop, weeds, or other debris. Printing on the seed packet usually indicates essential information about the variety, the year for which the seeds were packaged, germination percentage you may typically expect, and notes of any chemical seed treatment. If seeds are obtained well in advance of the actual sowing date or are stored surplus seeds, keep them in a cool, dry place. Laminated foil packets help ensure dry storage. Paper packets are best kept in tightly closed containers and maintained around 40ºF in a low humidity environment.

Some gardeners save seed from their own gardens; however, if such seed are the result of random pollination by insects or other natural agents, they may not produce plants typical of the parents. This is especially true of the many hybrid varieties. (See Chapter 13: *The Vegetable Garden* for information on saving vegetable seed.) Most seed companies take great care in handling seeds properly. Generally, do not expect more than 65% to 80% of the seeds to germinate. From those germinating, expect about 60% to 75% to produce satisfactory, vigorous, sturdy seedlings.

Germination

There are four environmental factors which affect germination: water, oxygen, light, and heat.

Water

The first step in the germination process is the imbibition or absorption of water. Even though seeds have great absorbing power due to the nature of the seed coat, the

amount of available water in the germination medium affects the uptake of water. An adequate, continuous supply of water is important to ensure germination. Once the germination process has begun, a dry period will cause the death of the embryo.

Light

Light is known to stimulate or to inhibit germination of some seed. The light reaction involved here is a complex process. Some crops which have a requirement for light to assist seed germination are ageratum, begonia, browallia, impatiens, lettuce, and petunia. Conversely, calendula, centaurea, annual phlox, verbena, and vinca will germinate best in the dark. Other plants are not specific at all. Seed catalogs and seed packets often list germination or cultural tips for individual varieties. When sowing light-requiring seed, do as nature does and leave them on the soil surface. If they are covered at all, cover them lightly with fine peat moss or fine vermiculite. These two materials, if not applied too heavily, will permit some light to reach the seed without limiting germination and will help keep soil uniformly moist. When starting seed in the home, supplemental light can be provided by fluorescent fixtures suspended 6 to 12 inches above the seeds for 16 hours a day.

Oxygen

Respiration takes place in all viable seed. The respiration in dormant seed is low, but some oxygen is required. The respiration rate increases during germination, therefore, the medium in which the seeds are placed should be loose and well-aerated while still holding adequate water. If the oxygen supply during germination is limited or reduced, germination can be severely retarded or inhibited.

Heat

A favorable temperature is another important requirement of germination. It not only affects the germination percentage but also the rate of germination. Some seeds will germinate over a wide range of temperatures, whereas others require a narrow range. Many seed have minimum, maximum, and optimum temperatures at which they germinate. For example, tomato seed has a minimum germination temperature of 50ºF and a maximum temperature of 95ºF, but an optimum germination temperature of about 80ºF. Where germination temperatures are listed, they are usually the optimum temperatures unless otherwise specified. Generally, 65 to 75ºF is best for most plants. This often means the germination flats may have to be placed in special chambers or on radiators, heating cables, or heating mats to maintain optimum temperature. The importance of maintaining proper medium temperature to achieve maximum germination percentages cannot be over-emphasized.

Germination will begin when certain internal requirements have been met. A seed must not be in a dormant state, have a mature embryo, contain a large enough endosperm to sustain the embryo during germination, and contain sufficient hormones or auxins to initiate the process.

Methods of Breaking Dormancy

One of the functions of dormancy is to prevent a seed from germinating before it is surrounded by a favorable environment. In some trees and shrubs, seed dormancy is difficult to break, even when the environment is ideal. Various treatments are performed on the seed to break dormancy and begin germination. Most vegetable and flowering annuals do not have significant dormancy.

Seed Scarification

Seed scarification involves breaking, scratching, or softening the seed coat so that water can enter and begin the germination process. There are several methods of scarifying seeds. In acid scarification, seeds are put in a glass container and covered with concentrated sulfuric acid. The seeds are gently stirred and allowed to soak from 10 minutes to several hours, depending on the hardness of the seed coat. When the seed coat has become thin, the seeds can be removed, washed, and planted. Another scarification method is mechanical. Seeds are filed with a metal file, rubbed with sandpaper, or cracked with a hammer to weaken the seed coat. Hot water scarification involves putting the seed into hot water (170 to 212ºF). The seeds are allowed to soak in the water, as it cools, for 12 to 24 hours before being planted. A fourth method is one of warm, moist scarification. In this case, seeds are stored in nonsterile, warm, damp containers where the seed coat will be broken down by decay over several months.

Seed Stratification

Seeds of some fall-ripening trees and shrubs of the temperate zone will not germinate unless chilled underground as they overwinter. This so called “after-ripening” may be accomplished artificially by a practice called stratification.

The following procedure is usually successful. Put sand or vermiculite in a clay pot to about 1 inch from the top.

Place the seeds on top of the medium and cover with 1/2 inch of sand or vermiculite. Wet the medium thoroughly and allow excess water to drain through the hole in the pot. Place the pot containing the moist medium and seeds in a plastic bag and seal. Place the bag in a refrigerator. Periodically check to see that the medium is moist, but not wet. Additional water will probably not be necessary. After 10 to 12 weeks, remove the bag from the refrigerator. Take the pot out and set it in a warm place in the house. Water often enough to keep the medium moist. Soon the seedlings should emerge. When the young plants are about 3 inches tall, transplant them into pots to grow until they are ready to be set outside.

Another procedure that is usually successful uses sphagnum moss or peat moss. Wet the moss thoroughly, then squeeze out the excess water with your hands. Mix seed with the sphagnum or peat and place in a plastic bag. Seal the bag and put it in a refrigerator. Check periodically. If there is condensation on the inside of the bag, the process will probably be successful. After 10 to 12 weeks remove the bag from the refrigerator. Plant the seeds in pots to germinate and grow. Handle seeds carefully. Often the small roots and shoots are emerging at the end of the stratification period. Care must be taken not to break these off. Temperatures in the range of 35 to 45ºF (2 to 7ºC) are effective. Most refrigerators operate in this range. Seeds of most fruit and nut trees can be successfully germinated by these procedures. Seeds of peaches should be removed from the hard pit. Care must be taken when cracking the pits. Any injury to the seed itself can be an entry path for disease organisms.

Starting Seed Indoors

Media

A wide range of materials can be used to start seeds, from plain vermiculite or mixtures of soilless media to the various amended soil mixes. With experience, you will learn to determine what works best under your conditions. However, keep in mind what the good qualities of a germinating medium are. It should be rather fine and uniform (to promote good seed to soil contact), yet well-aerated and loose. It should be free of insects, disease organisms, and weed seeds. It should also be of low fertility or total soluble salts and capable of holding and moving moisture by capillary action. Traditionally, one mixture which has been used to supply these factors is a combination of 1/3 sterilized soil, 1/3 sand or vermiculite or perlite, and 1/3 peat moss. Most frequently today, seedlings are started in a synthetic soil mix compound of sphagnum peat moss and vermiculite. **Do not use garden soil by itself to start seedlings; it is not sterile, is too heavy, and will not drain well.**

The importance of using a sterile medium and container cannot be over-emphasized. The home gardener can treat a small quantity of soil mixture in an oven. Place the slightly moist soil in a heat-resistant container in an oven set at about 250ºF Use a candy or meat thermometer to ensure that the mix reaches a temperature of 180ºF for at least 1/2 hour. Avoid over-heating as this can be extremely damaging to the soil. Be aware that the heat will release very unpleasant odors in the process of sterilization. This treatment should prevent damping-off and other plant diseases, as well as eliminate potential plant pests. Growing containers and implements should be washed to remove any debris, then rinsed in a solution of 1 part chlorine bleach to 10 parts water.

An artificial, soilless mix also provides the desired qualities of a good germination medium. The basic ingredients of such a mix are sphagnum peat moss and vermiculite, both of which are generally free of diseases, weed seeds, and insects. Sphagnum peat moss also contains anti-fungal properties which can be beneficial for seedlings. The ingredients are also readily available, easy to handle, lightweight, and produce uniform plant growth. “Peat-lite” mixes or similar products are commercially available or can be made at home using this recipe: 4 quarts of shredded sphagnum peat moss, 4 quarts of fine vermiculite, 1 tablespoon of superphosphate, and 2 tablespoons of ground limestone. Mix thoroughly. These mixes have little fertility, so seedlings must be watered with a diluted fertilizer solution soon after they emerge.

Containers

Flats and trays can be purchased or you can make your own from scrap lumber. A convenient size to handle would be about 12 to 18 inches long, 12 inches wide, and 2 inches deep. Leave cracks of about 1/8-inch between the boards in the bottom or drill a series of holes to ensure good drainage.

You can also make your own containers for starting seeds by recycling such things as cottage cheese containers, styrofoam cups, the bottoms of milk cartons or bleach containers, and pie pans, as long as good drainage is provided. At least one company has developed a form for recycling newspaper into pots, and another has developed a method for the consumer to make and use compressed blocks of soil mix instead of pots.

Clay or plastic pots can be used, and numerous types of pots and strips made of compressed peat are also on the market. Plant bands and plastic cell packs are also available. Each cell or minipot holds a single plant which reduces the risk of root injury when transplanting. Peat pellets, peat or fiber-based blocks, and expanded foam cubes can also be used for seeding.

Seeding

The proper time for sowing seeds for transplants depends upon when plants may safely be moved outdoors in your area. This period may range from 4 to 12 weeks prior to transplanting, depending upon the speed of germination, the rate of growth, and the cultural conditions provided. A common mistake is to sow the seeds too early and then attempt to hold the seedlings back under poor light or improper temperature ranges. This usually results in tall, weak, spindly plants which do not perform well in the garden.

After selecting a container, fill it to within 3/4-inch of the top with moistened growing medium. For very small seeds, at least the top 1/4-inch should be a fine, screened mix or a layer of vermiculite. Firm the medium at the corners and edges with your fingers or a block of wood to provide a uniform, flat surface.

For medium and large seeds, make furrows 1 to 2 inches apart and 1/8 to 1/4-inch deep across the surface of the container using a narrow board or pot label. By sowing in rows, good light and air movement results, and if damping-off fungus does appear, there is less chance of it spreading. Seedlings in rows are easier to label and handle at transplanting time than those which have been sown in a broadcast manner. Sow the seeds thinly and uniformly in the rows by gently tapping the packet of seed as it is moved along the row. Lightly cover the seed with dry vermiculite or sifted medium if they require darkness for germination. A suitable planting depth is usually about twice the diameter of the seed.

Do not plant seeds too deeply. Extremely fine seed such as petunia, begonia, and snapdragon are not covered, but lightly pressed into the medium or watered in with a fine mist. If these seeds are broadcast, strive for a uniform stand by sowing half the seeds in one direction, then sowing the other way with the remaining seed in a crossing pattern.

Large seeds are frequently sown directly into some sort of a small container or cell pack which eliminates the need for early transplanting. Usually 2 or 3 seeds are sown per unit and later thinned to allow the strongest seedling to grow.

When planting seeds in a container that will be set out in the garden later, place 1 seed in a 2- to 3-inch container. Plant the seeds at only 1/2 the recommended depth. Gently press a little soil over the sprouted seed and then add about 1/4 inch of milled sphagnum or sand to the soil surface. These materials will keep the surface uniformly moist and are easy for the shoot to push through. Keep in a warm place and care for them as for any other newly transplanted seedlings.

Pregermination

Another method of starting seeds is pregermination. This method involves sprouting the seeds before they are planted in pots (or in the garden). This reduces the time to germination, as the temperature and moisture are easy to control. A high percentage of germination is achieved since environmental factors are optimum. Lay seeds between the folds of a cotton cloth or on a layer of vermiculite in a shallow pan. Keep moist, in a warm place. When roots begin to show, place the seeds in containers or plant them directly in the garden. While transplanting seedlings, be careful not to break off tender roots. Continued attention to watering is critical.

Watering

After the seed has been sown, moisten the planting mix thoroughly. Use a fine mist or place the containers in a pan or tray which contains about 1 inch of warm water. Avoid splashing or excessive flooding which might displace small seeds. When the planting mix is saturated, set the container aside to drain. The soil should be moist but not wet.

Ideally, seed flats should remain sufficiently moist during the germination period without having to add water. One way to maintain moisture is to slip the whole flat or pot into a clear plastic bag after the initial watering. The plastic should be at least 1 inch from the soil. Many home gardeners cover their flats with panes of glass instead of using a plastic sleeve. Keep the container out of direct sunlight, otherwise the temperature may rise to the point where the seeds will be harmed. Be sure to remove the plastic bag or glass cover as soon as the first seedlings appear. Surface watering can then be practiced if care and good judgement are used.

Temperature and Light

Several factors for good germination have already been mentioned. The last item, and by no means the least important, is temperature. Since most seeds will germinate best at an optimum temperature that is usually higher than most home night temperatures, often special warm areas must be provided. The use of thermostatically controlled heating cables is an excellent method of providing constant heat.

After germination and seedling establishment, move the flats to a light, airy, cooler location, at a 55 to 60ºF night temperature and a 65 to 70ºF day reading. This will prevent soft, leggy growth and minimize disease troubles.

Seed Germination Requirements

Plant	*Approximate time to seed before last spring frost*	*Approximate germination time (days)*	*Germination Temperature (°F)*	*Germinate in light (L) or dark (D) conditions*
Begonia	12 weeks or more	10-15	70	L
Browallia	12 weeks or more	15-20	70	L
Geranium	12 weeks or more	10-20	70	L
Larkspur	12 weeks or more	5-10	55	D
Pansy (Viola)	12 weeks or more	5-10	65	D
Vinca	12 weeks or more	10-15	70	D
Dianthus	10 weeks	5-10	70	-
Impatiens	10 weeks	15-20	70	L
Petunia	10 weeks	5-10	70	L
Portulaca	10 weeks	5-10	70	D
Snapdragon	10 weeks	5-10	65	L
Stock	10 weeks	10-15	70	-
Verbena	10 weeks	15-20	65	D
Ageratum	8 weeks	5-10	70	L
Alyssum	8 weeks	5-10	70	-
Broccoli	8 weeks	5-10	70	-
Cabbage	8 weeks	5-10	70	-
Cauliflower	8 weeks	5-10	70	-
Celosia	8 weeks	5-10	70	-
Coleus	8 weeks	5-10	65	L
Dahlia	8 weeks	5-10	70	-
Eggplant	8 weeks	5-10	70	-
Head lettuce	8 weeks	5-10	70	L
Nicotiana	8 weeks	10-15	70	L
Pepper	8 weeks	5-10	80	
Phlox	8 weeks	5-10	65	-
Aster	6 weeks	5-10	70	D
Balsam	6 weeks	5-10	70	-
Centurea	6 weeks	5-10	65	-
Marigold	6 weeks	5-10	70	D
Tomato	6 weeks	5-10	80	-
Zinnia	6 weeks	5-10	70	-
Cucumber	4 weeks or less	5-10	85	-
Cosmos	4 weeks or less	5-10	70	-
Muskmelon	4 weeks or less	5-10	85	-
Squash	4 weeks or less	5-10	85	-
Watermelon	4 weeks or less	5-10	85	-

Some crops, of course, may germinate or grow best at a different constant temperature and must be handled separately from the bulk of the plants.

Seedlings must receive bright light after germination, and natural daylight (even that from a south-facing window) is most often not adequate enough to produce viable seedlings indoors. Instead, place the seedlings under a fluorescent light. Use two 40-watt, cool-white fluorescent tubes or special plant growth lamps. Position the plants 6 inches from the tubes and keep the lights on about 16 hours each day. As the seedlings grow, the lights should be raised. When seedlings have formed 1 to 2 sets of true leaves they are ready to be transplanted.

For information on planting seeds outdoors, see Chapter 13: The Vegetable Garden.

Study Questions

1. A seed is made up of three parts: _____, _____, and _____.
2. Of the four environmental factors that affect germination, the one that affects both the germination percentage and the germination rate is: a) water; b) light; c) temperature; d) oxygen.
3. An example of seed stratification is: a) soaking seeds in concentrated sulfuric acid; b) rubbing seeds with sand paper; c) soaking seeds in hot water; d) putting seeds in the refrigerator for 10-12 weeks.
4. Characteristics of a good germination media do NOT include: a) well-aerated and loose; b) high in fertility; c) fine and uniform texture; d) low in total soluble salts.
5. Large seeds are generally planted to a depth of _____ their diameter.
6. Mist systems are preferred over manual watering because: a) it promotes uniform watering; b) it prevents overwatering; c) it prevents drying out; d) all of the above.
7. A good night temperature for most seedlings is: a) 45-50ºF; b) 55-60ºF; c) 65-75ºF; d) it doesn't matter, as long as it is the same during the day.

Answers:
1 - endosperm, embryo, seed coat; 2 - c; 3 - d; 4 - b; 5 - twice; 6 - d; 7 - b

Transplanting and Handling

If the plants have not been seeded in individual containers, they must be transplanted to give them proper growing space. One of the most common mistakes made is leaving the seedlings in the seed flat too long. The ideal time to transplant young seedlings is when they are small and there is little danger from setback. This is usually when the first set of true leaves appear above or between the cotyledon leaves (the cotyledons or seed leaves are the first leaves the seedling produces). Don't let plants get hard and stunted or tall and leggy.

Seedling growing mixes and containers can be purchased or prepared similar to those mentioned for germinating seed. The medium should contain more plant nutrients than a germination mix, however. Some commercial soilless mixes have fertilizer already added.

Containers for Transplanting

There is a wide variety of containers from which to choose for transplanting seedlings. These containers should be economical, durable, and make good use of space. The type selected will depend on the type of plant to be transplanted and individual growing conditions. Standard pots are not recommended for the transplant from germination flats as they waste a great deal of space and may not dry out rapidly enough for the seedling to have sufficient oxygen for proper development.

There are many types of containers available commercially. Those made out of pressed peat can be purchased in varying sizes. Individual pots or strips of connected pots fit closely together, are inexpensive, and can be planted directly in the garden. When setting out plants grown in peat pots, be sure to cover the pot completely. If the top edge of the peat pot extends above the soil level, it will act as a wick, and draw water away from the soil in the pot. To avoid this, tear off the top lip of the pot and then plant flush with the soil level. Compressed peat pellets, when soaked in water, expand to form compact, individual pots. They waste no space, don't fall apart as badly as peat pots, and can be set directly out in the garden. If you wish to avoid transplanting seedlings altogether, compressed peat pellets are excellent for direct sowing.

Community packs are containers in which there is room

to plant several plants. These are generally inexpensive. The main disadvantage of a community pack is that the roots of the individual plants must be broken or cut apart when separating them to put out in the garden. Cell packs, which are strips of connected individual pots, are also available in plastic and are frequently used by commercial bedding plant growers, as they withstand frequent handling. In addition, many homeowners find a variety of materials from around the house useful for containers. These homemade containers should be deep enough to provide adequate soil and have plenty of drainage holes in the bottom. For example, styrofoam egg cartons make good cell packs.

Transplanting

Carefully dig up the small plants with a knife or plant label. Avoid tearing roots in the process. Let the group of seedlings fall apart and pick out individual plants. Gently ease them apart in small groups which will make it easier to separate individual plants. Handle small seedlings by their leaves, not their delicate stems. Punch a hole in the medium into which the seedling will be planted. Make it deep enough so the seedling can be put at the same depth it was growing in the seed flat. After planting, firm the soil and water gently. Keep newly transplanted seedlings in the shade for a few days, or place them under fluorescent lights. Keep them away from direct heat sources. Begin a fertilization program. When fertilizing, use a soluble house plant fertilizer, at the dilution recommended by the manufacturer, about every 2 weeks after the seedlings are established. Remember that young seedlings are easily damaged by too much fertilizer, especially if they are under any moisture stress.

Hardening Plants

Hardening is the process of altering the quality of plant growth to withstand the change in environmental conditions which occurs when plants are transferred from a greenhouse or home to the garden. A severe check in growth may occur if plants produced in the home are planted outdoors without a transition period. Hardening is most critical with early crops, when adverse climatic conditions can be expected.

Hardening can be accomplished by gradually lowering temperatures and relative humidity and reducing water. This procedure results in an accumulation of carbohydrates and a thickening of cell walls. A change from a soft, succulent type of growth to a firmer, harder type is desired.

This process should be started at least 2 weeks before planting in the garden. If possible, plants should be moved to a 45 to 50ºF temperature indoors or outdoors in a shady location. A coldframe is excellent for this purpose. When put outdoors, plants should be shaded, then gradually moved into sunlight. Each day, gradually increase the length of exposure. Don't put tender seedlings outdoors on windy days or when temperatures are below 45ºF. Reduce the frequency of watering to slow growth, but don't allow plants to wilt. Even cold-hardy plants will be hurt if exposed to freezing temperatures before they are hardened. After proper hardening, however, they can be planted outdoors and light frosts will not damage them.

The hardening process is intended to slow plant growth. If carried to the extreme of actually stopping plant growth, significant damage can be done to certain crops. For example, cauliflower will make thumb size heads and fail to develop further if hardened too severely. Cucumbers and melons will stop growth if hardened.

Propagation of Ferns by Spores

Though ferns are more easily propagated by other methods, some gardeners like the challenge of raising ferns from spores. One tested method for small quantities follows:

Put a solid, sterilized masonry brick (bake at 250ºF for 30 minutes) in a pan and add water to cover the brick. When the brick is wet throughout, squeeze a thin layer of moist soil and peat (1:1) into the top of the brick. Pack a second layer (about an inch) on top of that. Sprinkle spores on top. Cover with plastic (not touching the spores) or put in a plastic shoe box and put in a warm place in indirect light. It may take a month or more for the spores to germinate. Keep moist at all times. A prothallus (one generation of the fern) will develop first from each spore, forming a light green mat. Mist lightly once a week to maintain high surface moisture; the sperm must be able to swim to the archegonia (female parts). After about three weeks, fertilization should have occurred. Pull the mat apart with tweezers in 1/4-inch squares and space them 1/2-inch apart in a flat containing a 2-inch layer of sand, 1/4-inch of charcoal, and about 2 inches of soil/peat mix. Cover with plastic and keep moist. When fern fronds appear and become crowded, transplant to small pots. Gradually reduce the humidity until they can survive in the open. Light exposure may be increased at this time.

Study Questions

8. The best time to transplant seedlings is: a) immediately after germination; b) when the first set of true leaves emerge; c) when the cotyledons fall off; d) when the seedlings are large enough to fill a 4" pot.

9. Pots made of _____ can be directly transplanted into the garden if handled properly.

10. After transplanting, seedlings should be placed: a) outside in direct light; b) in a dark area; c) near a heat source; d) away from direct heat.

11. Hardening can be accomplished by the following conditions EXCEPT: a) increasing fertilization; b) gradually lowering temperature; c) gradually lowering relative humidity; d) reducing water.

12. When propagating ferns by spores, if a light green mat forms on the media, this means: a) the spores weren't viable; b) mold destroyed the spores; c) the ferns are in their first generation of growth; d) the spores were all female and didn't get fertilized for adequate growth to occur.

Answers: 8 - b; 9 - compressed peat; 10 - d; 11 - a; 12 - c

Asexual Propagation

Asexual propagation, as mentioned earlier, is the best way to maintain some species, particularly an individual that best represents that species. Clones are groups of plants that are identical to their one parent and that can only be propagated asexually. The Bartlett pear (1770) and the Delicious apple (1870) are two examples of clones that have been asexually propagated for many years.

The major methods of asexual propagation are cuttings, layering, division, and budding/grafting. Cuttings involve rooting a severed piece of the parent plant; layering involves rooting a part of the parent and then severing it; and budding and grafting are joining two plant parts from different varieties.

Rooting Media

Rooting media for asexual propagation should be clean and sterile. Cuttings are not susceptible to damping-off, but are attacked by other fungi and bacteria which may come along in the medium. Most commercially prepared media are purchased clean.

This media needs a combination of good aeration and water-holding capacity. In order for a plant to form a new root system, it must have a ready moisture supply at the cut surface. Oxygen, of course, is required for all living cells. The coarse textured media choices often meet these requirements.

The media should be low in fertilizer, as discussed for sexual propagation. Excessive fertility will damage or inhibit new roots.

100% coarse perlite can be used to start some cuttings. This doesn't hold much water for long, but it is fine for rooting cuttings of cactus-type plants which would ordinarily rot in higher moisture media. 100% coarse vermiculite has excellent water holding capacity and aeration, but may dry out rapidly via evaporation if not covered in some way. 50% peat moss and 50% perlite is a good mix that favors aeration. An equal mix of peat moss, vermiculite, and perlite is also a good mix which favors moisture retention.

Plain water can be used to propagate some cuttings. This is possible and actually works quite well for some species which root easily. It certainly provides the needed moisture, but if the water is not changed on a weekly basis it will become stagnant, oxygen deficient, and inhibitory to rooting. Furthermore, roots produced in 100% water are different than those produced in solid media; they may undergo greater transplant shock with a greater incidence of death. So it is not the most desirable, but certainly feasible.

Rooting Enhancement Conditions

Once you've selected the right medium, your first priority is to get roots produced as quickly as possible. The consequences of slow rooting invariably mean death because the cutting must rely on its limited water reserves. Water is required for major chemical reactions in plants which will be shut down in its absence. Even though the exposed cells on the cut surface of the cutting ordinarily transport water throughout the plant, they are not equipped to absorb it from the medium. This can only be done in most plants by roots, and particularly root hairs. Root hairs are tiny, single cell projections from the larger roots.

Make sure the medium is moist prior to inserting cuttings. If incompletely moist, then the cut surface may contact a dry pocket and have its own water absorbed away by the medium component. Try to keep both the air and medium temperature warm: 70-75ºF. Higher temperatures enhance growth, but excessively high temperatures do not allow for production via photosynthesis to keep up with food breakdown in normal cell energy use (respiration). You can buy electric heating pads to put beneath containers holding cuttings to maintain a constant temperature.

Get some air circulation around the cuttings as often as possible. This discourages fungal growth. Place in bright, but not direct light. An east window is fine but a west window is too warm and a south facing window too bright. North is too dim. Indoor florescent lights are the best way to ensure adequate light supply to the cuttings.

One way to provide good environmental conditions for asexual propagation is through the use of a mist bed. This system sprays a fine mist of water over the cuttings once every few minutes, and the time is adjustable. It should only be on during the day, as nighttime operation would keep the medium too wet and encourage rotting. Misting inhibits transpiration and forces the plant to conserve water while it forms new roots. If a mist system

Stem Cuttings

Type of Cutting	*Method*
Tip Cuttings	Detach a 2 to 6-inch piece of stem, including the terminal bud. Make the cut just below a node. Remove lower leaves that would touch or be below the medium. Cuttings should retain three or four leaves for best rooting. Dip the stem in rooting hormone if desired. Gently tap the end of the cutting to remove excess hormone. To prevent the root hormone from being scraped off, create a hole in the media with a pencil before inserting the cutting into the media. Insert deeply enough into the media for the tip to be able to support itself.
Medial Cuttings	Make the first cut just above a node, and the second cut just below a node 2 to 6 inches down the stem. Remove the leaves below the bottom node. Prepare and insert the cutting as you would a tip cutting. Be sure to position right side up. Axial buds are always above leaves. Make sure the cutting is inserted base down. 
Cane Cuttings 	Cane cuttings provide an easy way to propagate new plants from overgrown ones, especially house-plants such as diffenbachia, corn plant, Chinese evergreen, and other plants with thick stems. Cut cane-like stems into sections containing one or two eyes, or nodes. Dust ends with fungicide or activated charcoal. Allow to dry several hours. Lay horizontally with about half of the cutting below the media sur-face, eye facing upward. Cane cuttings are usually potted when roots and new shoots appear but new shoots from dracaena and croton are often cut off and rerooted in sand.
Single Eye 	The eye refers to the bud which emerges at the axil of the leaf at each node. This is used for plants with alternate leaves when space or stock material are limited. Cut the stem about 1/2 inch above and 1/2 inch below a node. Place the cutting horizontally or vertically in the medium.
Double Eye 	This is used for plants with opposite leaves when space or stock material is limited. Cut the stem about 1/2 inch above and 1/2 inch below the same node. Insert the cutting vertically in the medium with the node just touching the surface.

Stem Cuttings	
Type of Cutting	*Method*
Heel Cutting 	This method uses stock material with woody stems efficiently. Make a shield-shaped cut about halfway through the wood around a leaf and axial bud. Insert the shield horizontally into the medium.

is unavailable, one can be imitated in a small propagation tray in the home. Choose an appropriate medium, moisten it, and place it in a tray. Place the tray in a perforated or slitted clear plastic bag. This increases the relative humidity and inhibits water loss by the plant and medium yet allows air circulation.

Tug gently at the cuttings after 2-3 weeks to test for rooting and transplant to individual pots when roots resist your tugs. Dig them out, do not pull them out! Different plants require different rooting times, so do not expect them all to root at the same time. For information on starting plants outdoors, see Chapter 13: The Vegetable Garden.

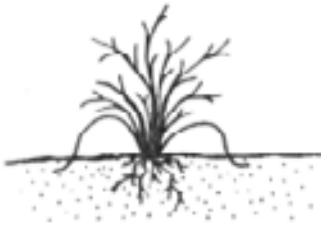
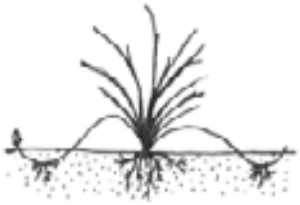
Leaf Cuttings	
Type of Cutting	*Method*
Whole leaf with petiole 	Detach the leaf and up to 1-1/2 inches of petiole. Insert the lower end of the petiole into the medium. One or more new plants will form at the base of the petiole. The leaf may be severed from the new plants when they have their own roots, and the petiole can be reused. (Example: African violet).
Whole leaf without petiole 	This is used for plants with sessile leaves. Insert the cutting vertically into the medium. A new plant will form from the axillary bud. The leaf may be removed when the new plant has its own roots. (Example: donkey's tail).
Split vein 	Detach a leaf from the stock plant. Slit its veins on the lower leaf surface. Lay the cutting, lower side down, on the medium. New plants will form at each cut. If the leaf tends to curl up, hold it in place by covering the margins with the rooting medium. (Example: Rex begonia).
Leaf sections 	This method is frequently used with snake plant and fibrous rooted begonias. Cut begonia leaves into wedges with at least one vein. Lay leaves flat on the medium. A new plant will arise at the vein. Cut snake plant leaves into 2-inch sections. Consistently make the lower cut slanted and the upper cut straight so you can tell which is the top. Insert the cutting vertically. Roots will form fairly soon, and eventually a new plant will appear at the base of the cutting. These and other succulent cuttings will rot if kept too moist.

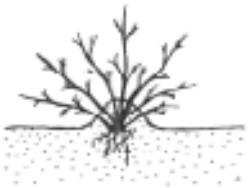
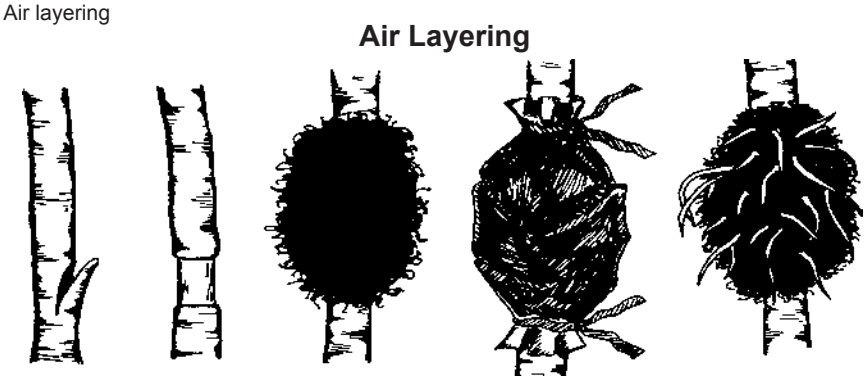
Root Cuttings	
Type of Cutting	*Method*
Plants with large roots 	Make a straight top cut. Make a slanted cut 2 to 6 inches below the first cut. Store about 3 weeks in moist sawdust, peat moss, or sand at 40ºF. Remove from storage. Insert the cutting vertically with the top approximately level with the surface of the rooting medium. This method is often used outdoors (Example: horse radish).
Plants with small roots 	Take 1 to 2 inch sections of roots. Insert the cuttings horizontally about 1/2 inch below the medium surface. This method is usually used indoors or in a hotbed. (Example: bleeding heart).

Cuttings

Many types of plants, both woody and herbaceous, are frequently propagated by cuttings. A cutting is a vegetative plant part which is severed from the parent plant in order to regenerate itself, thereby forming a whole new plant. Take cuttings from healthy, disease-free plants, preferably from the upper part of the plant (this season's growth). Avoid taking cuts from leggy stems, heavily fertilized plants, or plants showing symptoms of moisture stress or nutrient deficiency.

Remove cuttings from the plant with a sharp blade to reduce injury to the parent plant. Dip the cutting tool in rubbing alcohol or a mixture of one part bleach to nine parts water to prevent transmitting diseases from infected

Layering	
Type of Layering	*Method*
Tip layering 	Dig a hole 3 to 4 inches deep. Insert the shoot tip and cover it with soil. The tip grows downward first, then bends sharply and grows upward. Roots form at the bend, and the recurved tip becomes a new plant. Remove the tip layer and plant it in the early spring or late fall. Examples: purple and black raspberries, trailing blackberries.
Simple layering 	Bend the stem to the ground. Cover part of it with soil, leaving the last 6 to 12 inches exposed. Bend the tip into a vertical position and stake in place. The sharp bend will often induce rooting, but wounding the lower side of the branch or loosening the bark by twisting the stem may help. Examples: forsythia, honeysuckle.
Compound layering 	This method works for plants with flexible stems. Bend the stem to the rooting medium as for simple layering, but alternately cover and expose stem sections. Wound the lower side of the stem sections to be covered. Examples: heart-leaf philodendron, pothos.

Layering	
Type of Layering	*Method*
Mound (stool) layering 	Cut the plant back to 1 inch above the ground in the dormant season. Mound soil over the emerging shoots in the spring to enhance their rooting. Examples: gooseberries, apple rootstocks.
Air layering 	Air layering is used to propagate some indoor plants with thick stems, or to rejuvenate them when they become leggy. On monocots, slit the stem just below a node; for dicots, girdle the stem as show in the figure. Pry the slit open with a toothpick. Surround the wound with wet unmilled sphagnum moss. Wrap plastic or foil around the sphagnum moss and tie in place. When roots pervade the moss, cut the plant off below the root ball.

plant parts to healthy ones. Remove flowers and flower buds to allow the cutting to use its energy and stored carbohydrates for root and shoot formation rather than fruit and seed production. To hasten rooting, increase the number of roots, or to obtain uniform rooting (except on soft, fleshy stems), use a rooting hormone, preferably one containing a fungicide. Prevent possible contamination of the entire supply of rooting hormone by putting some in a separate container for dipping cuttings.

Place stem and leaf cuttings in bright, indirect light. Root cuttings can be kept in the dark until new shoots appear. Some additional tips for successful propagation include: cuttings from young plants root better than those from mature plants; lateral shoot cuttings are more successful than terminal shoots; avoid flower buds; take cuttings in the morning and keep them cool and moist until ready to plant; space cuttings so that each will receive adequate light and ventilation; ensure that buds on cuttings are pointed upwards.

Stem Cuttings

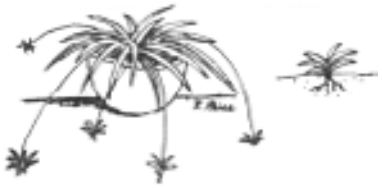
Numerous plant species are propagated by stem cuttings. Some can be taken at any time of the year, but stem cuttings of many woody plants must be taken in the fall or in the dormant season. Success with herbaceous plants is generally enhanced when done in the spring; these plants are actively growing then, and more apt to root quickly on their own. Herbaceous plant cuttings can be taken into September, however, or up to the time they start to form woody stems. There are several different types of stem cuttings depending on the part of the stem needed. At least one node should be below the surface. Although some plants root at internodes, others only root at nodal tissue.

Leaf Cuttings

Leaf cuttings are used almost exclusively for a few indoor plants. Leaves of most plants will either produce a few roots but no plant, or just decay.

Root Cuttings

Root cuttings are usually taken from 2 to 3 year old plants during their dormant season when they have a large carbohydrate supply. Root cuttings of some species produce new shoots, which then form their own root systems, while root cuttings of other plants develop root systems before producing new shoots.

Division	
Type of Division	*Method*
Stolons and runners: 	A stolon is a horizontal, often fleshy stem that can root, then produce new shoots where it touches the medium. A runner is a slender stem that originates in a leaf axil and grows along the ground or downward from a hanging basket, producing a new plant at its tip. Plants that produce stolons or runners are propagated by severing the new plants from their parent stems. Plantlets at the tips of runners may be rooted while still attached to the parent, or detached and placed in a rooting medium. Examples: strawberry, spider plant.
Offsets: 	Plants with a rosetted stem often reproduce by forming new shoots at their base or in leaf axils. Sever the new shoots from the parent plant after they have developed their own root system. Unrooted offsets of some species may be removed and placed in a rooting medium. Some of these must be cut off, while others may be simply lifted off of the parent stem. Examples: date palm, haworthia, bromeliads, many cacti.
Bulbs (separation):  **Tulip Bulbs**	New bulbs form beside the originally planted bulb. Separate these bulb clumps every 3 to 5 years for largest blooms and to increase bulb population. Dig up the clump after the leaves have withered. Gently pull the bulbs apart and replant them immediately so their roots can begin to develop. Small, new bulbs may not flower for 2 or 3 years, but large ones should bloom the first year. Examples: tulip, narcissus.
Corms (separation): 	A large new corm forms on top of the old corm, and tiny cormels form around the large corm. After the leaves wither, dig up the corms and allow them to dry in indirect light for 2 or 3 weeks. Remove the cormels, then gently separate the new corm from the old corm. Dust all new corms with a fungicide and store in a cool place until planting time. Examples: crocus, gladiolus.
Crowns (separation):	Plants with more than one rooted crown may be divided and the crowns planted separately. If the stems are not joined, gently pull the plants apart. If the crowns are united by horizontal stems, cut the stems and roots with a sharp knife to minimize injury. Divisions of some outdoor plants should be dusted with a fungicide before they are replanted. Examples: snake plant, iris, prayer plant, day lilies.

Layering

Stems still attached to their parent plants may form roots where they touch a rooting medium. Severed from the parent plant, the rooted stem becomes a new plant. This method of vegetative propagation, called layering, promotes a high success rate because it prevents the water stress and carbohydrate shortage that plague cuttings. Some plants layer themselves naturally, but sometimes plant propagators assist the process. Layering may be enhanced by wounding one side of the stem or by bending it very sharply. The rooting medium should always provide aeration and a constant supply of moisture.

Study Questions

13. Plant parts that can be used for cuttings include:
    a) leaves; b) stems; c) roots; d) all of the above

14. _____ is used to hasten rooting, increase the number of roots, and obtain uniform rooting.

15. All stem cuttings must contain: a) a node; b) three leaves; c) roots; d) all of the above

16. Plants that can be propagated by leaf cuttings do NOT include: a) African violets; b) Rex begonias; c) dieffenbachia; d) donkey's tail

17. Layering differs from cuttings in that:
a) it can only be done to tips of plants; b) it is only done to fruit crops; c) it can only be done on roots; d) the new plant is not completely severed from the parent until after roots form

18. The method of layering that is done on indoor plants with thick stems is _____.

Answers:
13 - d; 14 - rooting hormone; 15 - a; 16 - c; 17 - d; 18 - air layering

Division

Propagation from plant parts can be considered a modification of layering, as the new plants form before they are detached from their parent plants.

Separation is a term applied to a form of propagation by which plants that produce bulbs or corms multiply.

See Chapter 17: *Herbaceous Landscape Plants* for more information on dividing perennials.

Grafting

Grafting and budding are methods of asexual plant propagation that join plant parts so they will grow as one plant. These techniques are used to propagate cultivars that will not root well as cuttings, whose own root systems are inadequate, or to get larger plants faster. One or more new cultivars (scion) can be added to existing fruit and nut trees by grafting or budding.

The portion of the cultivar that is to be propagated

Grafting

Type of Graft	*Method*
Cleft grafting: 	Cleft grafting is often used to change the cultivar or top growth of a shoot or a young tree (usually a seedling). It is especially successful if done in the early spring. Collect scion wood 3/8 to 1/2 inch in diameter. Cut the limb or small tree trunk to be reworked perpendicular to its length. Make a 2-inch vertical cut through the center of the previous cut. Be careful not to tear the bark. Keep this cut wedged apart. Cut the lower end of each scion piece into a wedge. Prepare two scion pieces 3 to 4 inches long. Insert the scions at the outer edges of the cut in the rootstock. Tilt the top of the scion slightly outward and the bottom slightly inward to be sure the cambial layers of the scion and rootstock touch. Remove the wedge propping the slit open and cover all cut surfaces with grafting wax.
Bark grafting: 	Unlike most grafting methods, bark grafting can be used on large limbs, although these are often infected before the wound can completely heal. Collect scion wood 3/8 to 1/2 inch in diameter when the plant is dormant, and store the wood wrapped in moist paper in a plastic bag in the refrigerator. Saw off the limb or trunk of the rootstock at a right angle to itself. In the spring, when the bark is easy to separate from the wood, make a 1/2-inch diagonal cut on one side of the scion, and a 1-1/2-inch diagonal cut on the other side. Leave two buds above the longer cut. Cut through the bark of the stock, a little wider than the scion. Remove the top third of the bark from this cut. Insert the scion with the longer cut against the wood. Nail the graft in.
Whip or tongue grafting: 	This method is often used for material 1/4 to 1/2 inch in diameter. The scion and rootstock are usually of the same diameter, but the scion may be narrower than the stock if the cambium of the scion is aligned with the cambium of the root stock on one side. This strong graft heals quickly and provides excellent cambial contact. Make one 2-1/2-inch long sloping cut at the top of the rootstock and a matching cut on the bottom of the scion. On the cut surface, slice downward into the stock and up into the scion so the pieces will interlock. Fit the pieces together, then tie and wax the union.

is called the scion. It consists of a piece of shoot with dormant buds that will produce the stem and branches. The rootstock (see Chapter 14: *Fruits in the Home Garden* for further discussion) provides the new plant's root system and sometimes the lower part of the stem. The cambium is a layer of cells located between the wood and bark of a stem from which new bark and wood cells originate.

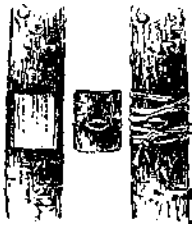
Four conditions must be met for grafting to be successful: the scion and rootstock must be compatible; each must be at the proper physiological stage; the cambial layers of the scion and stock must meet; and the graft union must be kept moist until the wound has healed.

Care of the Graft

Very little success in grafting will be obtained unless proper care is maintained for the following year or two. If a binding material such as strong cord or nursery tape is used on the graft, this must be cut shortly after growth starts to prevent girdling. Rubber budding strips have some advantages over other materials. They expand with growth and usually do not need to be cut, as they deteriorate and break after a short time. It is also an excellent idea to inspect the grafts after 2 or 3 weeks to see if the wax has cracked, and if necessary, rewax the exposed areas. After this, the union will probably be strong enough and no more waxing will be necessary.

Limbs of the old variety which are not selected for grafting should be cut back at the time of grafting. The total leaf surface of the old variety should be gradually reduced as the new one increases until at the end of 1 or 2 years, the new variety has completely taken over. Completely removing all the limbs of the old variety at the time of grafting increases the shock to the tree and

Budding

Type of Bud Union	*Method*
Patch Budding 	Plants with thick bark should be patch budded. This is done while the plants are actively growing, so their bark slips easily. Remove a rectangular piece of bark from the rootstock. Cover this wound with a bud and matching piece of bark from the scion. If the rootstock's bark is thicker than that of the scion, pare it down to meet the thinner bark so that when the union is wrapped the patch will be held firmly in place.
Chip Budding 	This budding method can be used when the bark is not slipping. Slice downward into the rootstock at a 45 degree angle through 1/4 of the wood. Make a second cut about one inch upward from the first cut. Remove a bud and attending chip of bark and wood from the scion shaped so that it fits the rootstock wound. Fit the bud chip to the stock and wrap the union.
T-budding 	This is the most commonly used budding technique. When the bark is slipping, make a vertical cut (same axis as the root stock) through the bark of the rootstock, avoiding any buds on the stock. Make a horizontal cut at the top of the vertical cut (in a T shape) and loosen the bark by twisting the knife at the intersection. Remove a shield-shaped piece of the scion, including a bud, bark, and a thin section of wood. Push the shield under the loosened stock bark. Wrap the union, leaving the bud exposed.

causes excessive suckering. Also, the scions may grow too fast, making them susceptible to wind damage. Future maintenance will be necessary to remove any sprouts from rootstock to prevent it crowding out the scion.

Budding

Budding is the union of one bud and a small piece of bark from the scion with a rootstock. It is especially useful when scion material is limited. It is also faster and forms a stronger union than grafting.

Care of Buds

Place the bud in the stock in August. Force the bud to develop the following spring by cutting the stock off 3 to 4 inches above the bud. The new shoot may be tied to the resulting stub to prevent damage from the wind. After the shoot has made a strong union with the stock, cut the stub off close to the budded area.

Study Questions

19. Stolons, runners, and offsets are propagated by _____.
20. Separation is used to propagate: a) bulbs and corms; b) African violets and pansies; c) fruit crops; d) none of the above
21. In grafting, the portion of the cultivar to be propagated is called the _____.
22. For grafts to be successful, the conditions that must be met include: a) a compatible scion and rootstock; b) the scion and rootstock centers must be aligned; c) the graft must be kept dry; d) the scion and rootstock must be from the same plant
23. _____ grafting can be done on large limbs.
24. Compared to grafting, budding:
    a) is faster; b) forms a stronger union; c) uses less plant material; d) all of the above
25. The type of budding that can be done when the bark is NOT slipping is _____.

Answers:
19 - division; 20 - a; 21 - scion; 22 - a; 23 - bark; 24 - d; 25 - chip

Plants Suited for Asexual Methods of Propagation

Cuttings:	*Stem*	*Leaf*	*Root*
	Tip - used for almost all house plants except those that don't form stems such as African violet, and those with rigid stems such as dieffenbachia	Whole Leaf with Petiole - Petiolegloxinia, African violet, peperomia, begonia	Large - horse radish
	Medial - same as tip	Without Petiole - donkey's tail, jade, ghost plant, peperomia	Small - bleeding heart, geraniums, ming aralia
	Cane - dieffenbachia, swiss cheese plant, aglaonema	Split Vein - begonia	
	Single eye - alternate leaf plants such as devil's ivy	Leaf Sections - sansevieria, begonia	
	Double eye - opposite leaf plants such as coleus		
	Heel - dieffenbachia		
Layering:	Tip - purple and black raspberries, trailing blackberries		
	Simple - forsythia, honeysuckle, spider plant, most vine-type plants (philodendron, grape ivy, devil's ivy, Swedish ivy, etc.)		
	Compound - heartleaf philodendron, pothos		
	Mound - gooseberries, apple rootstocks		
	Air Layering - plants with rigid stems such as dieffenbachia, ficus, rubber plant, aralia, croton		
Division:	Stolons/Runners - date palm, haworthia, bromeliads, cacti and succulents, flame violet, strawberry begonia, spider plant		
	Separation - spider plant, strawberry begonia, bromeliads. Bulbs: tulip, narcissus, hyacinth, amaryllis, lilies		
	Corm - crocus, gladiolus, freesia. Crowns: sansevieria, iris, prayer plant, day lilies, Boston fern, cast iron plant, peace lily		
Grafting:	Cacti and succulents, various fruit trees, ornamental trees		
Budding:	Various fruit trees, ornamental trees		

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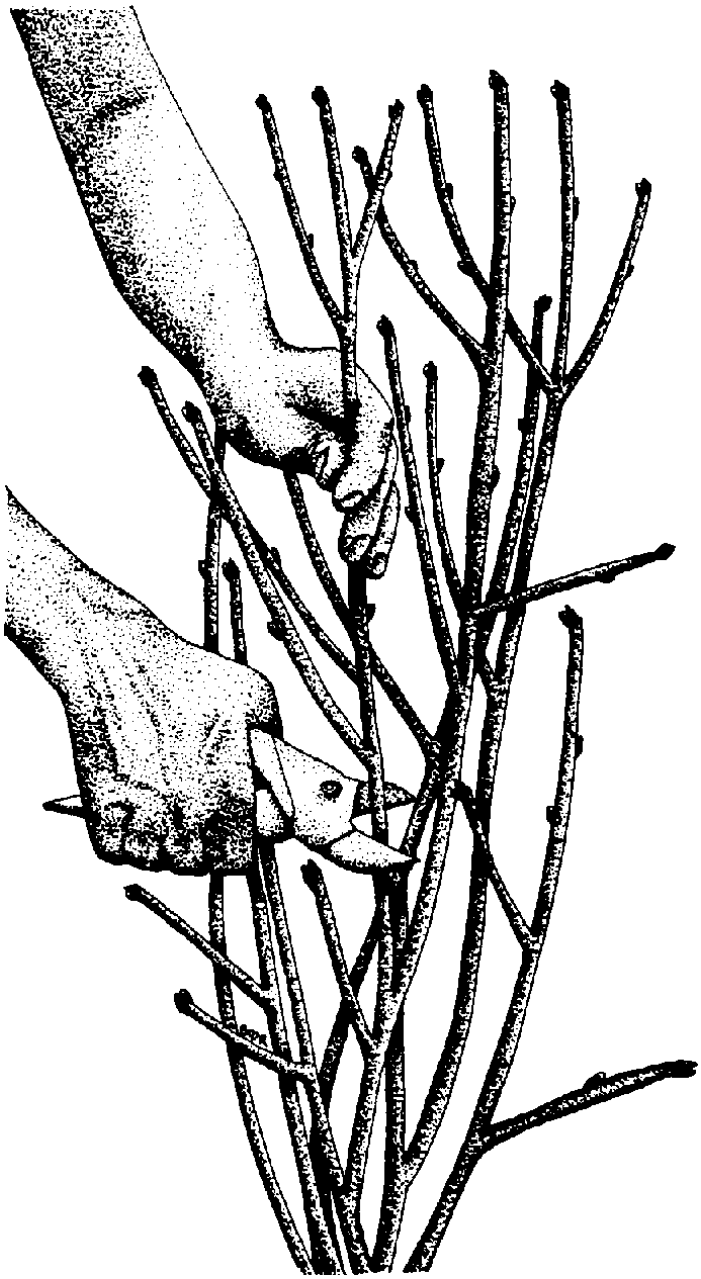
Chapter 11
Pruning

Pruning

Chapter 11



Pruning

Chapter 11

Revised by *John Freeborn, Assistant State Master Gardener Coordinator (2015)*
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"Pruning is one of the best things you can do for a tree and one of the worst things you can do to a tree."
-Alex Shigo, Father of Modern Arboriculture

To prune or not to prune? This is a question that gardeners often face. Most feel they ought to, but are not sure why or how. Pruning is a routine and necessary practice for the orchard, often done in the rose garden, but rather haphazard elsewhere in the landscape. Often it is only performed when a shrub or tree begins to encroach on neighboring property, a path, or a building. However, proper pruning should be a regular part of woody plant maintenance. This chapter explains the reasons for pruning, the proper techniques and tools to use, and when various types of plants should be pruned.

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Reasons for Pruning

The reasons for pruning can be grouped under the following categories:

* Training the plant
* Maintaining or improving plant health
* Improving the quality of flowers, fruit, foliage, or stems
* Controlling plant size
* Preventing personal injury or property damage

Training the Plant

Trees

The first pruning of young trees and shrubs consists of removing broken, crossing, and pest-infested branches. This is best done at the time of transplanting. Additional pruning should not be done until the next year.

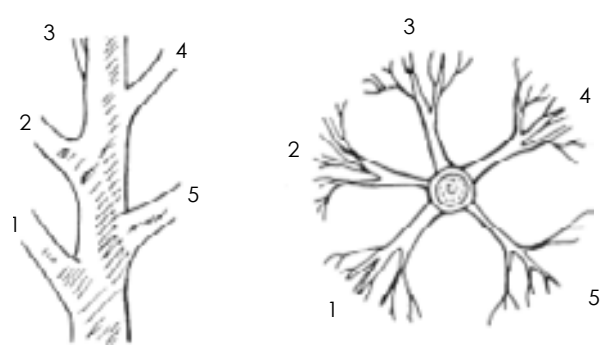
The old rule of pruning away $^1/_3$ of the top growth at transplanting to compensate for root loss is not recommended. Research proves that excessive pruning at transplanting is detrimental to plant establishment.

It is easier to shape branches with hand pruners when trees are young than to prune larger branches later. As a rule, the central leader of a tree should not be pruned unless a leader is not wanted, as is the case with some naturally low-branched trees or where multiple-stemmed plants are desired. Trees with a central leader such as linden, sweet gum, or pin oak may need little or no pruning except to eliminate branches competing with the central leader; these should be shortened or removed. Train main scaffold branches (those that form the structure of the canopy) to produce stronger and more vigorous trees.

The height of the lowest branch can be from a few inches above the ground (for screening or windbreaks) to 8 feet or more above the ground (as needed near a street or patio). Allow some branches to grow below the lowest permanent scaffold branches. Leave these limbs for three to four years after planting, then remove them over the next two to three years. These temporary branches protect young bark from sun scald, add strength to the trunk, and help produce food.

For greatest strength, branches selected for permanent scaffolds should have a wide angle of attachment with the trunk. Branch angles of less than 30 degrees from the main trunk ("V" shaped crotch) result in a higher percentage of breakage, while those between 60 and 70 degrees have a very small breakage rate. The breakage on "V" crotches is caused by the inclusions of bark within the crotch as the tree grows. This prevents the development of strong connective tissue.

Vertical branch spacing and radial branch distribution are important. Major scaffold branches of trees that will grow to large shade trees should be spaced at least 10 to 12 inches apart vertically. Closely spaced scaffolds will have fewer lateral branches. The result will be long, thin branches with poor structural strength. Good radial spacing prevents one limb from overshadowing another and, therefore, reduces competition for light and nutrients. Remove or prune shoots that are too low, too close, or too vigorous in relation to the leader and scaffold branches.



Vertical and Radial Arrangement of Scaffold Branches

Shrubs

Shrubs require little, if any, pruning at transplanting. Occasionally, branches may have been damaged in transit, and these should be removed at the time of planting.

Training for Special Effects

Specialized training techniques such as bonsai, topiary, and espalier require special pruning techniques. **Bonsai** is an art form that stems from ancient oriental culture, originating in China and developed by the Japanese. Bonsai techniques severely dwarf trees through careful pruning of both roots and shoots over many years. Bonsai strives to create a miniature tree that is shaped to create the illusion of age. **Topiary** uses special pruning and training techniques to create unusually shaped shrubs, vines, and trees. Typical topiary forms include spiral, turret and tiered globe shapes. Animals are also popular topiary forms. Topiary requires a long-term commitment to gradual pruning to achieve and maintain the desired shape. **Espalier** is a technique that trains a tree to a flat surface in a decorative pattern. It is commonly used for fruit trees as it allows the production of high quality fruit in a relatively small space.

Maintaining Plant Health

Pruning can be a useful tool in maintaining plant health. For example, diseased tissue and the reproductive structures of pathogens can be removed from a plant to minimize spread of disease. Pruning can improve light and air circulation which can suppress certain diseases and insects. Pruning low-growing branches from a plant can reduce plant/soil contact which can affect the spread of some soil-borne diseases.

When pruning to maintain plant health, first consider sanitation, which includes the elimination of dead, dying, or diseased wood. Any dying branch or stub can be the entry point or build-up chamber for insects or disease that could spread to other parts of the tree. When removing diseased wood such as a fungal canker or fire blight, it is important that the cut be made in healthy wood beyond the point of infection. Do not prune during wet weather, as the disease inoculum is easily spread by water. Carefully dispose of diseased wood in the trash or by burning. Do not put it in a household compost pile or place by the curb for municipal recycle pick up as both of these processes lead to spread of inoculum. Disinfect your tools between plants, or between cuts on the same plant when disease is present. Use rubbing alcohol of 70%, 91%, or 99% concentration. Don't use household bleach to disinfect your tools. Tests show that it is highly corrosive to metal. Remember that no disinfectant can provide complete protection against disease.

The development of a sound framework through proper thinning will help prevent disease and loss of vigor while maintaining or improving form. To avoid future problems, remove crossing branches that rub or interfere with each other. Even evergreen shrubs usually will benefit from an occasional thinning of foliage. This thinning will allow penetration of light and air throughout the shrub.

Improving the Quality of Plants

The more flowers and fruit a plant produces, the smaller they become, as can be seen on an unpruned rose bush or fruit tree. Pruning reduces the amount of wood and so diverts energy into the production of larger, though possibly fewer, flowers and/or fruit. Most flowering shrubs will bloom either on 1-year old growth or on new growth. Properly timed pruning will increase the production of wood that will bear flowers.

Some deciduous shrubs have colored barks which are especially delightful in winter. The best color is produced on young stems; the greatest stem length and most intense color results from hard pruning

Controlling Size

This is often the worst reason for pruning. Generally it is hard on the plant and creates unnecessary yard waste. Over time, poor planning results in trees and shrubs which grow to sizes that exceed the space allowed for them. Where space is limited, regular pruning becomes necessary to keep plants in bounds. To reduce labor, select plants that will not exceed the allotted space when mature. Regular pruning is necessary on formal hedges to maintain a uniform growth rate. For hedges, labor and yard waste can be reduced by choosing small or slow-growing plants and allowing them to grow in a more natural form, rather than keeping them tightly pruned.

Increasing Safety

Remove dead or hazardously low limbs to make underlying areas safer. Prune shrubs with thorny branches back from walkways and other well-travelled areas. Have a certified arborist handle any pruning work in the crowns of large trees.

Pruning Tools

Pruning shears are good for branches up to 3/4-inch in diameter. Attempting to cut larger branches risks making a poor cut and/or ruining the shears. There are two blade or cut styles of hand shears: scissor action (also called bypass blades) and anvil cut. In the anvil style, a sharpened blade cuts against a broad, flat plate. In the scissor style, a thin, sharp blade slides closely past a thicker blade. The scissor style may cost more, but generally makes cleaner, closer cuts. When buying pruners, test the pruners in your hand to make sure you can hold them comfortably. If they are too large or small, too heavy or too hard to squeeze, try another style or brand - there is a wide variety of pruning tools available. If you have trouble using pruning tools, there may be special equipment available to suit you. For example, ratchet pruners are useful if your grip is not strong because they can be closed easily with very little pressure.

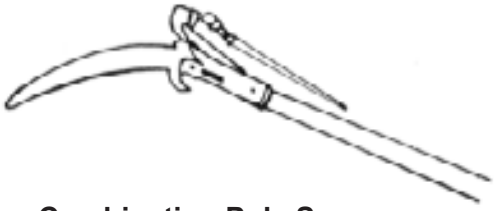
Scissor Style Shears

Anvil Shears

Lopping shears have long handles and are operated with both hands. Even the cheapest can cut 1/2-inch diameter material. The better ones can slice through branches of 2 inches or more, depending on species and condition (e.g., pin oak is tougher than linden, and dead wood is tougher - until decay sets in - than live wood). Lopping shears are also available with telescoping handles (to extend reach) and a ratchet mechanism.

Lopping Shears

Pole pruners have a cutter with a hooked blade above and a cutting blade beneath. The cutter is on a pole and is operated by a cord or chain pulled downward. Fully extended, they can be used to reach branches 12 feet or more above the ground. The poles can either be in sections that fit together or telescoping. Wooden poles are heavy. Aluminum poles are light but can conduct electricity if they touch an overhead wire. Fiberglass or some type of plastic compound is probably the best option. Poles can be fitted with saws, but these can be frustrating to use. Use of pole pruners can be dangerous, as material cut overhead can fall on the operator (unless it hangs up in other branches); exercise caution and wear head and eye protection. Obtaining an accurate pruning cut with a pole saw is very difficult. Consider employing a professional to make those cuts that you cannot easily reach with from the ground.



Combination Pole Saw-pruner

Hedge shears have long, flat blades and relatively short handles, one for each hand. Heavy-duty shears, with one blade serrated, are good for difficult jobs. Power hedge shears are also available. The most common for home use are electric models. Although these are less physically demanding, they often result in ragged and improperly placed cuts that are entry points for insects and disease. Keep blades sharp. If there is a choice in plants, consider using a plant that will stay small so as not to need shearing or need shearing as often.

Hedge Shears

There are many makes and models of **pruning saws**. Fineness of cutting edge is measured in points (teeth per inch). An 8-point saw is for delicate, close work on small shrubs and trees. Average saws are about 6 points, while 4-1/2-point saws are for fairly thick cuts. A fixed-blade saw with a protective scabbard is safe and easy to

use. Folding saws come in two types, with a wingnut or screw, or with a locking mechanism. Saws with a locking mechanism are safer than wingnut saws, which can fold suddenly and cause potential serious injury to the operator's fingers. Blades can be either straight or curved. Many prefer a curved blade that cuts on the draw stroke. A double-edged saw has fine teeth on one side, coarse on the other; these can do significant damage to surrounding branches and may be difficult to use in densely branched plants. Bow saws are good where no obstruction exists for a foot or more above the area to be cut.

Pruning Saw

Bow Saw

Chain saws come in a variety of sizes, both gas and electric. Chain saws are used to remove large limbs or entire trees. Chain saws should be used only with appropriate safety gear by people who fully understand their operation and handling for pruning. Improper or careless handling can do significant damage to trees and people in a very short time. Therefore, the use of chain saws is best left to professionals..

Chain Saw

Care of Tools

Clean and oil tools regularly. Thoroughly remove all plant residue, disinfect if needed, and wipe an oily cloth on blades and other surfaces after each use. Keep cutting edges sharp. Several passes with a good file or oil-stone will usually suffice for hand pruners, loppers, and shears. Saws probably need to be sharpened by a professional or have the blade replaced. Wooden handles should be painted, varnished, or regularly treated with linseed oil. Use tools properly. Don't twist or strain pruners or loppers. Keep the branch to be cut as deeply in the jaws and near the pivot as possible. Don't cut wire with pruning tools.

Study Questions

1. A good angle of trunk attachment for scaffold branches is: a) less than 30 degrees; b) 60 to 70 degrees; c) 90 degrees; d) any natural angle
2. _____ is an art form that severely dwarfs trees through careful pruning of roots and shoots over many years to create an illusion of age.
3. A procedure that is NOT recommended for maintenance pruning is: a) not pruning in wet weather; b) disinfecting all tools after use; c) eliminating dead, dying, or diseased wood; d) putting diseased wood in the home compost pile
4. The reason for pruning that is hard on plants and creates unnecessary yard waste is _____.
5. _____ have long, flat blades and relatively short handles, one for each hand.

Answers:
1 - b; 2 - bonsai; 3 - d; 4 - controlling size; 5 - hedge shears

Pruning Techniques

There are two basic types of pruning cuts: **heading cuts** and **thinning cuts**. Heading cuts reduce the height or width of a plant by cutting back lateral branches and removing terminal buds. Heading cuts may stimulate growth of buds closest to the cut. Heading cuts are not the same as topping cuts. Topping cuts are made indiscriminately in internode areas; heading cuts are made at nodal areas either above side branches or buds.

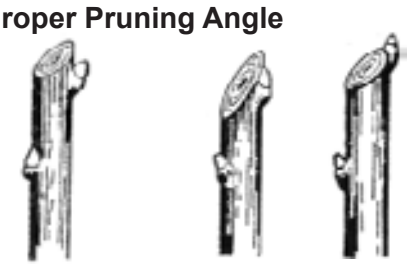
Topping cuts should not be made to trees because they reduce the tree's food-making capacity, stimulate undesirable water-sprout growth; leave large wounds that are more vulnerable to insect attack and fungal decay; create a hazard as weakened shrubs are more prone to wind and storm breakage; injure bark and increase harmful sun exposure on trunk and branches; and disfigure trees leaving ugly stubs, conspicuous pruning cuts, and a broom-like branch growth habit which replaces the tree's natural beauty and form. Topping trees reduces their real estate value by 20 to 100%. For more information, see Extension publication 430-458, Stop Topping Trees!

Thinning cuts remove branches at their points of origin or attachment. When you prune a branch back to another branch or prune a branch from the trunk, you are thinning. Thinning cuts stimulate growth throughout the tree, rather than in single branches as do heading cuts.

Twigs and Small Branches

When pruning twigs and small branches, always cut back to a vigorous bud or an intersecting branch. This location is called a node, and there is a concentration of meristem cells here that will help to heal the pruning wound faster. When cutting back to a bud, choose a bud that is pointing in the direction you wish the new growth to take. Be sure not to leave a stub over the bud or cut too close to the bud. Be sure to make branch collar cuts as described under *"Larger Branches"* later in this chapter.

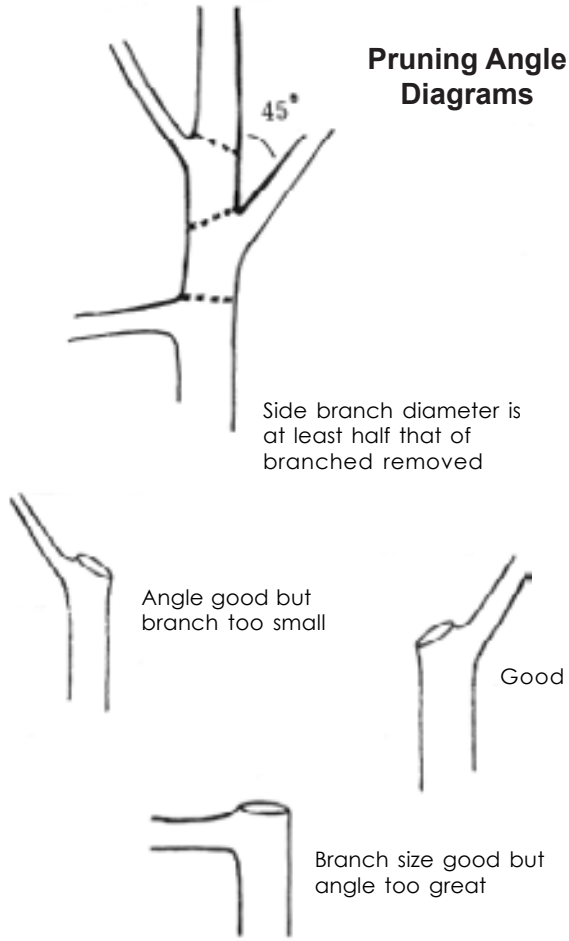
Proper Pruning Angle



Right **Wrong**

When cutting back to a side (lateral) branch, choose a branch that forms an angle of no more than 45 degrees with the branch to be removed. Also, the branch that you cut back to should have a diameter at least half that of the branch to be removed.

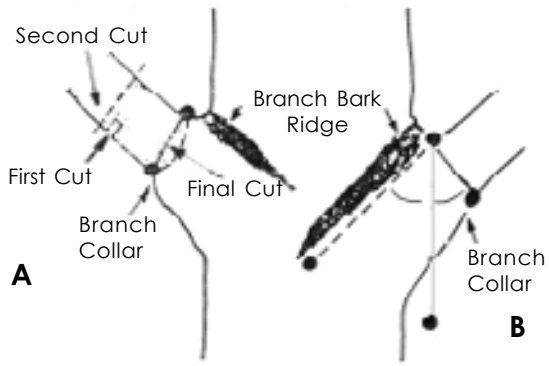
Pruning Angle Diagrams



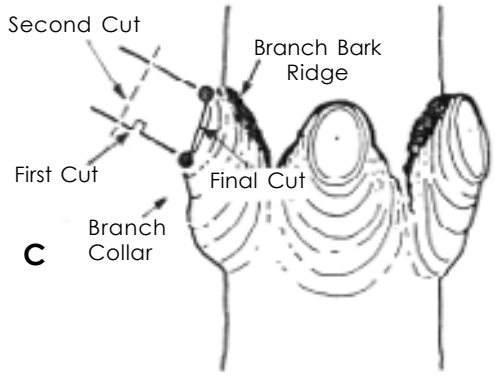
Larger Branches

All branches with discernible branch collars should be removed outside the collar, not flush with the trunk. The **branch collar** is the swollen area of trunk tissue that forms around the base of a branch. If you wound the branch collar, you compromise the zone protecting the rest of the tree (the trunk and roots) from decay. The collar area contains a chemically protective zone. In the natural decay of a dead branch, when the decay advancing downward meets the internal protected zone, an area of very strong wood meets an area of very weak wood. The branch then falls away at this point, leaving a small zone of decayed wood within the collar. The decay is designed to stop in the collar. When the collar is removed or compromised, the protective zone is removed or compromised, causing a serious trunk wound. Wood-decay fungi can then easily infest the trunk. Even if the pruned branch is living, removal of the collar at the base still causes injury to the tree. If the collar is not evident, find the branch bark ridge - a prominent ridge of raised

bark that forms within the branch crotch, extending down the trunk on both sides at an angle. The angle formed by this ridge and the trunk can be used to estimate the location of the branch collar as shown in illustration B.



Hardwoods



Conifers

Don't coat pruning cuts with tree paint or wound dressing; these products actually inhibit the tree's ability to heal the pruning wound. Some tests have shown wound dressings are beneficial when pruning trees that are susceptible to canker or systemic disease (oak wilt and Dutch elm disease). Tree paint won't prevent decay, promote wound closure, or prevent disease-carrying insects from entering tree wounds. The best way to prevent oak wilt and Dutch elm disease is to avoid pruning oaks and elms in May and June when insects are more active.

When cutting branches too large or too heavy to support with one hand while removing with pruners, use a 3-part cut to prevent the limb from falling before it's fully cut and tearing bark away from the tree. A 3-part cut is accomplished by first making an undercut; that is, sawing the bottom of the branch 6 to 12 inches out from the trunk and about $^1/_3$ of the way through the branch. Next, make a second cut from the top, about 3 inches further out from the undercut, until the branch falls away. The resulting stub can then be cut back at the collar of the branch as shown in illustrations A and C. If there is danger of the branch damaging other limbs below or objects on the ground, it must be properly roped and supported, then carefully lowered to the ground after the second cut by a professional arborist.

Root Pruning

A tree growing in the woods or landscape for several years develops a wide-spreading root system. The area in a 3-foot radius of the trunk of the tree more than five to ten years old contains very few of the small feeding roots essential to gathering nourishment for the tree. As a consequence, if the tree were to be dug and moved, as much as 90-95% of the necessary feeding roots would be cut off in the balling operation. This is the reason many nurseries root-prune trees and shrubs: to force them to grow a large number of small feeding roots near the base of the plant which are moved in the balling operation and aid in establishment after transplanting.

To make it possible to safely dig and move small trees or shrubs, such trees should be root-pruned a year or so before they are moved. In the spring, sever half the roots by forcing a sharp spade into the soil around the plant alternately leaving a shovel width of untouched soil between cuts. The circle of cuts should be smaller than the size of the ball that will eventually be dug. In the fall, sever the other half of the roots, thus cutting all the roots that are at a depth of a foot or less. The tree can then be moved the following spring. Recent research indicates that most of the new roots grow from the cut root end. Therefore, a root ball 4 to 6 inches larger than the root-pruned area must be dug to get the newly developed roots.

Root pruning is also used to force a vigorously growing fruit tree or wisteria vine into bloom. Using a spade to cut the roots early in the spring, as explained above, is all that is sometimes necessary to force a tree, shrub, or vine into bloom the following year. This takes advantage of a plant's natural reaction to stress or wounding: propagation beginning with flowering.

Occasionally arborists will prune roots of large trees that are facing damage from construction or utility line installation. This practice has two benefits. First, it allows roots to be severed at a time of year when it will be less harmful to plant health (in the dormant season). Second, it ensures a cleaner cut than will be made by

heavy excavating equipment such as backhoes. Root pruning for this purpose should be done in advance of any construction and just within the area to be disturbed.

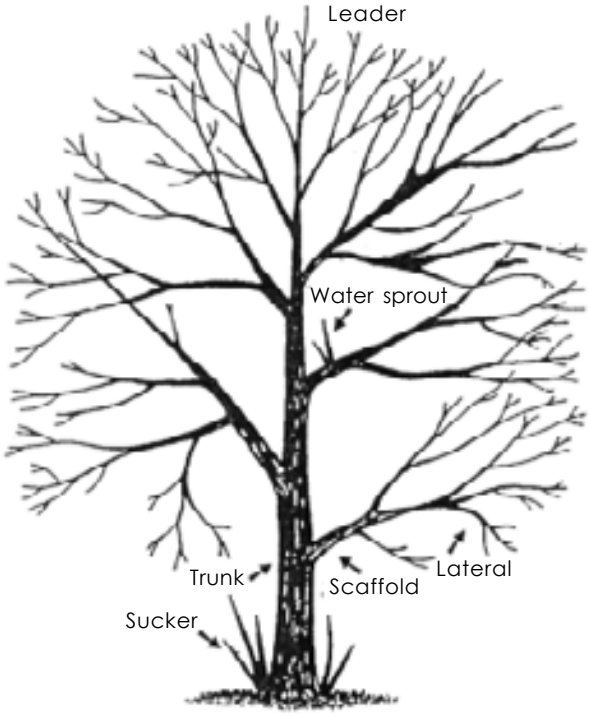
Pruning Trees

Deciduous Trees

Trees that shed their leaves annually are classified as deciduous. Deciduous trees in a landscape setting often require training when young, as described earlier. Young tree pruning is often preventive, eliminating structural problems before they occur. Maintenance pruning includes removing dead or diseased branches as soon as they are noticed. Water sprouts and suckers are two types of vigorous shoot growth generally considered undesirable and should be removed except on over mature trees which may form water sprouts for photosynthesis reserves (extra food production). Water sprouts occur along branches, often at pruning sites. Suckers grow from the trunk or roots. Both are rapid vegetative growths with weak attachments to the root of the tree, and can be an indication of decline or stress.

Corrective pruning may also be required. Corrective pruning removes damaged wood and eliminates rubbing branches. When a tree's leader is lost due to storm damage or disease, replace it by splinting an upper lateral on the highest scaffold to a vertical position. Prune all laterals immediately below the new leader. Use wood or flexible wire splints, removing them after one growing season.

Pruning at different seasons triggers different responses. Late winter or early spring, before bud break, is a good time to prune many species because callus tissue forms rapidly and food production is unaffected. However, sap from the tree may be cosmetically undesirable. When pruning flowering trees, take care not to cut off flower buds. Some trees, such as cherry, plum, and crab apple, form buds on old wood. Others, such as crape myrtle, bloom on new wood. Summer pruning tends to suppress growth of both suckers and foliage. Late summer or early fall pruning causes vigorous regrowth, which in some species may not harden off by winter, leading to possible cold damage. Whenever unexpected damage from vandalism or bad weather occurs, prune immediately.



Evergreen Trees

Evergreen trees have leaves that persist year round, and include most conifers and some broad-leaved trees. Conifers generally need less pruning than deciduous trees.

Because conifers have dominant leaders, young trees rarely require training-type pruning. If a young tree has two leaders, prune one out to prevent multiple leader development. Selective branch removal is generally unnecessary as evergreens tend to have wide angles of attachment to the trunk.

Evergreens are grouped on the basis of their branch arrangement. Spruces, firs, and some pines (white pine) have whorled branches that form a circular pattern around the growing tip. The annual growth of a whorl-branched conifer is determined by the number of shoots that are pre-formed in the buds. Whorl-branched conifers usually have only one flush of growth each year in which these preformed shoots expand into stems that form the next whorl. The second group of evergreens are those with a random branching habit. Yew, arborvitae, cedar, false cypress, and juniper are all random-branched species.

Corrective pruning for evergreen trees consists mainly of removal of dead, diseased, or damaged branches. Allow evergreen trees to grow in their natural form. Don't prune into the inactive center (where no needles or leaves are attached) of whorl-branched conifers because new branches won't form to conceal the stubs. When a tree's leader is lost due to storm damage, train a replacement leader as described for deciduous trees.

Random-branched Conifer

Whorl-branched Conifer

Most evergreen pruning is done for corrective reasons, so seasonal timing is usually not as important as it is for deciduous species. Pruning during dormancy is the most common practice and will result in a vigorous burst of spring growth. Pines and other whorl-branched conifers become denser if new growing tips (candles) are pinched in half as they expand in the spring. Use your fingers or shears to remove part of the candle. Prune random-branched conifers in early spring when new growth will cover the pruning wounds. Maintenance pruning of random-branched conifers is done in summer to keep plants within a desired size range. Remove spent flowers of evergreen magnolias at the end of their blooming season to stimulate new growth and development of a thicker crown. Whenever possible, avoid pruning evergreen trees in late summer and early fall. Pruning at this time can stimulate new growth that may not harden off before winter, and thus may be damaged or killed by the cold.

Study Questions

6. _____ cuts are made at nodal areas either above side branches or buds.

7. The branch collar should not be pruned because it: a) will sprout a new limb in time; b) compromises the trees ability to stop the decay from spreading; c) requires the use of a chain saw; d) all of the above

8. Before transplanting, a tree or shrub should be root pruned: a) about a week before hand; b) about a year before hand; c) to reduce flowering; d) to stop nutrient absorption

9. _____ and _____ are two types of vigorous growth that are considered undesirable and should be removed.

10. When performing corrective pruning on whorl-branched conifers,: a) don't prune to the inactive center; b) prune out the central leader; c) only prune in late summer; d) always train them in perfect Christmas tree form

Answers:
6 - heading; 7 - b; 8 - b; 9 - water sprouts, suckers; 10 - a

Pruning Shrubs

Growth Habit

Understanding the natural **habit** or shape of shrubs should guide pruning decisions. All shoots grow outward from their tips. Whenever tips are removed, lower buds are stimulated to grow. Buds are located at nodes, where leaves are attached to twigs and branches. Buds may occur singly or in groups of up to three.

Shrubs have mounding, cane, or tree-like growth habits. Those with mounding habits, such as evergreen azalea and spirea, generally have soft, flexible stems, small leaves, and are often used in mass plantings. Shrubs with cane habits include forsythia and nandina. These shrubs spread by sending up erect new branches, called canes, from their base. Tree-like shrubs have woodier, finely divided branches. Witch hazel and rhododendron are examples of shrubs with tree-like habits.

Deciduous Shrubs

The pruning recommended for most deciduous shrubs consists of maintenance pruning, gradual rejuvenation, and extensive rejuvenation pruning. This is required to keep them healthy and in scale with their surroundings. Older shrubs often grow out of proportion with their surroundings, and may have large amounts of unproductive wood. Two rejuvenation techniques are used to restore old shrubs, provided they still have sufficient vigor and are growing in a favorable location. Maintenance pruning practices should begin at the time

Proper Method of Pruning

This plant, pictured before pruning, needs to have all weak and dead stems removed.

Same shrub after removal of weak and interfering wood, also base sucker growth.

Results of proper pruning: graceful, vigorous growth with distinctive shape.

Improper Method of Pruning

Cutting at the dotted line is the usual course taken by those who prune shrubs.

The same plant after a bad pruning, as indicated above. The sucker growth remains.

Result: the lovely natural shape of the shrub is lost, and bloom will be sparse.

of planting or after rejuvenation of older shrubs. Always remove dead, diseased, or broken branches first.

Maintenance Pruning

To reduce height of shrubs with a cane habit, first remove the tallest canes by cutting or sawing them out near ground level. Then, thin out any canes crowding the center, as well as those growing in an unwanted or unruly direction. For height maintenance of mounding-type shrubs, prune only the longest branches. Make thinning cuts well inside the shrub mass where they won't be visible. This method reduces mounding shrubs by up to $^1/_3$ their size without sacrificing their shape.

Shrubs with a tree-like habit are the most difficult to shorten. After removing any rubbing branches, prune to open up the center of the shrub. Keep the crown open and maximize light penetration by careful use of thinning cuts. Prune branches that touch the ground and suckers originating from the roots. Wait until the very end of the job to make any heading cuts. Tree-like shrubs can usually tolerate removal of $^1/_8$ to $^1/_4$ of their branches.

Rejuvenation Pruning

Some older shrubs will recover and regain beauty if rejuvenated by removal of old wood by one of the following methods.

Gradual rejuvenation removes growth gradually. The first year, remove $^1/_3$ of the oldest, unproductive branches. New, productive stems should quickly replace the old wood. The next year, take $^1/_2$ of the lingering old stems. Finally, in the third year, prune out the remainder of the old branches. Thus, all the branches should be less than 4 years old. This method takes longer to complete, but the shrub stays more attractive throughout the rejuvenation period. Renewal pruning is the term used for a continual maintenance system of annually removing $^1/_3$ of the oldest growth throughout the life of the shrub. Forsythia will respond to this type of renewal pruning as an ongoing procedure to maintain its health and vigor.

Extensive rejuvenation involves complete removal of the entire plant 6-10 inches above the ground. Use heavy lopping shears and a pruning saw. Remove half of the new canes that develop by mid-summer, and head back some of the remaining canes. When using a heading cut, be sure to prune to outward-pointing buds so that the inner portion does not become too dense. Shrubs that tolerate extensive rejuvenation are abelia, honeysuckle, hydrangea, lilac, mallow, rose-of-sharon, spirea, and St. John's wort (hypericum).

Gradual Rejuvenation

Pruning for Flowers

When the shrub to be pruned is grown for its flowers, the pruning must be timed to minimize disruption of the blooming. Spring flowering shrubs bloom on last season's growth and should be pruned soon after they bloom. This allows for vigorous growth during the summer, which will provide flower buds for the following year.

Examples of Shrubs and Small Trees that Bloom on Last Season's Growth	
Cercis chinensis	Chinese redbud
Chaenomeles japonica	Japanese Quince
Chionathus virginicus	Fringe tree
Deutzia species	Spring-Flowering deutzias
Exochorda racemosa	Pearlbush
Forsythia species	Forsythia
Kerria japonica	Kerria
Lonicera species	Honeysuckle
Magnolia stellata	Star magnolia
Philadelphus species	Mockorange species
Pieris species	Pieris species
Rhondodendron species	Azaleas and Rhododendron
Rosa species	Rambling rose species
Spiraea species	Early white spirea species
Syringa species	Lilac species
Tamarix parviflora	Small-flowred tamarix

Examples of Shrubs and Small Trees that Bloom on Last Season's Growth	
Viburnum species	Viburnums
Weigela florida	Old-fashioned weigela

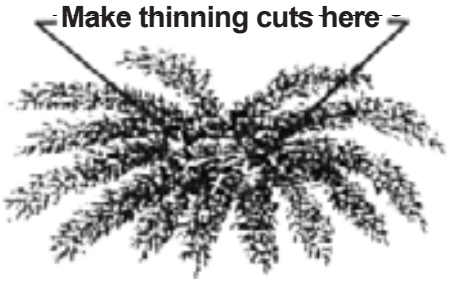
Most shrubs that bloom after June usually do so from buds which are formed the same spring. Such shrubs should be pruned in late winter to promote vigorous growth in the spring.

Examples of Shrubs and Small Trees that Bloom on Current Season's Growth	
Abelia x grandiflora	Glossy abelia
Buddleia davidii or *globosa*	Butterfly bush
Callicarpa japonica	Japanese beauty bush
Clethra alnifolia	Summer sweet
Hibiscus syriacus	Shrubs althea
Hydrangea arborescens	Hills of Snow
Hydrangea paniculata	Pegee Hydrangea
Hypericum species	Saint John's wort
Lagerstroemia indica	Crape Myrtle
Rosa species	Bush rose
Spiraea bumalda	Anthony Waterer Spirea
Spirea japonica	Mikado Spirea
Symphoricarpos species	Snowberry
Tamarix hispida	Kashgar
Tamarix odessana	Odessa
Vitex agnus-castus	Chaste tree

The general pruning procedure, illustrated above for crape myrtle, applies to many other large shrubs and small trees of similar structure.

Evergreen Shrubs

For most evergreen shrubs, thinning is the most desirable procedure. Some evergreens can be sheared when a stiff, formal appearance is desired; however, they will still need to be thinned occasionally. Late season shearing can stimulate new growth that may not be properly acclimated for cold winter temperatures, resulting in plant injury. Both evergreen and deciduous shrubs grown for foliage should be pruned in late winter before new growth starts. Minor corrective pruning can be done at any time.

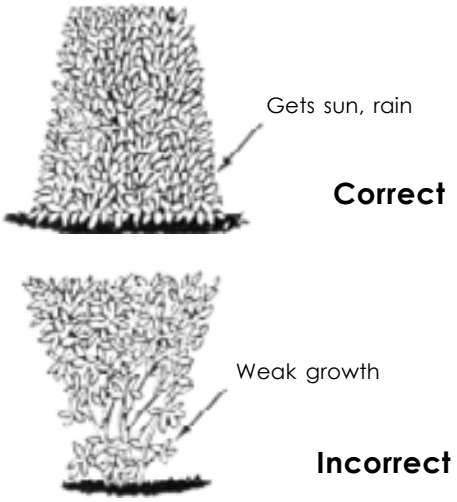


Pruning Hedges

Hedges consist of plants set in a row so as to merge into a solid, linear mass. They have served gardeners for centuries as screens, fences, walls, and edgings.

A well-shaped hedge is no accident. It must be trained from the beginning. The establishment of a deciduous hedge begins with the selection of nursery stock. Choose young trees or shrubs that are 1 to 2 feet high, preferably multiple-stemmed. When planting, cut the plants back to 6 or 8 inches. This will induce low branching. Late in the first season or before bud-break in the next season, prune off half of the new growth. In the following year, again trim off half the new growth to encourage branching.

Pruning Hedges



In the third year, start shaping. Hedges are often shaped with flat tops and vertical sides. This unnatural shaping is seldom successful. The best shape, as far as the plant is concerned, is a natural form - rounded or slightly pointed top with sides slanting to a wide base. After plants have been pruned initially to induce low branching, the low branching will be maintained by trimming the top narrower than the bottom, so that sunlight can reach all of the leaves on the plant.

Rounded or peaked tops aid shedding snow, which may break branches if not removed. Before shaping, some thought should be given to the shape of the untrimmed plant. For example, naturally conical arborvitae does particularly well in a Gothic arch shape. Common buckthorn, a spreading plant, is more easily shaped to a Roman arch.

Trim to the desired shape before the hedge grows to the desired size. Never allow the plants to grow untrimmed to the final height before shearing; by that time it will be too late to get maximum branching at the base. After the hedge has reached the dimensions desired, trim closely in order to keep it within bounds.

Snow accumulates on broad, flat tops.

Straight lines require more frequent trimming.

Hedge Shapes

Peaked and rounded tops hinder snow accumulation.

Rounded forms, which follow nature's tendency, require less trimming.

Evergreen nursery stock for hedging need not be as small as deciduous material, and should not be cut back when planted. Trim lightly after a year or two. Start shaping as the individual plants merge into a continuous hedge. Do not trim too closely, because many needle-bearing evergreens do not easily generate new growth from old wood.

These questions often arise: "How often should this hedge be trimmed?" and "When should I trim?" Answers depend to some extent on how formal an appearance is desired. In general, trim before the growth exceeds 1 foot. Hedges of slow-growing plants, such as boxwood, need trimming sooner. Excessive untrimmed growth will kill leaves beneath and also pull the hedge out of shape. This is especially true with weak-stemmed shrubs. In the

mountain areas of Virginia, yews and other evergreens may need shearing only once annually, and then not before July; in milder areas, two or even three shearings may be necessary. Deciduous material should be trimmed earlier than July, but after the spring flush of new growth, and will often need to be trimmed once or twice more. Frequency depends on the kind of shrub, season, and degree of neatness desired.

What can be done with a large, overgrown, bare-bottomed, and misshapen hedge? If it is deciduous, the answer is fairly simple. In the spring, before leaves appear, prune to one foot below the desired height. Then trim carefully for the next few years to give it the shape and fullness desired. Occasionally, hedge plants may have declined too much to recover from this treatment; replacing them may be necessary.

Rejuvenating evergreen hedges is more difficult. As a rule, evergreens cannot stand the severe pruning described above. Arborvitae and yew are exceptions; other evergreen hedges may have to be replaced.

What tools should be used to trim hedges? The traditional pair of scissor-action hedge shears is still the best all-round tool. It will cut cleaner and more closely than electric trimmers, which often break and tear twigs. Hand shears can be used on any type of hedge, while electric trimmers do poorly on large-leaved and wiry-twigged varieties, and sometimes jam on thick twigs. Hand shears are also quieter and safer, less likely to gouge the hedge or the operator. Hand pruners are useful for removing a few stray branches. Larger branches can be removed with loppers and/or a pruning saw.

It should be pointed out that shearing of hedges consists of cuts which stimulate a dense canopy or shell of foliage that encourages diseases in the interior of the hedge and increases the amount of yard waste produced. Where possible, natural unsheared hedges should be used.

Pruning Roses

All roses need some type of pruning. If roses are not pruned for a number of years, plants deteriorate in appearance, often develop more than the usual disease and insect problems, and the flowers become smaller and smaller.

Hybrid Tea, Grandiflora, and Floribunda roses require annual pruning in the spring, after winter protection has been removed. As a guideline, follow the old saying that roses are pruned when the forsythia blooms. If rosebushes are pruned too early, injury from repeated frost may make a second pruning necessary.

The only tools necessary are sharp hand pruners and gloves. If the rose collection is large, a small saw and loppers will also help. Loppers are used to cut out large dead canes.

Remove branches that are dead, damaged, diseased, thin, weak, growing inward, and branches that cross or interfere with other branches. Proper pruning encourages new growth from the base, making the plant healthy and attractive and resulting in larger blossoms. Cut at least 1 inch below damaged areas. Remove all weak shoots. If two branches rub or are close enough that they will do so soon, remove one. On old, heavy bushes, cut out one or two of the oldest canes each year.

Cut back the remaining canes. The height to which a rose should be cut will vary depending upon the normal habit of the particular cultivar. The average pruning height for Floribundas and Hybrid Teas is between 12 and 18 inches, but taller growing Hybrids and most Grandifloras may be left at 2 feet. Make cuts at 45-degree angles above a strong outer bud. Aim the cut upward from the inner side of the bush to push growth outward and promote healthy shoots and quality flowers.

Other types of roses have special pruning needs:

A **rose standard,** or tree rose, is a Hybrid Tea, Grandiflora, or Floribunda budded at the top of a tall trunk. Prune tree roses as you do Hybrid Teas, cutting the branches to within 6 to 10 inches of the base of the crown in order to encourage rounded, compact, vigorous new growth.

Miniature roses are 6 to 12 inches high with tiny blooms and foliage. Miniature roses do not need special pruning. Just cut out dead growth and remove the hips.

Old-fashioned **rambler roses** have clusters of flowers, each usually less than 2 inches across. They often produce canes 10 to 15 feet long in one season. Ramblers produce best on year-old wood, so that this year's choice blooms come on last year's growth. Prune immediately after flowering. Remove some of the large, old canes. Tie new canes to a support for the next year.

Large-flowering **climbing roses** have flowers more

than 2 inches across, borne on wood that is 2 or more years old. Canes are larger and sturdier than those of Ramblers. Many flower just once in June, but some, called ever-blooming climbers, flower more or less continuously. This group should be pruned in autumn, any time before cold weather sets in. First cut out dead and diseased canes. After this, remove 1 or 2 of the oldest canes each season to make room for new canes. The laterals, or side shoots, are shortened 3 to 6 inches after flowering. If the plant is strong, keep 5 to 8 main canes, which should be tied to the trellis, fence, wall, or other support. If it is not strong, leave fewer canes.

Pruning Vines and Ground Covers

Pruning ornamental vines is similar to pruning shrubs. Flowering vines are pruned according to flower production; those that flower on new wood are pruned before new growth begins, those that flower on previous season's growth are pruned immediately after flowering. Vines that are grown for foliage are pruned to control growth and direction. Timing is less critical than for flowering vines.

Ground cover plants require very little pruning. Dead or damaged stems should be removed whenever observed. Some trailing ground covers, such as English ivy, may need pruning to prevent encroachment to natural areas, on lawn areas, or other plants. With liriope, a grass-like ground cover, appearance is improved by annual pruning. Before new leaves are an inch tall, remove the dead leaves from the previous year. For large liriope plantings, a lawn mower set to cut above the new leaf tips will speed this early spring job.

Invasive plant cuttings, such as English Ivy should be burned or discarded as trash. Do not compost or otherwise discard.

Study Questions

11. Shrub growth habits do NOT include:
    a) mounding; b) cane; c) trailing; d) tree-like

12. _____ pruning of deciduous shrubs involves complete removal of the entire plant 6-10" above the ground.

13. Plants that flower after _____ should be pruned in late winter to promote vigorous growth in spring.

14. A good shape for a formal hedge would be:
    a) flat topped with vertical sides; b) rounded or slightly pointed top with sides slanting to a wide base; c) flat top with sides slanting to a narrow base; d) a slightly concave top with a wide base

15. The frequency of hedge pruning depends on:
    a) the kind of shrub; b) the season; c) the desired degree of neatness; d) all of the above

16. In general, roses should be pruned:
    a) when in bloom; b) right after bloom; c) in winter; d) in spring

17. Roses that do NOT require specialized pruning techniques are: a) standard roses; b) miniature roses; c) rambler roses; d) climbing roses

18. An ornamental ground cover that can be pruned with a lawn mower set to cut above the new leaf tips in early spring is _____.

Answers:
11 - c; 12 - extensive rejuvenation; 13 - June; 14 - b; 15 - d; 16 - d; 17 - b; 18 - liriope

Training & Pruning Apple Trees

Young, Nonbearing Apple Trees

The objectives of training, directing, or modifying growth into a desired form include early fruit production, development of an optimum tree structure for supporting future crops, and producing quality fruit. These objectives can be met by maintaining a proper balance between vegetative and potential fruiting wood. Excess shoot growth will delay the onset of fruiting. However, excess pruning of young, nonbearing trees will also delay the beginning of fruit production in the life of that tree. Training should be emphasized in the development of trees, with pruning used as a tool in the training process to redirect limbs, stimulate branching when desired, or to remove growth that is in an undesirable location. Pruning should not be used to invigorate growth in an attempt to compensate for poor fertilization, poor weed control, or drought conditions.

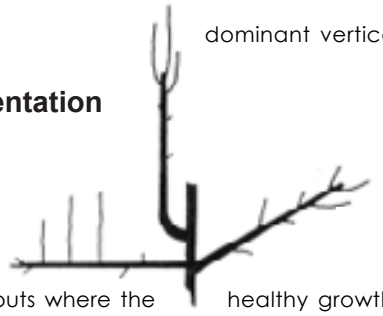
Future pruning of an apple tree is greatly affected by early training. Much of the pruning of young, bearing trees is the result of errors made in training in the early life of the tree. Thus, it is imperative that training begin early.

A delay for the first 3 to 4 years will result in a poorly-developed, weak tree. Correction of such a problem, usually with heavy pruning, will only further delay and decrease fruit production.

Limb Spreading

An integral part of a tree-training program is limb-spreading. Limb orientation affects vigor in various ways. An upright or vertical limb produces the longest shoots near the apex and tends to exhibit high vegetative vigor. As limbs are oriented away from vertical, they exhibit reduced vigor of shoots near the apex, more uniform branching along the shoot, and favor development of fruiting spurs. Fruits hang along the limb and are less prone to rub. A limb orientation around 60 degrees from vertical is desired.

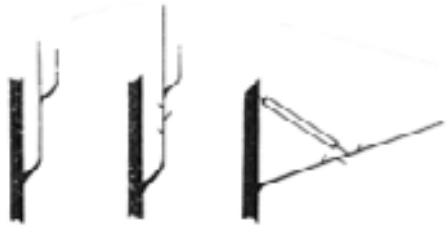
Limb Orientation



Horizontal orientation of limbs results in the development of vigorous watersprouts along the upper surface of the limb, at the expense of potential fruiting spurs.

Limb Angles

Wide crotch angles (left) are strong



Using limb spreaders to achieve proper crotch angle

Thus, correct limb-spreading (near 60 degrees from vertical) can be used to develop a proper balance between vegetative and fruiting growth. Steel wire about $^1/_8$" thick or wooden strips with finishing nails in each end are inserted between the selected scaffold limb and the main trunk of the tree. Limb-spreading should begin early, as many cultivars, such as Red Delicious (particularly spur-types), naturally develop narrow crotch angles. If these narrow crotch angles are not widened (greater than 35 degrees), a situation can quickly develop in which bark is trapped between the trunk and scaffold (bark inclusion). This bark inclusion prevents layers of annual wood from growing together and creates the potential for splitting. If these narrow crotch angles with bark inclusions are allowed to develop, later attempts at limb-spreading may result in splitting of the crotch. Two objectives exist for limb-spreading: 1) development of a strong, wide crotch angle (greater than 35 degrees) free of bark inclusion and 2) limb orientation at 60 degrees from vertical to balance vegetative and fruiting growth. To derive the benefits of limb-spreading, the crotch must be physically strong, to undergo spreading without splitting.

Poor pruning practices are not a wise substitute for proper limb-spreading in the training of upright scaffolds. Improper pruning cuts will not change the crotch angle, improve limb position, or aid in the control of vegetative vigor. Scaffolds should be spread and lower laterals removed if necessary.

Pruning Schedule

Scaffold Selection for Spacing

Scaffold selection can begin in the early summer, especially on cultivars developing narrow crotch angles. Shoots developing below the lowest desired scaffold should be removed. Generally, in the first year, 4 to 6 good scaffolds can be selected that are evenly distributed and not directly above one another.

The vertical spacing between scaffolds can vary from 3 inches to 12 inches depending on the ultimate size of the tree. Limbs with crotch angles less than 35 degrees should be spread or removed. Hardwood toothpicks and clothespins can be used if training is done in early summer while shoots are soft. Short pieces of #9 wire can also be used. Shoots undesirably located can be completely removed at this time.

At Planting

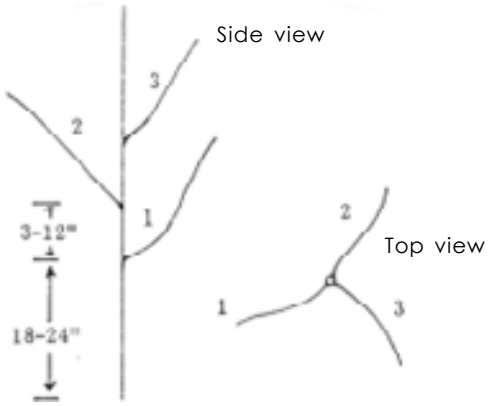
Trees must be pruned at planting. Pruning forces the

growth of laterals from which future scaffolds will be selected. Head trees to a height of 30 to 35 inches. If feathered (branched) trees are planted, they should be headed to a strong bud to stimulate growth of the central leader. Feathers desirably located can be retained as scaffolds and should be headed by a third. Undesirable feathers should be removed.

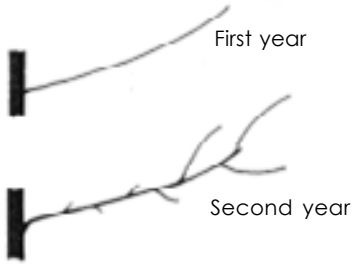
First Year Dormant Season

Select shoots to be retained as scaffolds if this was not done earlier. Spread selected scaffolds before any pruning is done. Spreading changes the shape of the tree and may influence pruning decisions. Remove only branches with narrow crotches or branches that are too low. The central leader should be headed to maintain dominance and induce branching. This is done 3 to 5 inches above the point where the next tier of scaffolds is desired. Refrain from heading scaffolds unless they need to be shortened or stiffened. Generally a year-old shoot naturally branches in the season after development. Spreading that scaffold will encourage uniform branching. However, a scaffold will often exhibit excess vigor and upset the balance of the tree.

Training of Apple Trees



Select well spaced scaffolds



Natural branching of a shoot

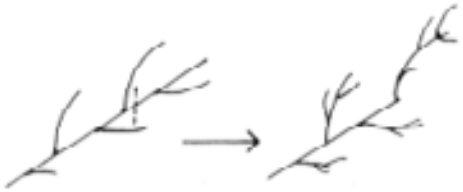
Second Growing Season

Limbs not previously trained can be easily spread early in the growing season when wood is flexible. Fruit developing on the central leader should be removed to prevent the leader from bending. Retain all branches with wide crotch angles.

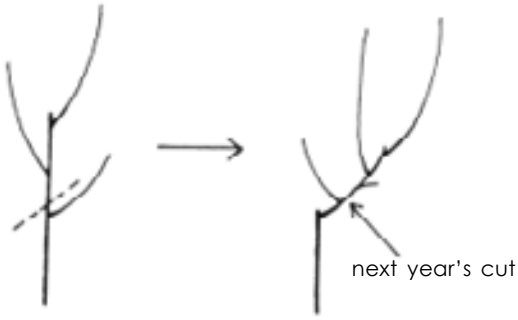
Second Year Dormant Season

Some of the scaffolds that were selected and spread in the first year may turn up and resume vertical growth. Longer spreaders can be used to spread the limbs back to the desired orientation. The smaller spreaders can be moved further up into the tree. Again, scaffolds should be spread before pruning. The central leader should be headed again to maintain vigor and stimulate branching. Typically, only one or two pruning cuts are required the second winter.

Reducing Length



Shorten limbs with thinning cuts



Prune to lateral to maintain height

Succeeding Years

Continue training and pruning following the previously discussed principles of central leader dominance and proper scaffold selection and training. Scaffolds should be maintained in a 60 degree orientation. A conical tree shape should be maintained. Thus, the upper scaffold should be shorter than the scaffold below it. After the third year, upper scaffolds can be shortened with the use of thinning cuts to remove shoots at the junction with a lateral scaffold or trunk. Thinning cuts are less invigorating than heading cuts, improve light penetration, and can redirect the limb. Remove crossing branches and vigorous watersprouts. Shoots growing up into the tree

should be removed. Weak water sprouts can be spread to induce fruiting

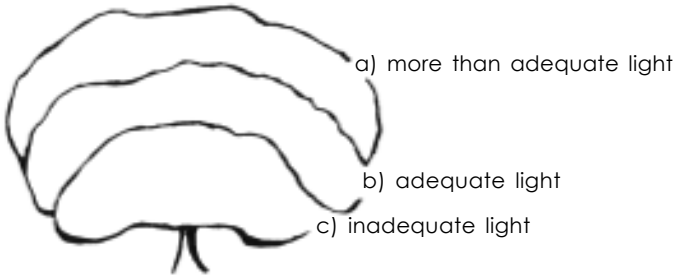
Once the desired tree height is reached, the tree can be maintained by annually cutting back to a weak lateral on the central leader. This will maintain vigor in the top center of the tree while maintaining desired tree height. In the top half of the tree, remove branches with a diameter half the diameter of the trunk at the point of attachment.

Bearing Apple Trees

When pruning is underway, older, bearing trees should be pruned first. Young, nonbearing apple trees and stone fruits should not be pruned until after February 1 to minimize chances of winter injury.

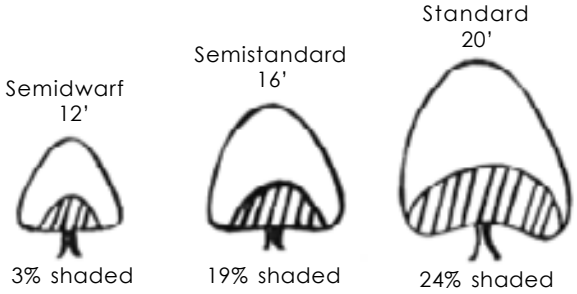
The balance between vegetative and fruiting growth is influenced by the crop load, fertilization, and pruning. Fruiting may be poor because vigor is too high or too low. Low vigor can be the result of inadequate fertilization, no pruning, excessive cropping, or shading of fruiting wood. Good fruiting wood requires moderate vigor and exposure to good light levels.

Zones of Light Exposure



Light is the source of energy that produces the crop. Bearing wood that is shaded is low in vigor and produces small, poorly colored fruits. Good light exposure is necessary for the development of flower buds as well as optimum size, color, and sugar content of the fruit. Studies have shown that a typical tree canopy is composed of different layers or zones in respect to light exposure. As shown below, an outside zone of leaves and fruit receives a high proportion of direct light and light levels above those required for good growth and fruiting; a second zone receives adequate light exposure; and a third, inner zone receives inadequate light exposure and is unproductive.

The relative proportion of these zones in a tree is influenced by tree size and shape. As tree size increases, the percentage of the tree that is shaded and unproductive (third zone) increases. Trees that have wide tops and narrow bottoms also have a high percentage of shaded areas in the tree canopy. Trees should be cone-shaped, or larger at the bottom than the top, to maximize adequate light exposure.



Tree Shape and Light Exposure

Good light exposure in the tree canopy can also be maintained by a good pruning program. Ideally, pruning should remove unproductive wood and develop a uniform distribution of vigor and light exposure throughout the tree. Proper pruning can also help to maintain desired tree size and shape.

Pruning should be done on a regular basis and consist of moderate cuts made throughout the tree to distribute vigor and provide good light penetration. Heading cuts should only be used where branching is desired or in areas where vigor is low. Drooping or low-hanging branches should be removed or pruned to a lateral that is positioned above horizontal. Remove crossing, dead, or damaged limbs. Watersprouts should be removed unless one is needed for the development of new bearing surface. Watersprouts can be easily removed by hand as they develop in the summer.

Without regular annual pruning, trees often become overly thick, and irregular bearing may occur. Spray penetration is reduced, and problems such as scale may develop in the dense areas of the tree. With this type of tree, make

many thinning cuts throughout the tree with emphasis on the upper, outer portions of the tree. This will open up areas into the tree canopy as well as reestablish good tree shape.

Avoid heading cuts to outward-growing limbs unless necessary. Such cuts result in weak limbs and an umbrella shape that creates a sucker problem. Remove no more than 2 large limbs per year. If large amounts of pruning are required, it should be spread over a 2 to 3 year period. In addition, such pruning should be preceded and followed for 1 to 2 years by a reduction or elimination of nitrogen application depending on soil type, variety, and grower experience.

The excess vigor that can result from severe pruning can decrease fruit quality. The effect is much the same as from excessive nitrogen application, and may include excessively large, poorly colored, soft apples which will not store well. Vegetative growth competes with fruit for calcium; thus, under conditions of excessive vigor, cork spot may develop.

Hedging and topping should only be used to maintain tree size when trees are at or near desired size. Such pruning is often used in an attempt to reduce tree size. Misuse can result in a disruption of vigor and loss of yield which may take several years to control. Hedging and topping (mainly heading cuts), especially of one-year shoots, induce masses of shoots close to the plane where cutting takes place. This localized invigoration of shoots can shade and weaken inner areas of the tree.

Study Questions

19. Objectives of pruning apple trees do NOT include: a) early fruit production; b) delayed fruit production; c) improvement of fruit quality; d) development of tree structure

20. Correct limb-spreading is used to: a) develop a proper balance between vegetative and fruiting growth; b) prevent weak, narrow crotch angles; c) orient limbs about 60 degrees from vertical; d) all of the above

21. Vertical spacing between scaffolds: a) should be 7-8 inches; b) should be 3 feet; c) depends on the ultimate size of the tree; d) is irrelevant

22. Shading of fruit wood, no pruning, and excessive cropping can result in: a) high vigor; b) moderate vigor; c) low vigor; d) good fruiting

23. To maximize light exposure, trees should have a _____ shape.

24. _____ should only be done to maintain, not reduce, tree size.

Answers: 19 - b; 20 - d; 21 - c; 22 - c; 23 - conical; 24 - hedging or topping

Pruning Other Fruit Trees

The general purpose of pruning fruit trees is to regulate growth, improve fruit size and quality, and reduce production costs. Pruning is necessary to shape trees for convenience of culture and repair of damage.

Most pruning is done during the dormant season, preferably just before active growth begins in the spring. At this time, pruning wounds heal quickly, flower buds can be easily recognized, and injury from low winter temperature is avoided. Summer pruning may be done to help train trees to the desired form and maintain small tree size. It should be remembered, however, that all pruning has a dwarfing effect. For maximum yield of high quality fruit, prune only as necessary to establish a tree with a strong framework capable of supporting heavy crops annually without damage and to maintain a tree sufficiently open to allow penetration of sunlight, air, and spray material for good fruit development and pest control.

Pear

Pear trees are trained along the same general lines as those recommended for apples. Heading back is undesirable because of the tendency of the tree to throw out soft terminal shoots, which are highly susceptible to fire blight. It is best to limit pruning to thinning-out cuts.

Cherry

Sweet cherry trees are trained to the modified leader system recommended for the apple. Special attention should be given to the selection of scaffold limbs because sweet cherry is subject to winter injury and splitting at the point where the limbs join the main stem of the tree. It is essential that the crotch angles be as wide as possible to ensure a strong framework.

A sour cherry tree with no strong branches at the time of planting should be headed to about 24 inches above the ground. Selection of laterals can be made at the beginning of the second year's growth. If it has some good laterals when planted, remove those lower than 16 inches from the ground. Select about three permanent lateral or scaffold limbs along the leader, 4 to 6 inches apart and not directly over one another. Do not head them back, since this tends to stunt terminal growth.

In the following years, select side branches from the leader until there is a total of 5 or 6 scaffold limbs well distributed above the lowest branch along 3 or 4 feet of the main stem. The leader is then usually modified by cutting to an outward-growing lateral. After fruiting begins, pruning consists mainly of thinning out excessive and crowded growth each year to allow sunlight to filter through the tree.

Plum

The plum may also be pruned in a manner similar to the apple. European and prune types generally develop into well-shaped trees, even if little pruning is done. Thinning out excessive growth constitutes the bulk of pruning after heading back to 30 to 36 inches at the time of planting. Varieties of the Japanese type are usually a little more vigorous, and may need some heading back as well as thinning of excessive growth after they come into bearing.

Peach

Peach trees are usually trained to the open-center system. Newly planted trees should be headed to about 30 inches in height, just above a lateral branch or bud. If the tree is branched when it comes from the nursery, select 3 or 4 laterals that are well-spaced up and around the trunk for the permanent scaffold limbs. The lowest limb should be about 15 inches and the highest about 30 inches from the ground. Cut these back to two buds each, and remove all other laterals.

If no desirable laterals are available, head the tree to the desired height and cut out all side branches to one bud. A number of shoots will develop during the season, from which you can select scaffold limbs. Selection can be made during the summer or delayed until just before growth begins the second season.

Once the scaffold system of the young peach tree is established, fairly heavy pruning is required to develop a low spreading tree. Remove all strong, upright shoots growing in the center of the tree, and lightly head back terminal growth on the scaffold limbs to outward-growing laterals. This aids in the development of an open-center tree.

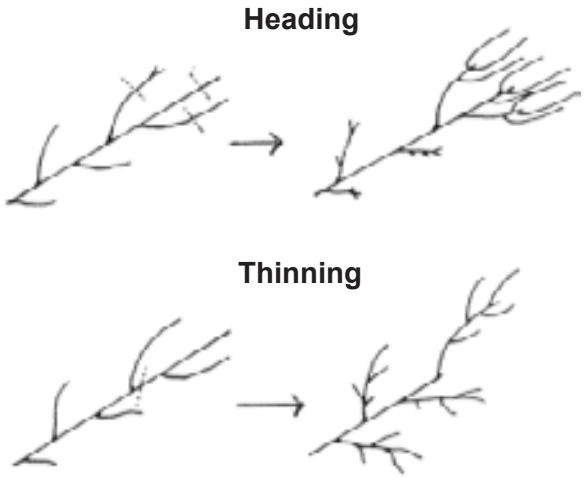
As fruit is borne on wood of the previous year's growth, it is necessary that the peach be pruned annually to stimulate new growth and maintain production near the main body of the tree. Pruning of the mature peach tree consists mainly of moderate thinning and heading back to outward-growing laterals to keep the tree low and spreading. A height of 8 or 9 feet is usually preferred.

Pruning Summary

When pruning fruit trees for best production, remember these basic concepts:

Pruning invigorates and results in rapid growth close to the pruning cut. Pruning reduces the number of shoots, so remaining shoots are stimulated. However, total shoot growth and size of the limb is reduced. Pruning always reduces yield.

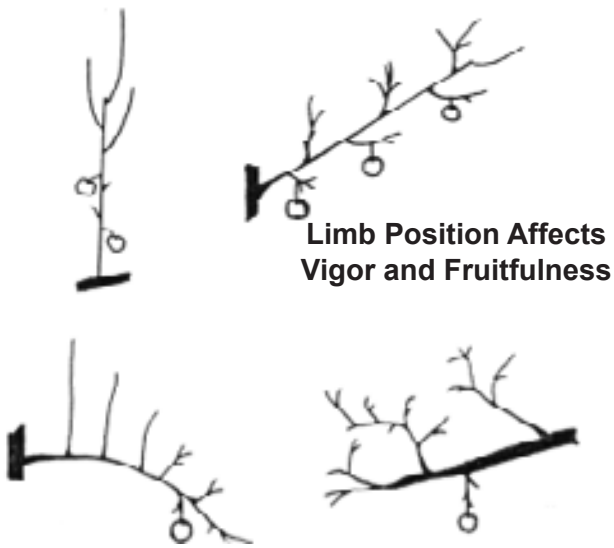
Two types of pruning cuts are heading back and thinning out. Heading is cutting off part of a shoot or branch to stimulate branching and stiffen the limb. Thinning cuts remove the entire shoot or branch at its junction with a lateral, scaffold, or trunk. Thinning cuts are less invigorating, improve light penetration, and can redirect the limb.



Limb position affects vigor and fruitfulness. Vertical or upright branches, typical in the tops of trees, produce the longest shoots near the end of the limb and tend to be excessively vigorous and not very fruitful. Fruit are often of poor quality and subject to limb rub. Limbs growing

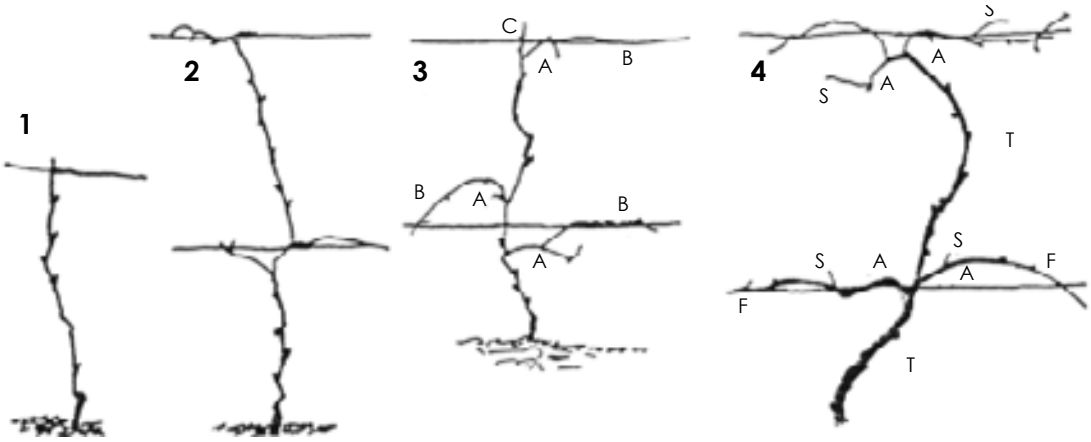
slightly above horizontal are more apt to develop a uniform distribution of vigor and fruitfulness. Light distribution tends to be even, and because fruit hang along the branch, they are less prone to limb rub. Limbs growing below horizontal tend to develop suckers along the upper surface. Excess sucker growth will result in shading. Hangers, or limbs developing on the underside of branches or scaffolds, are heavily shaded and low in vigor. Fruit developing on such wood is of poor size and color.

Invigoration from pruning is, in part, a nitrogen response. Pruning alters the balance between the tree top and root system. Removal of part of the top increases the amount of nitrogen available for the remaining growing points. Thus, a pruning program should be developed along with a good fertilization program. Severe pruning and/or excess fertilization can disrupt the vigor of the tree and decrease fruiting.



Limb Position Affects Vigor and Fruitfulness

Single Trunk, Four-arm Kniffen Training System



Stages in training the young vine to the single trunk, four-arm Kniffen system:

1. After pruning the first winter. The single cane is cut back and tied to the lower wire. If the cane has grown less than 3' during the first summer, it should be cut back to two buds.
2. After pruning the second winter. Two new canes of four or five buds each are tied on the bottom wire. A third new cane is tied up to the top of the wire and cut off.
3. After pruning the third winter. Three of the arms (A) and fruiting canes (B) have been formed. A cane (C) with four or five buds is left to establish the fourth arm.
4. A fully formed vine after pruning the fourth winter. The arms (A) should be shorter than those shown. The vine consists of a single, permanent trunk (T), four semi-permanent fruiting arms (F), and four renewal spurs (S), with two new buds on each.

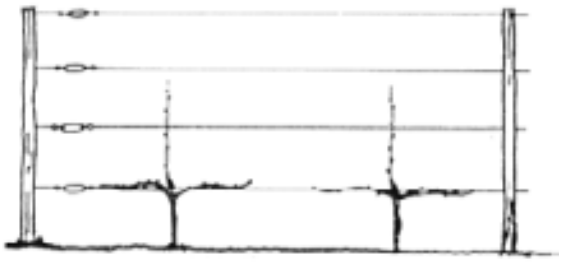
Special Training System

Numerous training systems, based on the art of *espalier*, which originated in France and Italy about 400 years ago, have been devised. Some are quite elaborate, requiring considerable time and patience as well as detailed knowledge of the plant's growth characteristics. The easiest espalier system is the horizontal cordon. Apples, pears, and plums adapt well to this system. The trees are usually supported by a wall, fence, or wire trellis. Training to the four-tier cordon or four-wire trellis is relatively easy.

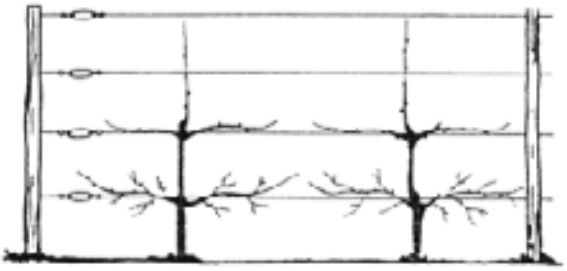
An espalier system can serve to separate yard areas and to provide an effective way of producing a large volume of high quality fruit in a limited area. Trees trained in this fashion should be grafted on dwarfing rootstock. Otherwise, they tend to grow too large and are difficult to hold within bounds.

A simple, four-wire trellis may be constructed by setting 8-foot posts 2 feet in the ground, spacing them 12 feet apart, and running wires through the posts at heights of 18, 36, 54, and 72 inches. Plant two unbranched whips of the desired variety 6 feet apart between each two posts.

Espalier Horizontal Cordon



First Winter



Second Winter

Before growth begins in the spring, cut off the whip just above the first bud, below the point where the whip crosses the lowest wire. Usually three or more shoots will develop near the point of the cut. Retain the uppermost shoot and develop it as the central leader. The other two can be developed into main scaffold branches to be trained along the lower wire, one on each side of the central stem. Remove all other growth. The two shoots selected for scaffold limbs should be loosely tied to the wire as soon as they are 10 to 12 inches long. Twine, plastic chain link ties, or other suitable material may be used. Tie the shoots so that they are nearly horizontal. This reduces vegetative vigor and induces flower bud formation. If the end of the shoot is tied below the horizontal, however, new growth at the end will stop, and vigorous shoots will develop along the upper side. At the end of the first season, the lateral branches on the lower wire should be established and the central leader should have grown above the second wire.

During the dormant pruning at the end of the first winter, cut the central leader off at a bud just below the second wire. Repeat the process of the previous spring by developing two scaffold branches to tie to the second wire and allow the central leader to grow above the third wire.

This process is repeated during the next two seasons, at which time a total of eight scaffolds, four on each side of the tree, should be firmly established. The leaders should be bent to form one of the scaffolds, rather than being cut off at the top wire.

By the end of the fourth season, the trees should be in heavy production. All pruning is then done during the spring and summer months. After new growth in the spring is about 2 inches long, cut it off, and remove about $^1/_4$ of the previous season's growth. Terminals of the scaffold are left untouched.

About the first of August, or as soon as new growth reaches 10 to 12 inches in length, cut it back to two or three buds. Repeat about a month later, if necessary. This encourages fruit bud formation and prevents excessive vigorous growth.

Study Questions

25. Most pruning of fruit trees is done in the dormant season just before active growth starts in the spring because: a) pruning wood heals quickly at this time; b) flowers buds are easily recognized; c) injury from low winter temperatures is avoided; d) all of the above

26. _____ trees should not be headed back because of their high susceptibility to fire blight.

27. _____ trees are very susceptible to winter injury and splitting where the limbs join the main trunk.

28. _____ trees are trained to an open-center (no leader) system.

29. Optimum fruit and vegetative growth balance occurs on: a) vertical, upright limbs; b) limbs growing slightly above horizontal; c) horizontal limbs; d) hangers

30. A/an _____ training system can be an effective way to produce a large volume of high quality fruit in a limited area.

Answers: 25 - d; 26 - pear; 27 - sweet cherry; 28 - peach; 29 - b; 30 - espalier

Training and Pruning Small Fruit

Grapes

For grapes to be most productive, they must be trained to a definite system and pruned rather severely. There are several training systems used. The two most common are the vertical trellis and the overhead arbor. Both of these are satisfactory in the home planting if kept well-pruned.

Of the many variations of the vertical trellis, the single-trunk, four-arm, Kniffen system is the most popular. Posts are set 15 to 20 feet apart and extend 5 feet above the ground. Two wires are stretched between the posts, the lower being about $2^1/_2$ feet above the ground, and the upper at the top of the posts. The vine is set between the posts and trained to a single trunk with four semi-permanent arms, each cut back to 6 to 10 inches in length. One arm is trained in each direction on the lower wire.

During annual winter pruning, one cane is saved from those that grew from near the base of each arm the previous summer. This cane is cut back to about ten buds. The fruit in the coming season is borne on shoots developing from those buds. Select another cane from each arm, preferably one that grew near the trunk, and cut it back to a short stub having two buds. This is a renewal spur. It should grow vigorously in the spring and be the new fruiting cane selected the following winter. All other growth on the vine should be removed. This leaves four fruiting canes, one on each arm, with eight to ten buds each, and four renewal spurs, one on each arm, cut back to two buds each.

The same training and pruning techniques may be effectively used in training grapes to the arbor system. The only difference is that the wires supporting the arms are placed overhead and parallel with each other instead of in a horizontal position. Overhead wires are usually placed 6 to 7 feet above the ground.

If an arm dies or for any reason needs to be replaced, choose the largest cane that has grown from the trunk near the base of the dead arm and train it to the trellis wire. To renew the trunk, train a strong shoot from the base of the old trunk to the trellis as though it were the cane of a new vine. Establish the arms in the same manner as for a new vine, and cut off the old trunk.

Pruning may be done anytime after the vines become dormant. In areas and on varieties where there is danger of winter injury, pruning should be delayed until late winter or early spring. Vines pruned very late may bleed excessively, but there is no evidence that this is permanently injurious.

Blueberries

Until the end of the third growing season, pruning consists mainly of removing low spreading canes and dead and broken branches. As the bushes come into bearing, regular annual pruning will be necessary. This may be done any time from leaf fall until growth begins in the spring. Select six to eight of the most vigorous, upright-growing canes for fruiting wood and remove all others.

After about 5 or 6 years, the canes begin to lose vigor and fruit production is reduced. At the dormant pruning, remove the older canes of declining vigor and replace with strong, vigorous new shoots that grew from the base of the bush the previous season. Keep the number of fruiting canes to six or eight, and remove the rest. Head back excessive terminal growth to a convenient berry-picking height.

Pruning Blueberries

Brambles

Trailing blackberries need some form of support. They may be grown on a trellis, trained along a fence, or tied to stakes. Other brambles may either be trained to supports or, with more severe pruning, grown as upright, self-supporting plants. Red raspberries and erect-growing blackberries are frequently grown in hedgerows.

A simple trellis, used in many home gardens, consists of two wires stretched at 3 and 5 foot levels between posts set 15 to 20 feet apart. Fruiting canes are tied to these wires in the spring. The erect varieties are tied where the canes cross the wires. Canes of trailing varieties are tied horizontally along the wires or fanned out from the ground and tied where they cross each wire.

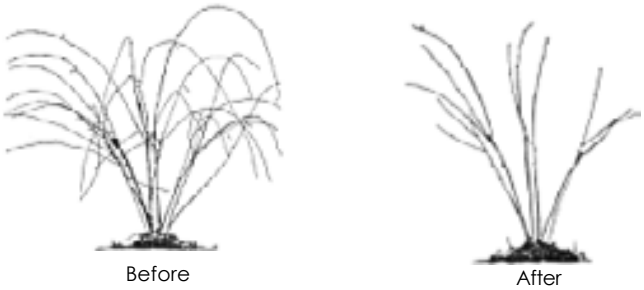
Where stakes are used for support, they are driven into the ground about 1 foot from each plant and allowed to extend 4 or 5 feet above the ground. Canes are tied to the stake at a point about midway between the ground and the tips of the canes, and again near the ends of the canes.

Canes of bramble fruits are biennial in nature; the crowns and roots are perennial. New shoots grow from buds at the crown each year. Late in the summer, the new canes develop lateral branches with fruit buds on them. Early in the second season, fruit-bearing shoots grow from these buds. After fruiting, the old canes wither and die, and new shoots spring up from the crowns.

These fruiting canes may be removed any time after harvest. They should be cut off close to the base of the plant, removed from the planting, and destroyed. As a sanitation practice, some growers do this immediately after harvest. Most, however, wait until the dormant pruning.

The dormant pruning is usually delayed until danger of severe cold is past and accomplished before the buds begin to swell. It consists of the removal of all dead, weak, and severely damaged canes, and the selection and pruning of the fruiting canes for the coming season. Where possible, fruiting canes $^1/_2$-inch or more in diameter are selected.

Pruning Black Raspberries



Black raspberries should be topped in the summer when the young shoots are about 24 inches high; purple raspberries, when about 30 inches high. Summer-topping consists of removing the top 3 to 4 inches of the new shoots by snapping them off with the fingers or cutting them with shears or a knife. Where trained to supports, let them grow 6 to 8 inches taller before topping.

At the dormant pruning, thin each plant until only four or five of the best canes remain. Cut the lateral branches of the black raspberry to 9 to 12 inches long; those of the purple raspberry to 12 to 15 inches long.

The following comments concerning red raspberries do not apply to the Heritage variety, which is an everbearing type.

Red raspberries should not be summer-topped. Canes of everbearing varieties are handled in the same manner as those of ordinary varieties. At the dormant pruning, where the hill system of culture is used, thin until only seven or eight of the best canes remain per hill.

If the plants are grown in hedgerows, keep the width of the rows to 18 inches or less, and remove all plants outside the row areas. Thin the canes within the hedgerows to 6 to 8 inches apart, saving the best canes.

Pruning Red Raspberries

Where the canes are supported either by a trellis or stakes, cut the canes back to a convenient height for berry-picking, usually 4 or 5 feet. Grown as upright, self-supporting plants, whether in hills or in hedgerows, the canes should be cut back to about 3 feet in height. Any lateral branches should be cut to about 10 inches in length.

New shoots of erect blackberries should be summer-topped when they are 30 to 36 inches high. To prevent the planting from becoming too thick and reducing yields, it may be necessary to remove excess sucker plants as they appear. This can be done either with a hoe or by hand. In the hedgerow type of culture, leave only three or four shoots per running foot of row. When grown in hills, four to five new shoots may be allowed to develop in each hill.

At the dormant pruning, where supports are used, head the canes to 4 to 5 feet in height. Canes grown without support should be headed to 3 feet. Cut lateral branches back to 15 or 18 inches long.

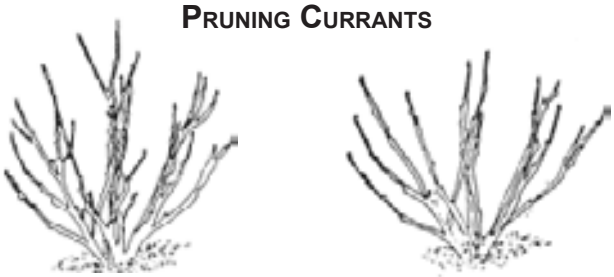
Trailing blackberries require little pruning. All dead and weak canes should be removed after harvest or at the dormant pruning. They should be thinned to seven or eight of the best canes per hill, cut to about 5 feet in length, and tied to either a stake or trellis.

Currants and Gooseberries

Currants and gooseberries typically form bushes with many branches arising near the ground level. Pruning may be done any time during the dormant period and consists primarily of thinning out excess stems. Except for the removal of weak, broken, or prostrate stems, very little pruning is done until the plants are 4 years old. The mature bush should have three or four stems each of 1-, 2-, and 3-year-old wood. The actual number should be determined by the vigor of the bush. Heading back is done only to reduce the height of extra long, 1-year-old shoots.

Remove all wood over 3 years old. Cut off the damaged and low prostrate stems, retaining only the most vigorous of the 2- and 3-year-old shoots. Head back young shoots that are too long.

Pruning Currants



Pruning Gooseberries

Study Questions

31. The vertical trellis and overhead arbor are training systems used for _____.

32. Blueberries should be pruned:
a) during the dormant season; b) naturally by birds; c) completely to the ground every year; d) by a chain saw

33. Canes of bramble fruits are ___, while crowns and roots are ___: a) biennial, perennial; b) perennial, biennial; c) biennial, annual; d) annual, perennial

34. The bramble that should not be topped in summer is: a) blackberries; b) purple raspberries; c) red raspberries; d) all of the above

35. Currants and gooseberries should be pruned:
a) to remove all but 1-year old wood; b) to reduce heavy fruiting; c) during the dormant season; d) only during their first four years of growth

Answers:
31 - grapes; 32 - a; 33 - a; 34 - c; 35 - c

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Chapter 12
Indoor Plants

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This chapter is designed to familiarize you with the basic aspects of tropical plant care rather then attempting to acquaint you with specific cultural requirements of the more than 250 commonly grown plants in the foliage industry. Bear in mind that in most cases, homes and offices are environments poorly suited to the needs of tropical plants. Thus the task of the indoor plant gardener is to select plants that can best withstand the conditions of a specific indoor location.

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Purchasing an Interior Plant

Select only those foliage plants which appear to be free of pests. Check the undersides of the foliage and the axils of leaves for signs of insects or disease. Select plants that look sturdy, clean, well-potted, and shapely.

Choose plants with healthy foliage. Avoid plants which have yellow or chlorotic leaves, brown leaf margins, wilted foliage, spots or blotches, or spindly growth. In addition, avoid those with torn leaves and those which have been treated with "leaf shines," which add an unnatural polish to the leaves. Plants which have new flower and leaf buds along with young growth are usually of superior quality.

Remember that it is easier to purchase a plant which requires the same environmental conditions your residence has than to alter the environment of your home or office to suit the plants.

Transporting House Plants

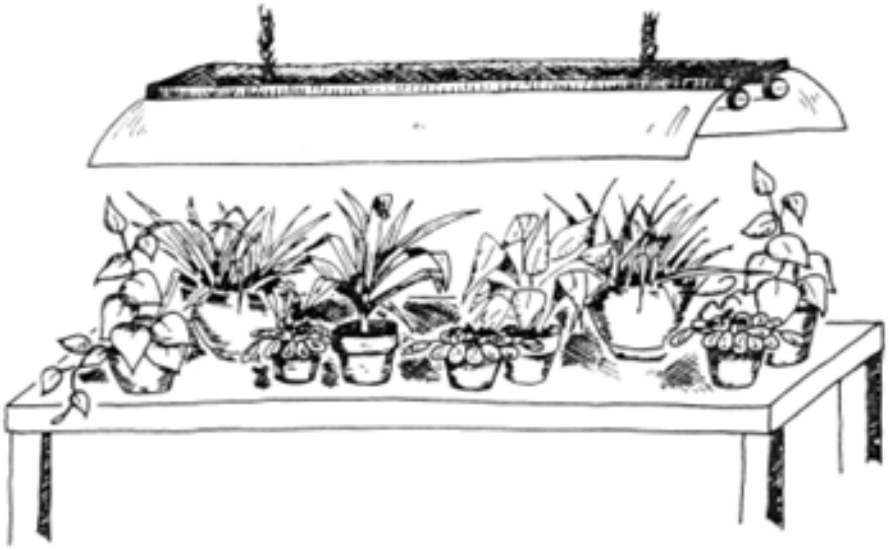
When transporting plants, remember the two seasons of the year that can cause damage to the plants: the hot summer and the cold winter months. In the summer, avoid placing plants in a car and leaving the car shut, because temperatures will rise and destroy the plant in a short period of time. If you have to travel for any distance at all, the plant can be burned by the sun shining on it, even though the air conditioner is on and it's comfortable in the car. Shade the plant from direct sun while it is in the car.

During winter months, wrap plants thoroughly before leaving the store to carry them to your car. Transporting a tropical plant in very low temperatures can kill or severely damage plants. Wrap plants thoroughly with newspaper or paper bags, place in the front of the car, and turn on the heater. The trunk of most cars is too cold to carry plants safely during winter months.

On an extended trip, make special arrangements so that plants will not be frozen or damaged by cold weather. Many foliage plants will be damaged considerably if the temperature drops much below 50ºF, so maintain as warm a temperature as possible around these plants when transporting them from one location to another. Never allow wind to blow across them from open car windows.

Acclimatization

Research conducted in Florida in the late 1970s revealed an interesting phenomenon. Tropical plants grown in full sun have leaves (so-called sun leaves) which are structurally different from the leaves of plants grown in shade (shade leaves). Sun leaves have fewer chloroplasts, and thus less chlorophyll. Their chloroplasts are located deep inside the leaves and the leaves are thick, small, and large in number. Shade leaves have greater numbers of chloroplasts and thus more chlorophyll, are thin, large, and few in number. When plants are grown in strong light, they develop sun leaves which are photosynthetically very inefficient. If these same plants are placed in low light, they must either remake existing sun leaves or drop their sun leaves and grow a new set of shade leaves which



are photosynthetically more efficient. To reduce the shock which occurs when a plant with sun leaves is placed in shade, gradually reduce the light levels it is exposed to. This process is called acclimatization. The gardener should acclimatize plants when placing them outdoors in summer by gradually increasing light intensities, and reverse the process before plants are brought indoors in the fall. For newly purchased plants grown in high-light conditions, acclimatize them by initially locating them in a high-light (southern exposure) area of your home and gradually moving them to their permanent, darker location over a period of 4 to 8 weeks.

Factors Affecting Plant Growth Indoors

Light, water, temperature, humidity, ventilation, fertilization, and soil are chief factors affecting plant growth, and any one of these factors in incorrect quantity will prevent proper plant growth indoors.

Light

Light is probably the most essential factor for indoor plant growth. The growth of plants and the length of time they remain active depend on the amount of light they receive. Light is necessary for all plants because they use this energy source to photosynthesize. When examining light levels for tropicals, consider three aspects of light: intensity, duration, and quality.

Light **intensity** influences the manufacture of plant food, stem length, leaf color, and flowering. A geranium grown in low light tends to be spindly and the leaves light green in color. A similar plant grown in very bright light would tend to be shorter, better branched, and have larger, dark green leaves. Indoor plants can be classified according to their light needs by high, medium, and low light requirements. The intensity of light a plant receives indoors depends upon the nearness of the light source to the plant (light intensity decreases rapidly as you move away from the source of light). The direction the windows in your home face will affect the intensity of natural sunlight that plants receive. Southern exposures have the most intense light, eastern and western exposures receive about 60% of the intensity of southern exposures, and northern exposures receive 20% of a southern exposure. A southern exposure is the warmest, a western exposure is warmer than eastern as it receives the warm afternoon sun, and a northern exposure is the coolest. Other factors which can influence the intensity of light penetrating a window are the presence of curtains, trees outside the window, weather, seasons of the year, shade from other buildings, and the cleanliness of the window. Reflective (light-colored) surfaces inside the home/office will increase the intensity of light available to plants. Dark surfaces will decrease light intensity. Excessive dust on leaves can decrease light intensity reaching the leaves.

Day-length or **duration** of light received by plants is also of some importance, but generally only to those plants which are photosensitive. Poinsettia, kalanchoe, and Christmas cactus bud and flower only when day-length is short (11 hours of daylight or less). Most flowering indoor plants are indifferent to day-length (for more information see the section on "Environmental Factors Affecting Plant Growth" in Chapter 2: Basic Botany).

Low light intensity can be compensated by increasing the time (duration) the plant is exposed to light, as long as the plant is not sensitive to day-length in its flowering response. Increased hours of lighting allow the plant to make sufficient food to survive and/or grow. However, plants require some period of darkness to develop properly, and thus should be illuminated for no more than 16 hours. Excessive light is as harmful as too little light. When a plant gets too much direct light, the leaves become pale, sometimes burn, turn brown, and die. Therefore, during the summer months, protect plants from too much direct sunlight.

Additional lighting may be supplied by either incandescent or fluorescent lights. Incandescent lights produce a great deal of heat and are not very efficient users of electricity. If artificial lights are to be used as the only source of light for growing plants, the **quality** of light (wavelength) must be considered. For photosynthesis, plants require mostly blues and reds, but for flowering, infrared light is also needed. Incandescent lights produce mostly red and some infrared light, but are very low in blues. Fluorescent lights vary according to the phosphorus used by the manufacturer. Cool-white lights produce mostly blue light, and are low in red light. Foliage plants grow well under cool-white fluorescent lights, which are also cool enough to position quite close to plants. Blooming plants require extra infrared light which can be supplied by incandescent lights or special horticultural-type (fluorescent or LED) lights.

Water

Overwatering and underwatering account for a large percentage of tropical plant losses. The most common question gardeners ask is, "How often should I water my plants?" There is not a good answer to this question. Some plants like drier conditions than others. Differences in potting medium and environment influence water needs. Watering as soon as the soil crust dries can result in overwatering.

Plant roots are usually in the bottom 2/3 of the pot, so do not water until the bottom 2/3 starts to dry out slightly. You can't tell this by looking at the plant. By the time the plant wilts or changes color due to lack of water, it has been damaged and will be less vigorous. You have to feel the soil. For a 6-inch pot, stick your index finger about 2 inches into the soil (approximately to the second joint of your finger). If the soil feels damp, don't water. Keep repeating the test until the soil is barely moist at the 2-inch depth. For smaller pots, 1 inch into the soil is the proper depth to measure.

Water the pot until water runs out of the bottom. This serves two purposes. First, it washes out all the excess salts (fertilizer residue). Second, it guarantees that the bottom 2/3 of the pot, which contains most of the roots, receives sufficient water. However, don't let the pot sit in the water that runs out. After a thorough watering, wait until the soil dries at the 2-inch depth before watering again. If the soil has become excessively dry and pulled away from the sides of the pot, it will be necessary to soak the container in the sink or other container until the soil is fully rehydrated and expanded.

When you test for watering, pay attention to the soil. If your finger can't penetrate 2 inches deep, you either need a more porous soil mix or the plant is becoming root-bound. Consider using distilled water rather than tap water, which contains fluoride. Fluoride causes leaf tip burn in many plants; peace lily and spider plants are particularly vulnerable. Be aware of the temperature of the water also; cold water can stun or damage some tropical plants. Warm tap water or room temperature bottled water is best.

Temperature

Most house plants tolerate normal temperature fluctuations. In general, indoor foliage plants grow best between 70 and 80ºF during the day and from 60 to 68ºF at night. Most flowering indoor plants prefer the same daytime range but grow best at nighttime temperatures from 55 to 60ºF. The lower night temperature induces physiological recovery from moisture loss, intensifies flower color, and prolongs flower life. Excessively low or high temperatures may cause plant failures, stop growth, or cause spindly appearance and foliage damage or drop. A cooler temperature at night is actually more desirable for plant growth than higher temperatures. A good rule of thumb is to keep the night temperature 10 to 15º lower then the day temperature.

Humidity

Atmospheric humidity is expressed as a percentage of the moisture saturation of air. When humidity is too low, brown tips and margins may appear on tropical plant leaves. To provide increased humidity, attach a humidifier to the heating or ventilating system in the home, or place gravel trays (in which an even water level is maintained) under the plant containers. This will increase the relative humidity in the vicinity of the containers. As the moisture around the pebbles evaporates, the relative humidity is raised. Make sure the bottom of the pot does not come in contact with the water in the pebble tray, as it could soak up too much water and damage the plant roots.

A layer of moist gravel or pebbles increases the humidity level

Moist sphagnum peat moss around the smaller pot

Another way to raise humidity is to group plants close together. Some people spray a fine mist on the foliage, however, this is of doubtful effectiveness for total humidity modification unless repeated frequently throughout the day. Time this so that the plants will be dry by night. If the soil has become excessively dry and pulled away from the sides of the pot, it will be necessary to soak the

container in the sink or another container until the soil is fully re-hydrated and expanded. This lessens the chance of disease, since cool dampness at night provides an ideal environment for disease.

A container plant may be set on a layer of wet gravel or pebbles; add water to the gravel to increases the humidity level. Another way of controlling moisture is to water sphagnum peat moss around the smaller pot.

Ventilation

Indoor plants, especially flowering varieties, are very sensitive to drafts or heat from registers. Forced air dries the plants rapidly, overtaxes their limited root systems, and may cause damage or plant loss. Plants are sensitive to natural or blended gas. Some plants refuse to flower, while others drop flower buds and foliage when exposed to gases. Blended gases are more toxic to plants than natural gases. Tomato plants are extremely sensitive to gas. They will turn yellow before the escaping gas is detected by household members, and are sometimes used in greenhouses as indicator plants for excessive ethylene gas (resulting from incomplete combustion in gas furnaces).

Fertilization

Indoor plants, like most other plants, need fertilizers containing three major plant food elements: nitrogen (N), phosphorus (P), and potassium (K). They are available in many different combinations and under a multitude of brand names. Each brand should be analyzed on the label, indicating specifically how much water-soluble elemental nitrogen, phosphate, or potash is available in every pound of the product. The three numbers on a package of fertilizer, such as 20-5-20, indicate the percentages (by weight) of nitrogen, phosphorus, and potassium, respectively, in the fertilizer product. Commercial fertilizers used for indoor plants are sold in granular, crystalline, liquid, or tablet forms. Each should be used according to instructions on the package label. Frequency of fertilizer application varies somewhat with the vigor of growth and age of each plant. Some need it every 2 weeks, while others will flower well for several months without needing any supplement. As a general rule, fertilize every 2 weeks from March to September. During the winter months, no fertilizer is needed because reduced light and temperature result in reduced growth. Fertilizing at this time could be detrimental to some plants.

Soluble Salts

Reduced growth, brown leaf-tips, dropping of lower leaves, small new growth, dead root-tips, and wilting are all signs of high soluble salts. These salts will accumulate on top of the soil forming a yellow to white crust. A ring of salt deposits may be formed around the pot at the soil line or around the drainage hole. Salts will also build up on the outside of clay pots, but is generally not harmful.

Soluble salts are minerals dissolved in water. Fertilizer dissolved in water becomes a soluble salt. When water evaporates from the soil, the minerals or salts stay behind. As the salts in the soil become more and more concentrated, plants find it harder and harder to take up water. If salts build to an extremely high level, water can be taken out of the root-tips, causing them to die.

High soluble salts damage the roots directly, and because the plant is weakened, it is more susceptible to attack from insects and diseases. One of the most common problems associated with high salt levels is root rot.

The best way to prevent soluble salt injury is to stop the salts from building up. Water correctly. When you water, allow some water to drain through, and then empty the drip plate. Water equal to 1/10 the volume of the pot should drain through each time you water. DO NOT ALLOW THE POT TO SIT IN WATER. If you allow the drained water to be absorbed by the soil, the salts that were washed out are taken back into the soil. Salts can be reabsorbed through the drainage hole or directly through a clay pot.

Plants should be leached every 4 to 6 months. You should leach a plant before you fertilize, so that you don't wash away the fertilizer you just added. Water the soil thoroughly, as you usually would. Then, after about five minutes, water again, letting excess water flow out the bottom drain holes. The first watering dissolves the fertilizer salts. The second washes the salt out of the soil. If a layer of salts has formed a crust on top of the soil, you should remove the salt crust before you begin to leach. Do not remove more than 1/4 inch of soil. It is best not to add more soil to the top of the pot. If the soluble salt level is extremely high or the pot has no drainage, repot the plant.

The level of salts that will cause injury varies with the type of plant and how it is being grown. A plant grown in the home may be injured by salts at concentrations of

200 ppm. The same plant growing in a greenhouse, where the light and drainage are good, will grow with salts at 10 times that level, or 2000 ppm. Some nurseries and plant shops leach plants to remove excess salts before the plant is sold. If you are not sure that has been done, leach a newly purchased plant the first time you water it.

Study Questions

1. Compared to sun leaves, shade leaves:
   a) have fewer chloroplasts; b) are thinner; c) are smaller; d) are more numerous

2. The three aspects of light that affect plant growth are _____, _____, and _____.

3. The window exposure that provides the LEAST amount of sunlight is:
   a) south; b) west; c) east; d) north

4. To avoid water stress, the best indicator that plants need water is: a) it's Monday, watering day;
   b) they are wilted; c) the soil feels dry about 2 inches deep; d) the leaves are yellow

5. A good rule of thumb is to keep night temperatures _____ day temperatures:
   A) 5-10ºF warmer than; b) 10-15ºF cooler than;
   c) 15-20ºF cooler than; d) the same as

6. Methods of increasing humidity do NOT include:
   a) placing plants near a fan; b) grouping plants close together; c) placing plants on a pebble tray;
   d) using a room humidifier

7. In general, fertilization should be reduced/ceased during _____ months.

8. Reduced growth, brown leaf tips, drop of older leaves, small new growth, dead root tips, and wilting are all signs of _____.

9. In order to prevent toxicity from soluble salts, plants must occasionally be _____.

Answers:
1 - b; 2 - intensity, duration, quality; 3 - d; 4 - c; 5 - b; 6 - a; 7 - winter; 8 - high soluble salts; 9 - leached

Growing Media

The potting soil, or medium in which a plant grows, must be of good quality. It should be porous for root aeration and drainage, but also capable of water and nutrient retention. Most commercially prepared mixes are termed soil-less, which means they contain no soil. High-quality artificial mixes generally contain slow-release fertilizers, which take care of a plant's nutritional requirements for several months. You can also prepare your own soil-less mix.

Preparing Soil-less Mixes

Soil-less mixtures can be prepared with a minimum of difficulty. Most mixes contain a combination of organic matter, such as peat moss or ground pine bark, and an inorganic material, like washed sand, vermiculite, or perlite. Materials commonly used for indoor plants are the peat-lite mixtures, consisting of peat moss and either vermiculite or perlite. The following are the most common media components.

Peat Moss is readily available baled or bagged; sphagnum peat moss is recommended. Such materials as Michigan peat, peat humus, and native peat are usually too decomposed to provide necessary structural and drainage characteristics. Most sphagnum peat moss is acid in reaction, with a pH ranging from 4.0 to 5.0 It usually has a very low fertility level.

Vermiculite is a sterile, lightweight, mica product. When mica is heated to approximately 1800ºF, its platelike structure expands. Vermiculite will hold large quantities of air, water, and nutrients needed for plant growth. Its pH is usually in the 6.5 to 7.2 range. Vermiculite is available in four particle sizes. For horticultural mixes, sizes 2 or 3 are generally used. If at all possible, the larger-sized particles should be used, since they give much better soil aeration. Vermiculite is available under a variety of trade names. Vermiculite collapses with time and looses its positive characteristics.

Perlite is a sterile material produced by heating volcanic rock to approximately 1800ºF. The result is a very lightweight, porous material that is white in color. Its principal value in soil mixtures is aeration. It does not hold water and nutrients as well as vermiculite. The pH is usually between 7.0 and 7.5. Perlite can cause fluoride burn on some foliage plants, usually on the tips of the leaves. The burn progresses from the tip up into the leaf. Fluoride burns can be prevented by adding 11/2 times the recommended amount of lime when mixing the soil. Artificial mixtures are usually very low in trace or minor elements, therefore, it is important to use a fertilizer that contains these trace elements. A good formula for

artificial mix (makes 3 bushels of media) follows.

* 1 bushel shredded peat moss
* 2 bushels perlite or vermiculite
* 1/2 cup finely ground agricultural lime
* 1/3 cup 20% superphosphate
* 1/2 cup 8-8-8 or similar analysis mixed fertilizer
* 1 level teaspoon chelated iron

Soil Mixes for Specific Plants

Soils must have the most efficient composition for the type of plant to be grown. According to generally accepted standards, we can divide indoor plant soils into four distinct groups, according to the type of plant to which they are most suited.

Artificial soil mixes work well but a mixture with soil could be used. Any soil containing garden loam should be pasteurized. This can be done easily at home. Spread the soil on a cookie tray and bake it at 180ºF for 30 minutes. Do not heat it longer than 30 minutes, and be aware that it will smell unpleasant while baking.

Foliage Plants: This soil should be moderately rich, have a good base of clay loam, and hold moisture and fertility adequately. It must be a crumbly, well-textured soil. It is generally made up of one part of good garden loam, one part of clean sand or perlite, and half to one part of either peat moss, compost, leaf mold, or vermiculite. Mixing about 1 teaspoon of superphosphate with each quart of mixed potting soil is desirable and encourages good root growth after repotting. If the garden soil is alkaline, sphagnum peat moss will have enough acid reaction to neutralize the mixture. This soil is used for all foliage plants and some flowering plants that do not prefer a rich soil.

Flowering House Plants: This soil is often referred to as humus soil because it contains about 50% humus-rich materials or similar ingredients. It is important that the soil does not become so rich that it is soggy after watering. Two parts of sphagnum, or one part sphagnum and one part vermiculite, are added to one part garden loam and one part clean sand. Also add 1 teaspoon of superphosphate per quart of soil mixture. This soil is generally used for African violets, gloxinias, begonias, calla lilies, and other tropical flowering plants.

Cacti and Succulents: This soil does not need any humus material. It is composed of equal parts of sand, garden soil, and vermiculite or perlite. It is preferred for cacti and other fleshy leaved, desert-type succulents.

Orchids: Fir-tree bark or Osmunda fiber is generally used in glazed or plastic pots. The container should be large enough so that new growth is 1 to 2 inches from the rim of container. Broken clay pieces can make up the lower inch in the container.

Containers

There are many types of containers from which to choose. A good container should be large enough to provide room for soil and roots, have sufficient room above the soil line for proper watering, provide bottom drainage, and be attractive without competing with the plant it holds. Containers may be made from ceramics, plastic, fiberglass, wood, aluminum, copper, brass, and many other materials.

Clay and Ceramic Containers

Unglazed and glazed porous clay pots with drainage holes are widely used. Ornate containers are often nothing but an outer shell to cover the plain clay or plastic pot. Clay pots absorb and lose moisture through their walls. Frequently the greatest accumulation of roots is next to the walls of the clay pot because moisture and nutrients accumulate in the clay pores. Although easily broken, clay pots provide excellent aeration for plant roots and are considered by some to be the healthiest type of container for a plant.

Ceramic pots are usually glazed on the outside, sometimes also on the inside. They are frequently designed without drainage holes. This necessitates careful watering practices and does not allow for leaching. Small novelty containers have little room for soil and roots and are largely ornamental. They should be avoided. It should be noted that putting pot chips, clay pot shards or gravel in the bottom of a pot does not improve soil drainage; they only provide a small space beneath the soil where some excess water can drain inside the pot.

Plastic and Fiberglass Containers

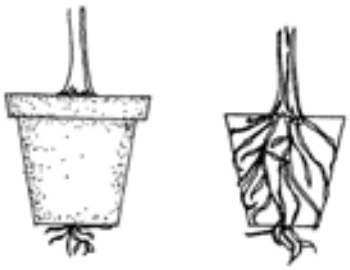
Plastic and fiberglass containers are usually quite light and easy to handle. They have become popular in recent years because they are relatively inexpensive and often

quite attractive in shape and color. Plastic pots are easy to sterilize or clean for reuse, and because they are not porous, they need less frequent watering and tend to accumulate fewer salts.

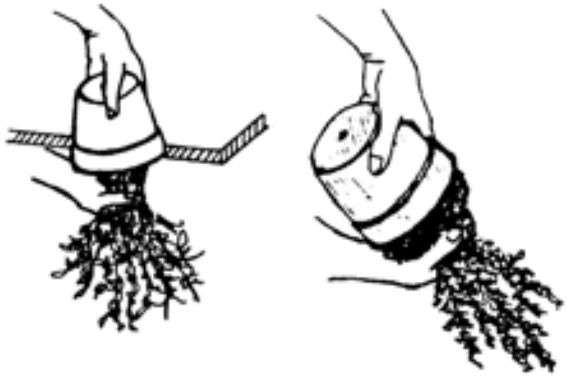
Repotting

Actively growing indoor plants need repotting from time to time. This occurs very rarely with some slower-growing plants, more frequently with others. Foliage plants require repotting when their roots have filled the pot and are growing out the bottom holes. It is useful to know that certain species actually prefer to be pot-bound, such as African violets, aloe, and jade plant.

When repotting becomes necessary, it should be done without delay. The pot selected for repotting should be no more than 2 inches larger in diameter than the pot the plant is currently growing in; should have at least one drainage hole; may be either clay, ceramic, or plastic; and must be clean. Wash soluble salts from clay pots with water and a scrub brush, and wash all pots in a solution of 1 part liquid bleach to 9 parts water.



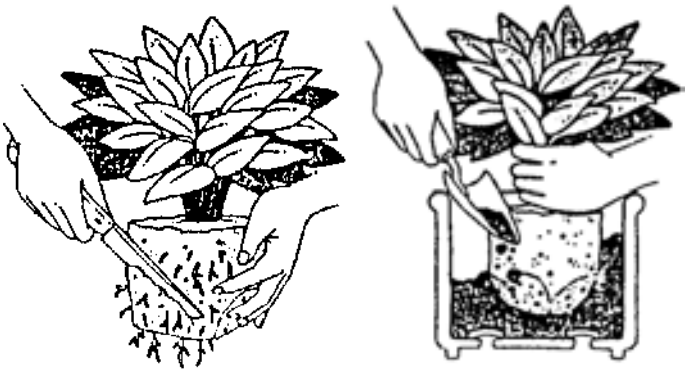
Potting media should be coarse enough to allow good drainage, yet have sufficient water retention capabilities. Most plants are removed easily from their pot if the pot is held upside-down while knocking the lip of the container sharply upon the edge of a table. Hold your hand over the soil, straddling the plant between the fore and middle fingers while knocking it out of its present container. Do not pull the plant out of the container.

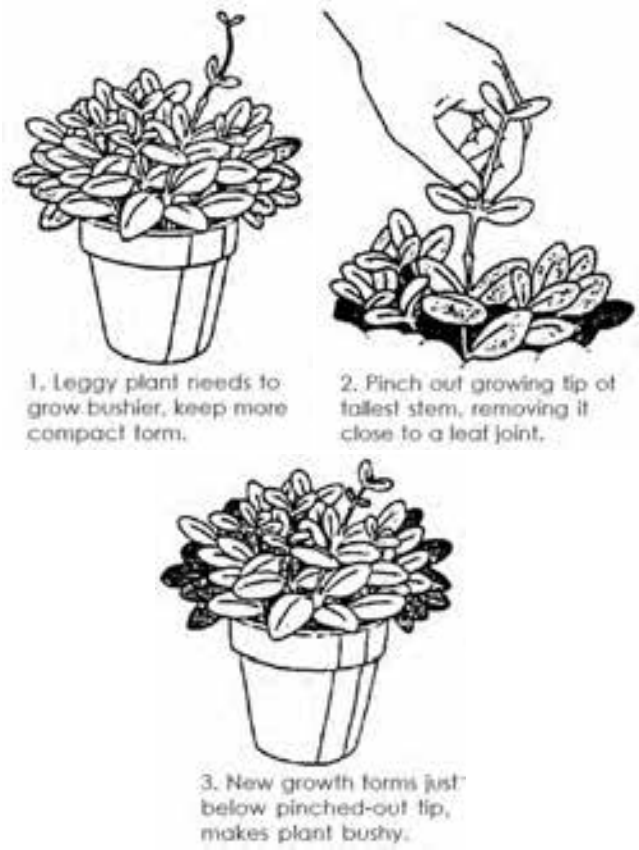


Potting media should be moistened before repotting begins. To repot, place soil in bottom of pot. If the plant has become root-bound it will be necessary to cut and unwind any roots that circle the plant, otherwise the roots will never develop normally. If the old soil surface has accumulated salts, the top inch should be removed. Set the rootball in the middle of the new soil. Fill soil around the sides between the rootball and pot. Do not add soil above the original level on the rootball, unless the roots are exposed or it has been necessary to remove some of the surface soil. Do not pack the soil as this decreases aeration. To firm or settle it, tap the pot on a level surface or gently press the soil with your fingers. After watering and settling, the soil level should be sufficiently below the level of the pot to leave an inch or more headroom.

Headroom is the space between the soil level and the top of the pot that allows for watering a plant. A properly potted plant has enough headroom to allow water to wash through the soil to thoroughly moisten it.

Repotting



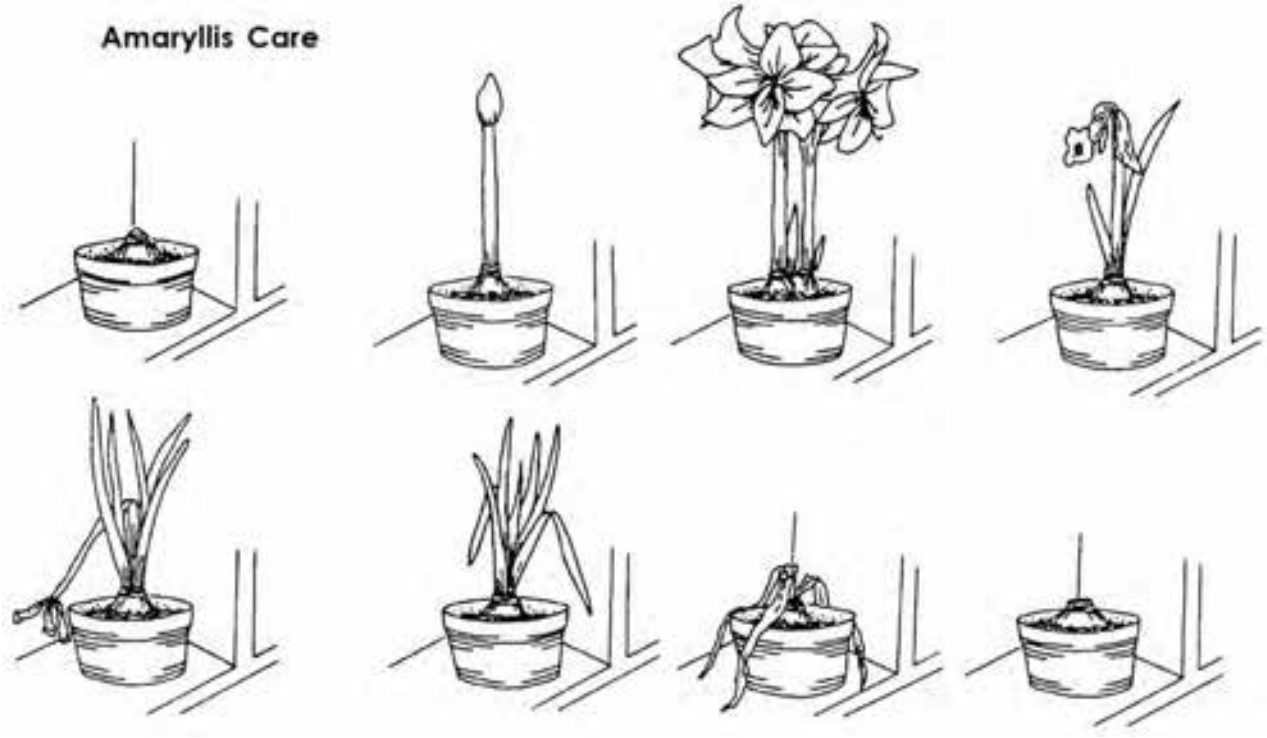


Training and Grooming

This includes a number of minor care activities that distinguish the beginner from the more experienced indoor plant grower. Pinching is one of them. Pinching is the removal of 1 inch or less of new stem and leaf growth, just above a node. This leaves the plant attractive and stimulates new growth. It can be a one-time or continuous activity, depending on the needs of the plant. If a plant should be kept compact but well-filled out, frequent pinching will achieve this.

Pruning is a similar activity. Pruning includes removal of other than terminal shoot tips. Sometimes an entire branch or section of a plant should be removed for the sake of appearance.

Disbudding is another related care activity. Certain flower buds are removed either to obtain larger blooms from a few choice buds or to prevent flowering of a very young plant (or recently rooted cutting) that should not bear the



physical drain of flowering early.

Ivies and hoya, as well as philodendron and syngonium, can be easily trained on trellises.

It is important to keep plants clean and neat. It not only improves the appearance of plants but reduces the incidence of insects and disease problems. Remove all spent flowers, dying leaves, and dead branches. Keep leaves dust-free by washing plants with warm water and mild soap (cover pot to prevent soap from entering the soil). Dust can clog stomata and reduce respiration. If tips of leaves become brown and dry, trim them off neatly with sharp scissors.

Care of Specific Plants

Too little light, excessive heat, and improper watering are the usual causes of failure in caring for gift plants. These plants are grown in a greenhouse, where the night temperatures are usually cool, there is ample light, and the air is moist. When they are brought into a dry home, where the light is poor and the temperatures are maintained for human comfort, results are frequently disappointing. Do not expect to keep a gift plant from year to year. Enjoy them while they are attractive and in season and then discard.

Poinsettia Care

The poinsettia requires bright light and should be kept away from drafts. A temperature between 65 and 70ºF is ideal. Avoid temperatures below 60ºF and above 75ºF. Keep plants well-watered but do not overwater. Some of the newer, long-lasting varieties can be kept attractive all winter.

Gardeners frequently ask whether they can carry their poinsettias over to bloom again next year. It is questionable whether the results are worth the effort, as the quality of home-grown plants seldom equals that of commercially grown plants. However, for those who wish to try, the following procedure can be followed.

After the bracts fade or fall, set the plants where they will receive indirect light and temperatures around 55 to 60ºF. Water sparingly during this time, just enough to keep the stems from shriveling. Cut the plants back to within 5 inches of the ground and re-pot in fresh soil. As soon as new growth begins, place in a well-lighted window.

After danger of frost, place the pot outdoors in a partially shaded spot. Pinch the new growth back to get a plant with several stems. Do not pinch after September 1st. About Labor Day, or as soon as the nights are cool, bring the plant indoors. Continue to grow in a sunny room with a night temperature of about 65ºF. Since the poinsettia blooms only during short days, exclude artificial light, either by covering with a light-proof box each evening or placing in an unlighted room or closet for a minimum of 12 hours of darkness. Plants require full light in the daytime, so be sure to return them to a sunny window. Start the short-day treatment in mid-September to have blooms between December 1 and Christmas.

Azaleas

Azaleas require direct sunlight to remain healthy. A night temperature of 60ºF will prolong bloom. Keep the soil constantly moist. If the leaves should turn yellow, the soil is not acid enough. Use an acid fertilizer sold especially for azaleas. Do not use softened water. When repotting, use a mixture high in acid peat moss.

Azaleas can be planted, pot and all, in a shady spot in the garden during the summer months. Examine them frequently and keep them watered during dry periods. Greenhouse azaleas are not hardy, and need to be brought indoors before freezing weather.

Azaleas need a cool, rest treatment before they are forced into bloom. Place the plants in a room with filtered light and a temperature between 35-50ºF. During this rest period, flower buds will develop. Then place in a well-lighted, warm (65ºF) room around January 1 to bring

them into bloom. Unless you have the proper growing conditions for the azalea, you should not attempt to carry the plants over in the house.

Gardenia

Gardenias grown indoors need special care. They demand an acid soil and should receive the same nutritional care as azaleas. The night temperature should be near 60ºF and the humidity around the plant should be kept high. High temperature and low light intensity will result in flower bud drop. Gardenias are hardy in the warmest parts of Virginia, but will not overwinter outside of Zone 7b.

Amaryllis

The secret of growing amaryllis is to keep the plants actively growing after they finish blooming. Keep the plants in full sun, with a night temperature above 60ºF. As soon as danger of frost has passed, set the plants in the garden in a semi-shaded spot. Bring them in during the first part of September, stop watering them to allow old growth to die back, and store them in a cool, dark place to rest. They will be ready to force again about November 1. Bring them into a warm light room and water moderately to begin new growth.

Christmas Cactus

The Christmas cactus has become increasingly popular with the development of several new varieties. At least three related species are sold in addition to a number of cultivars. All have similar cultural requirements.

The secret of good bloom seems to be one of temperature and photoperiod control. They will develop buds and bloom if given bright light, short days, and night temperatures between 55 and 65ºF. Christmas cacti bloom best when somewhat pot-bound. Repotting is necessary only about once in 3 years. Full sunlight is beneficial in midwinter, but bright sun during summer months can make plants look pale and yellow.

Christmas cacti require less water from October to March than they do when growth is active from April to September. A rest period is very important if plants are to bloom abundantly. Dormancy should be started about the middle of September and continued for 8 weeks. Care should be taken that soil never becomes water-logged during the dark days of winter.

Cyclamen

Cyclamen require full sunlight and a night temperature of between 50 and 60ºF. They are heavy users of water and must be watered whenever the surface of the soil is dry. Flower buds will fail to develop if night temperature is too high or if light is poor.

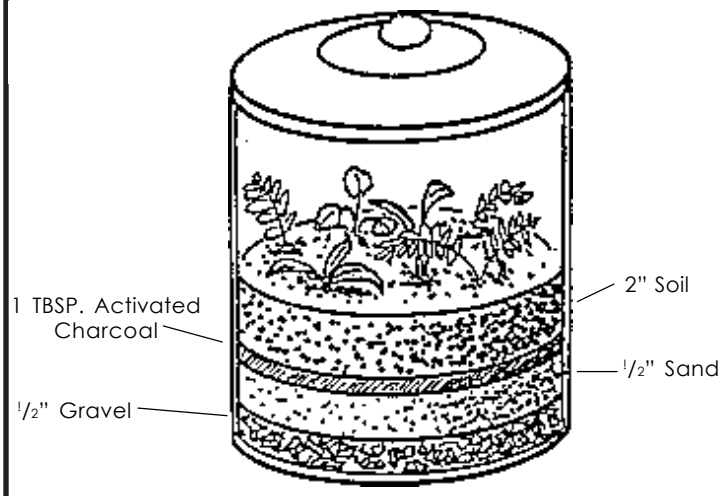
Cyclamen can be carried over, but as with the poinsettia, homegrown plants are seldom equal to those grown by a commercial grower. Let the plants die down after they finish flowering. Repot the fleshy corm in June with the top of the corm above the soil line. Allow resting bulbs to dry, but not to become shrivelled.

Terrariums and Dish Gardens

Terrariums

A terrarium is a “miniature garden” in which plants are often contained within a tightly closed glass or clear plastic vessel, usually with a moveable top and requiring very little attention. Because such containers are kept closed most of the time, air inside stays at high humidity, similar to a greenhouse. This is an ideal environment for a variety of houseplants. Condensate eventually forms on the inside of the container and is returned to the medium as water, which may preclude the addition of water for several weeks. Overwatering is one of the most common problems in terrarium care-- medium should be kept moist, not wet. If conditions inside become too moist, the top should be removed to evaporate excess water. A standard medium, along with a sand and/or gravel base for drainage and charcoal to absorb unpleasant odors are commonly used. Fertilizer applications are made only to sustain plants and when in use should be in soluble dilute form. The terrarium should be placed in bright, but not direct sunlight at average room temperatures.

Terrarium



Dish Gardens

Desert dish gardens can be made by planting various arid type cacti and other succulents together in a decorative dish container. Open, shallow dishes are the best choices for containers, and choice the soil based on the type of plant being grown.

Dish Garden

Study Questions

10. A media component that is acid in reaction is _____.

11. A media that is composed of equal parts sand, garden soil, and vermiculite or perlite would be good for: a) foliage plants; b) flowering plants; c) cacti and succulents; d) orchids

12. A container that needs less frequent watering and tends to accumulate fewer soluble salts is: a) clay; b) ceramic; c) plastic; d) compressed peat

13. When repotting, the new pot should not be more than _____ larger in diameter than the previous pot.

14. _____ is done to obtain larger blossoms or prevent flowering of a very young plant.

15. Special gift plants tend to do poorly in most homes because of: a) excessive light; b) excessive heat; c) excessive humidity; d) airborne soil pathogens

16. A special potted plant that requires acidic soil is: a) gardenia; b) poinsettia; c) Christmas cactus; d) cyclamen

17. A _____ creates an environment similar to a greenhouse by enclosing plants in glass or clear plastic containers.

Answers:
10 - sphagnum peat moss; 11 - c; 12 - c; 13 - 2 inches; 14 - disbudding; 15 - b; 16 - a; 17 - terrarium

Plant Lists

The remainder of this chapter is composed of lists of plants that will withstand specific indoor conditions of light intensity, temperature, and cultural form.

Light Requirements for Selected Indoor Plants				
Plant (common name)	*Direct Light*	*Bright Light*	*Average Light*	*Low Light*
Aluminum plant		X	X	
Areca palm		X	X	X
Asparagus - Sprengeri	X	X		
Asparagus - Meyeri	X	X		
Aloe vera		X	X	
Boston fern		X	X	
Burro's tail	X	X		
Chinese evergreen		X	X	X
Coleus	X	X		
Corn plant		X	X	
Croton		X	X	
Dumb cane	X	X	X	
Devil's ivy	X	X	X	
Fiddleleaf fig		X	X	
False aralia		X	X	
German ivy - green		X	X	
German ivy - variegated		X	X	
Gold dust dracaena		X	X	
Grape ivy		X	X	
Heartleaf philodendron		X	X	X
Jade plant	X	X		
Japanese aralia		X	X	
Kangaroo ivy		X	X	
Maidenhair fern			X	X
Moses-in-the-cradle		X	X	
Norfolk island pine		X		
Parlor palm		X	X	X
Peperomia		X	X	
Piggyback		X	X	
Ponytail palm	X	X		
Rubber plant	X	X		
Schefflera	X	X	X	
Snake plant	X	X	X	X
Spider plant		X	X	
Strawberry begonia		X		
Swedish ivy	X	X	X	
Tahitian bridal veil	X	X	X	
Velvet plant	X	X		
Wandering Jew	X	X	X	
Weeping fig		X		

Temperature Requirements of Selected Indoor Plants

Cool Temperature Plants	
Grow best at 50-60 °F during the day and 45-55 °F at night	
Azalea	Japanese aralia
Cacti and succulents[1,2] (only during winter rest periods)	Jasmine
Camellia	Jerusalem cherry
Cast-iron plant[2]	Miniature rose
Chrysanthemum	Mock orange
Citrus (grapefruit, lemon, orange)	Norfolk island pine
Creeping fig	Persian violet
Daffodil, Narcissus	Primrose
Easter lily[2]	Tulip
Euonymus japonica (Spindle tree)	Tree ivy
Ivy[2]	Wandering Jew
Hyacinth	White calla lily
Hydrangea	Zephyr lily

Medium Temperature Plants	
Grow best at 60-65 °F during the day and 55-60 °F at night	
Amaryllis	Gold-dust tree
Asparagus fern	Hibiscus
Avocado	Kangaroo vine[3]
Baby's tear	Living stones[3]
Begonia	Palms
Bird's nest fern	Panda plant
Bromeliads[3]	Peperomia
Bush violet	Piggyback plant
Cacti and Succulents[1,3]	Pilea
Cast-iron plant[1]	Podcarpus
Christmas cactus	Purple passion fruit
Citrus	Schefflera
Coleus	Shamrock plant
Crown of thorns[3]	Snake plant[3]
Earth star[3]	Staghorn fern[3]
Easter lily[1]	Strawberry begonia
English ivy[1]	Wax plant
German ivy	

High Temperature Plants	
Grow best at 70-80 °F during the day and 64-70 °F at night	
African violets	Geranium
Bromeliads	Golden pothos
Cacti and Succulents[2,3]	Hen and chicks
Caladium calathea (Peacock plant)	Impatiens
Chinese evergreen	Kangaroo vine[2]
Coconut palm	Living stones[2]
Copperleaf	Peace lily
Cordyline	Philodendron
Croton	Prayer plant
Crown of thorns[2]	Purple velvet plant[2]
Dracena	Sensitive plant
Earth star[2]	Snake plant
False Aralia	Staghorn fern[2]
Ficus	Swiss cheese plant
Flame violet	Screw pine

[1] *Will also do well at high temperatures*
[2] *Will also do well at medium temperatures*
[3] *Will also do well at cool temperatures*

Plants for Specific Indoor Gardening Uses

Plants that will Grow in Water	
Scientific Name	***Common Name***
Aglaonema modestum	Chinese Evergreen
Crassula arborescens	Jade Plant
Dieffenbachia (all varieties)	Dumbcane
Hedera helix	English ivy
Hemigraphis colorata	Hemigraphis
Hoya carnosa	Wax plant
Monstera deliciosa	Cutleaf Philodendron
Pellionia pulchra	Satin Pellionia
Philodendron cordatum	Philodendrons
Philodendron micans	(all climbing types)
Piper nigrum	Black Pepper
Piper ornatum	Celebes Pepper
Scindapsus aureus	Devil's Ivy
Scindapsus pictus	Painted Devil's Ivy
Stephanotis floribunda	Stephanotis
Syngonium podophyllum	Arrowhead, Syngonian
Tradescantia (all varieties)	Wandering Jew

Plant Lists

Plants that Withstand Adverse House Conditions

Scientific Name	Common Name
Aglaonema modestum	Chinese Evergreen
Anthurium aemulum	Climbing Anthurium
Aspidistra elatior	Iron Plant
Chamaedorea elegans 'bellas'	Dwarf Parlor Palm
Cissus rhombifolia	Grape Ivy
Crassula arborescens	Jade Plant
Dieffenbachia amoena	Dumbcane
Dracaena fragrans	Massangeana Dracaena
Euphorbia mili	Crown of Thorns
Ficus elastica	Indian Rubber Tree
Ficus benjamina 'Exotica'	Java Fig
Hemigraphis colorata	Hemigraphis
Howeia belmoreana	Kentia Palm
Pandanus veitchii	Screw pine
Peperomia obtusifolia	Peperomia
Philodendron cordatum	Philodendron
Sansevieria trifasciata	Snakeplant
Sansevieria laurentii	Goldenstripe
Sansevieria zeylanica	Sansevieria
Scindapsus aureus	Devil's Ivy
Syngonium podophyllum	Arrowhead, Syngonium

Plants Well-Suited as Large Container Decorative Specimens

Scientific Name	Common Name
Acanthus mollis	Artists Acanthus
Acanthus montanus	Mountain Acanthus
Alocasia cuprea	Giant Caladium
Alsophila australis	Australian Tree Fern
Codiaeum pictum	Croton
Dieffenbachia amoena	Spotted Dumbcane
Fatshedra lizei	Botanical Wonder
Fatsia japonica	Japan Fatsia
Ficus eburnea	Ivory Fig
Ficus elastica 'variegata'	Variegated India Rubber
Ficus lyrata	Fiddleleaf Fig
Monstera deliciosa	Cutleaf Philodendron
Pandanus veitchii	Screwpine
Philodendron elongatum	Philodendron
Philodendron giganteum	Giant Philodendron
Philodendron x mandaianum	Philodendron
Philodendron panduraeforme	Philodendron
Philodendron selloum	Philodendron
Philodendron wendlandii	Philodendron

Plants Well-Suited as Large Container Decorative Specimens

Scientific Name	Common Name
Polyscias paniculata 'variegata'	Jagged-leaf Aralia
Schefflera digitata	Schefflera
Strelitzia reginae	Bird of Paradise

Plants that Perform Well Under Average Home Conditions

Scientific Name	Common Name
Acanthus montanus	Mountain Acanthus
Aechmea calyculata	Bromeliad
Aechmea orlandiana	Bromeliad
Asparagus sprengeri	Sprenger Asparagus
Araucaria heterophylla	Norfolk Island Pine
Begonia aconitifolia	Begonia
Begonia ulmifolia	Elm-leaved Begonia
Beloperone guttata	Shrimp plant
Caladium bicolor	Fancy-leaved Caladium
Cissus antarctica	Kangaroo Vine
Cissus rhombifolia	Grape Ivy
Cordyline australis	Grass Palm
Cyrptanthus acaulis	Earth Star
Cyrtomium falcatum	Holly Fern
Dieffenbachia x bausei	Dumbcane
Dieffenbachia picta	Dumbcane
Euphorbia milii	Crown of Thorns
Fatsia japonica	Japanese Fatsia
Fatshedera lizei	Bush Ivy
Ficus benghalensis	Banyan Fig
Ficus eburnea	Ivory Fig
Ficus religiosa	Bo-tree Fig
Grevillea robusta	Silky Oak
Hedera helix (all varieties)	English Ivy
Pedilanthus tithymaloides	Slipper or Red Bird Flower
Peperomia clusiaefolia	Peperomia
Peperomia crassifolia	Peperomia
Peperomia obtusifolia Varie-gated'	Variegated Peperomia
Peperomia sandersii	Watermelon Peperomia
Pereskia aculeata	Lemon Vine
Philodendron cordatum	Heartleaf Philodendron
Philodendron 'dubia'	Philodendron
Philodendron giganteum	Giant Philodendron
Philodendron imbe	Imbe philodendron
Philodendron x mandaianum	Philodendron
Philodendron panduraeforme	Panda Plant

Plants that Perform Well Under Average Home Conditions

Scientific Name	Common Name
Philodendron erubescens	Redleaf Philodendron
Philodendron selloum	Philodendron
Philodendron tripartitum	Trileaf Philodendron
Philodendron wendlandii	Philodendron
Pilea involucrata	Artillary Plant
Piper nigrum	Black Pepper
Piper ornatum	Celebes Pepper
Polyscias balfouriana	Balfour Aralia
Polyscias filicifolia	Fernleaf Aralia
Polyscias paniculata 'Variegata'	Jagged-leaf Aralia
Rhoeo spathacea	Moses-in-the-cradle
Sansevieria trifaciata 'Hahni'	Hahn's Sansevieria
Sansevieria parva	Parva Sansevieria
Sansevieria subspicata	Rededge Sansevieria
Saxifraga sarmentosa	Strawberry geranium
Schismatoglottis picta	Painted Tongue
Scindapsus aureus	Devils Toy Pathos
Spathiphyllum 'Clevelandii'	Spathiphyllum
Syngonium podophylum 'Emerald Gem'	Variegated Arrowhead
Tradescantia (all varieties)	Wandering Jew

Low, Creeping Plants for Groundcovers in Interior Plant Boxes

Scientific Name	Common Name
Episcia cupreata	Episcia
Ficus pumila	Creeping Fig
Ficus radicans	Climbing Fig
Fittonia verschafeltii	Silver Fittonia
Hedera helix 'Hahns'	Hahn's English Ivy
Hemigraphis colorata	Hemigraphis
Pellionia daveauana	Pellionia
Pellionia pulchra	Pellionia
Philodendron cordatum	Heartleaf Philodendron
Pilea nummulariifolia	Creeping Artillery Plant
Saxifraga sarmentosa	Strawberry Begonia
Scindapsus aureus	Devil's Ivy
Tradescantia (all varieties)	Wandering Jew
Vinca major 'variegata'	Variegated Vinca

Plants that Withstand Dry, Warm Locations

Bromeliads	All species and varieties
Cacti	All species and varieties

Vines and Trailing Plants for Totem Poles and Trained Plants

Scientific Name	Common Name
Anthurium almulum	Climbing Anthurium
Cissus antarctica	Kangaroo Vine
Cissus discolor	Begonia Cissus
Cissus rhombifolia	Grape Ivy
Clerodendrum Balfouri	Glorybower
Ficus pumila	Creeping Fig
Vanilla fragrans 'Marginata'	Vanilla

Plants Suitable for Hanging Baskets

Scientific Name	Common Name
Achimenes grandiflora	Bigpurple Achimenes
Aeschynanthus parasiticus	Lobecup Basketvine
Aeschynanthus parasiticus 'Black Pagoda'	Black Pagoda Basketvine
Aeschynanthus radicans	Lobbs Basketvine, Lipstick plant
Aeschynanthus pulcher	Scarlet Basketvine
Asarina erubescens	Creeping Gloxinia
Asparagus plumosus	Fern Asparagus
Asparagus sprengeri	Sprengeri Fern
Begonia 'Elsie M. Frey'	Elsie M. Frey Begonia
Begonia x hiemalis	Winter Flowering Begonias
Callisia elegans	Striped Inch plant
Ceropegia woodii	String of Hearts, Rosary Vine
Chlorophytum bichetii	St. Bernard's Lily
Chlorophytum comosum 'Variegatum'	Green Lily
Chrysanthemum morifolium 'Anna'	Daisy Cascade
Chrysanthemum morifolium 'Jane Harte'	Daisy Cascade
Cissus quadrangula	Winged Treevine
Codonanthe crassifolia	Central American, Bellflower
Coleus rehneltianus 'Trailing Queen'	Trailing Coleus
Columnea x banksii	Goldfish Vine
Columnea microphylla	Small-leaved Goldfish Vine
Commelina communis aurea-striata	Variegated Widows Tear
Cyanotis kewensis	Teddy Bear Plant
Cyanotis somaliensis	Pussy Ear
Cymbalaria muralis	Kenilworth Ivy
Davallia fejeensis plumosa	Rabbit's Foot Fern
Episcia cupreata 'Amazon'	Amazon Flame Violet

Plants Suitable for Hanging Baskets

Scientific Name	Common Name
Episcia cupreata 'Chocolate Soldier'	Carpet Plant
Episcia cupreata	Ember Lace Episcia
Episcia cupreata 'Emerald Queen'	Emerald Queen Episcia
Episcia cupreata 'Silver Sheen'	Silver Sheen Episcia
Episcia dianthiflora	Lace Flower Vine
Episcia 'Moss Agate'	Panama Episcia
Erythrorhipsalis pilocarpa	Bristletufted twig cactus
Euphorbia mammillaris	Corncob Plant
Fittonia verschaffeltii	Mosaic Plant
Fittonia verschaffeltii	Silvernerve Fittonia
Fittonia verschaffeltii var. *Pearcei*	Snake Skin Plant
Fuchsia 'Jubilee'	Jubilee Fuchsia
Fuchsia 'Swingtime'	Swingtime Fuchsia
Hatiora salicornioides	Drunkard's Dream
Hedera helix 'Hahns Variegated'	Variegated Hahn's English Ivy
Hedera helix 'Ivalace'	Ivalace English Ivy
Hemigraphis colorata	Red Ivy
Hemigraphis Exotica	Waffle Plant
Hoya australis	Porcelain Flower
Hoya bella	Miniature Wax Plant
Hoya carnosa 'Compacta'	Compact Wax Plant
Hoya carnosa 'Exotica'	Exotic Wax Plant
Hoya carnosa 'Krinkle Curl'	Hindu Rope Plant
Hoya carnosa 'Tri-color'	Variegated Wax Plant
Hoya imperialis	Honey Plant
Hoya keysi	Pubescent Wax Plant
Hoya longifolia shepherdii	Shepherd's Wax Plant
Hoya motoskei	Spotted Wax Plant
Hoya purpureo-fusca	Silver Pink Wax Plant
Hypocyrta nummularia	Miniature Pouch Flower
Hylocereus undatus	Nightblooming Cereus
Ipomoea batatas	Blackleaf Sweet Potato
Kalanchoe gastonis-bonnieri	Life Plant
Kalanchoe manginii	Mangin Kalanchoe
Kalanchoe pubescens	Jinglebells Kalanchoe
Kalanchoe uniflora	Miniature Kalanchoe
Mammillaria elongata	Lace Mammillaria
Nephrolepis exaltata bostoni-ensis	Boston Fern
Nephrolepis exaltata 'Roos-eveltii'	Tall Featherfern
Pelargonium x frangrans	Scented Geranium
Pellonia daveauana	Trailing Watermelon Vine

Plants Suitable for Hanging Baskets

Scientific Name	Common Name
Pellonia pulchra	Satin Pellonia
Peperomia acuminata	Mexico Pepperface
Peperomia cubensis	Cuban Pepperface
Peperomia glabella 'Variegata'	Variegated Waxprivet Peperomia
Peristrophe hyssopifolia 'Aurea-Variegata'	Marble-leaf
Philodendron micans	Velvet-leaf Vine
Philodendron oxycardium	Heart-leaf Philodendron
Pilea nummulariifolia	Creeping Charley
Platycerium alcicorne	Elkhorn Fern
Plectranthus coleoides 'Marginatus'	Candle Plant
Plectranthus oertendahli	Prostrate Coleus
Plectranthus purpuratus	Moth King
Plectranthus tomentosus	Succulent Coleus
Polypodium aureum	Hare's Foot Fern
Portulacaria afra 'Variegata'	Rainbow Bush
Rhipsalis capilliformis	Treechair Rhipsalis
Rhipsalis cassutha	Mistletoe Rhipsalis
Rhipsalis houlletiana	Snowdrop Cactus
Rhipsalis paradoxa	China Rhipsalis
Rhipsalis pentaptera	Fivewing Rhipsalis
Rhipsalis trigona	Triangle Rhipsalis
Ruellia makoyana	Monkey Plant
Schlumbergera bridgesii	Christmas Cactus
Schlumbergera gaertneri	Easter Cactus
Scindapsus aureus	Devil's Ivy
Sedum morganianum	Burro Tail
Senecio herreianus	Green Marblevine
Setcreasea purpurea	Purple Heart
Stapelia gigantea	Giant Toadplant
Stenotaphrum secundatum 'Variegatum'	Variegated St. Augustine Grass
Streptocarpus saxorum	False African Violet
Tradescantia albiflora 'Albovittata'	Giant White Inch
Tradescantia sillamontana	White Velvet, White Gossamer

Plants Suitable for Desert Dish Gardens

Scientific Name	Common Name
Adromischus	Calico hearts, Leopard spots
Aloe	Medicine Plant
Astrophytum myriostigma	Bishop's cap
Cephalocereus nobilis	Cylinder cactus

Plants Suitable for Desert Dish Gardens

Scientific Name	Common Name
Cereus peruvianus 'Monstrosus'	Curiosity plant
Crassula	Jade plant
Crassula lycopodioides	Toy cypress, Watch chain
Crassula rupestris	Rosary Vine
Echeveria derenbergi	Painted lady
Echeveria elegans	Mexican snowball
Echeveria secunda var. *glauca*	Hens and chickens
Echinocactus Grusonii	Golden barrel cactus
Echinocereus pectinatus var. neomexicanua	Rainbow cactus
Echinocereus reichenbachii	Lace cactus
Echinocereus micromeris	Button cactus
Euphorbia lactea cristata	Crested euphorbia, Frilled fan
Faucaria tigrina	Tiger jaws
Gasteria liliputana	Miniature gasteria, Miniature ox tongue
Haworthia	Pearl plant, Wart plant
Haworthia fasciata	Zebra haworthia
Haworthia margaritifera	Pearl plant
Lithops species	Living stones
Mammillaria bocasana	Powder puff cactus
Mammillaria elongata	Golden star cactus
Mammillaria fragilis	Thimble cactus
Opuntia erectoclada	Dominoes, Pincushion cactus
Opuntia microdasys	Bunny ears
Opuntia vilis	Dwarf tree oputia
Portulacaria afra	Elephant bush
Portulacaria afra variegata	Rainbow bush
Rebutia kupperiana	Scarlet crown cactus
Rebutia minuscula	Red crown cactus
Sedum	Stonecrop
Sedum acre	Golden carpet, Gold moss
Sedum adolphi	Golden sedum
Sedum dasyphyllum	Golden glow
Sedum lineare	Carpet Sedum
Sedum morganianum	Burro's tail
Sedum multiceps	Miniature Joshua tree
Sedum pachyphyllum	Jelly beans
Sedum x rubrotinctum	Christmas cheer
Stahlii	Coral beads

Plants Suitable for Tropical Terrariums

Scientific Name	Common Name
Aglaonema commutatum	Chinese evergreen
Begonia boweri	Miniature begonias

Plants Suitable for Tropical Terrariums

Scientific Name	Common Name
Chamaedorea elegans	Neanthe bella, Parlor palm
Cissus antarctica 'Minima'	Dwarf kangaroo ivy
Coffea arabica	Arabian coffee plant
Cordyline terminalis minima 'Baby Ti'	Dwarf ti plant
Cryptanthus bivittatus minor	Dwarf rose-stripe earth star
Dizgygotheca elegantissima	False aralia
Dracaena sanderana	Belgian evergreen
Dracaena surculosa	Gold dust dracaena
Ficus diversifolia	Mistletoe fig
Ficus pumila 'Minima'	Dwarf creeping fig
Fittonia verschaffeltii	Mosaic plant
Maranta leuconeura kerchoveana	Prayer plant
Nephrolepis exaltata cvs.	Boston fern
Peperomia sandersii	Watermelon peperomia
Pilea cadierei 'Minima'	Aluminum plant
Pilea depressa	Miniature pilea
Pilea microphylla	Artillary plant
Pilea nummulariifolia	Creeping Charlie
Pteris species	Brake ferns, Table ferns
Saintpaulia cultivars	Miniature African violets
Selaginella	Club moss, Moss fern
Selaginella kraussiana	Creeping club moss
Selaginella emmeliana	Sweat plant
Sinningia pusilla (and other miniature cultivars)	Miniature gloxinias
Syngonium	Arrowhead vine, Nephthytis

Additional Resources

Houseplant Information - A wonderful resource from Colorado Cooperative Extension, this page from Planttalk provides growing information for a variety of common houseplants:

* http://www.ext.colostate.edu/ptlk/ptlk1300.html

Diagnostic Guide to Houseplant Problems - A helpful table of common houseplant ailments and potential causes:

* http://docs.lib.purdue.edu/cgi/viewcontent.cgi?article=2098&context=agext

Houseplant Toxicity - Two references to help determine toxicity of houseplants:

* http://www.ladybug.uconn.edu/FactSheets/houseplants--safe-or-poisonous.php
* https://www.aspca.org/pet-care/animal-poison-control/toxic-and-non-toxic-plants

Houseplants: Proper Care and Management of Pest Problems - North Dakota State University. A nice publication covering cultural concerns, houseplant trouble signs, common pests and diseases for houseplants:

* https://www.ag.ndsu.edu/extensionentomology/urban-and-forestry-insect-pests/documents/homes/pp-744-houseplants-proper-care-and-management-of-pest-problems-december-2009

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Chapter 13
Vegetable Gardening

The Vegetable Garden

Chapter 13

The Vegetable Garden

Chapter 13

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Introduction

When planning your garden, it is important to ask a few basic questions:

* Who will be doing the gardening work?
* Will the home garden be a group project with family members who will work willingly through the season to a fall harvest, or will you be handling the hoe alone? Remember, a small, weed-free garden will produce more than a large, weedy mess.
* What fruits and vegetables do you and your family like to eat? There is no value in taking up gardening space with vegetables that no one eats. Make a list of your family favorites, ranked in order of preference. This will make a useful guide in deciding how much of each to plant. Successive plantings of certain crops, such as beans, will give a longer harvest period and increase your yield. List recommended varieties and planting dates.
* How do you plan to use the produce from your garden? If you plan to can, freeze, dry, or store it, this will be a factor in planning the size of the garden and in selecting the varieties to grow. Some varieties have much better keeping quality than others. Care should be used in choosing the kinds of plants to grow, making sure the varieties you select are adapted to your area and intended use. It is always advisable to use a crop calendar suited for your area (see the Vegetable Planting Guide section of this chapter).
* How much space is available to be converted into usable garden space?

Vegetable vs. Fruit

Is it a fruit or a vegetable? Strictly speaking, the term vegetable refers to vegetation. This is a soft, non-flowering part of a plant that is used for food. This includes such plants at lettuce, cabbage, spinach, broccoli flower heads, and other leaf vegetables. Fruits, refer to the ripened ovary of a female flower part that contains seeds, and in some cases may only be the seed itself. This includes apples, peaches, tomatoes, peas, squash, beans, melons and many other products of flowering plants. However, through common usage we have come to refer to many fruits as vegetables in our gardens and in the produce section of the grocery store. Classification is often ambiguous and it really depends on whether you are engaged in a botanical or culinary discussion.

Economic Value of Crops

It is difficult to evaluate the economic value of crops grown in the vegetable garden due to the different lengths of time they require for maturity and harvest, the availability of varieties and vegetables types not generally found in the marketplace, and the lack of comparison values for vegetables that are not acceptable by commercial standards (cracked tomatoes, crooked cucumbers, etc.), but which are perfectly usable by the gardener. Nevertheless, several studies have attempted to determine what crops bring the most value per square foot of garden space, partly to aid small-space gardeners in making decisions about what to plant. Of course, if no one in the family likes beets, there is no point in growing them just because they are economically valuable, but this list may help you determine what vegetables to plant and what to buy.

Top 15 Vegetables in Economic Value	
Values based on pounds produced per square foot, retail value per pound at harvest time, and length of time in the garden	
Beans (pole, bush)	Leaf Lettuce
Beets	Peppers
Broccoli	Summer Squash
Carrots	Swiss chard
Cucumbers	Tomatoes
Edible pod peas	Turnip (greens & roots)
Green Bunching Onions	Onion storage bulbs, shallots
Head Lettuce	

Low-Value Crops	
(Not recommended for small spaces)	
Corn, sweet	Winter Squash
Melons	Pumpkins
Miniature varieties or trellising may increase value per square foot	

Planting Guidelines

* Winter is the best time to plan next year's garden and to order the seed.
* Plan the garden on paper first. Draw a map showing the arrangement and spacing of crops. To keep the garden growing all season, make a spring, summer, and fall garden plan.
* Plan the garden and order seeds at least three months earlier. Some plants may be started indoors as early as mid-February.
* In your plan, place tall and trellised crops on the north side of the garden so they won't shade the shorter vegetables.
* Group plants by length of growing period. Plant spring crops together so later crops can be planted in these areas when the early crops mature. Consider length of harvest as well as time to maturity. Place perennial crops to the side of the garden where they will not be disturbed by any tillage that is needed.

Locating the Garden

* Vegetables grow best in a level area with loose, well-drained soil and at least six hours of sun (eight to ten hours is ideal).
* Use contour rows, terraces, or raised beds on sloped or hillside sites to avoid erosion. South-facing slopes are warmer and less subject to damaging frosts.
* Avoid placing the garden in low spots, at the base of a hill, or at the foot of a slope bordered by a solid fence. Such areas are slow to warm up in the spring, and frost settles in these places since cold air naturally drains into low areas.
* Avoid windy locations; if you must plant in a windy spot, build or grow a windbreak.
* Locate near a good and easily accessible supply of water.
* Avoid planting near trees and shrubs; they compete for nutrients and water and may cause excessive shading.
* Sites too near buildings may result in plants not receiving enough sunlight. Observe shading patterns through the growing season, if possible, before starting the garden. If you have a shaded area you wish to use anyway, plant shade-tolerant crops. If needed, increase effective light by providing reflective surfaces around plants.
* Try not to plant vegetables from the same family (peas and beans or squash and pumpkin) in exactly the same location in the garden more often than once in three years. Rotation prevents the buildup of insects and disease. Use previous year's plans as guides for rotating crops.
* Avoid locating the garden on a site where buildings with lead paint have stood; lead may be present in toxic amounts. If you are unsure about your chosen location, have the soil tested for lead content, or have tissue analyses done on some leafy vegetables.
* Gardening where sod has long been established, whether converted pastures or lawns, requires a great deal of preparation to eliminate weeds.

Soil Preparation

The ideal vegetable garden soil is deep, well-drained, high in organic matter, and has good structure. Proper soil preparation provides the basis for good seed germination and subsequent growth of garden crops. Careful use of various soil amendments can improve garden soil and provide the best possible starting ground for your crops.

Soil Testing

Check soil fertility and pH by having your soil analyzed

at least once every three years. Vegetables vary to some extent in their nutrient and pH requirements, but most garden crops will do well within a soil pH range of 6.2 to 6.8. This is a little below neutral, or slightly acid. If soil pH is too high or low, poor crop growth will result, largely due to the effects of pH on the availability of nutrients to plants. In addition to pH, a soil test will also give you an idea of the relative nutrient level of phosphorus and potassium in the soil.

Soil sample kits are available for checking your soil's pH and may be obtained from your local Virginia Cooperative Extension office. Cooperative Extension will mail results to you with recommendations for adjusting pH and correcting nutrient deficiencies, if any are present. Private companies also do soil testing; these give detailed reports and recommendations in many cases, but may be expensive (3 to 5 times the cost of VCE). For best results, carefully follow the instructions for taking the soil sample.

Adjust nutrient and pH by adding recommended fertilizers and/or lime for raising the pH (or acidifiers if the goal is to lower the soil pH). In new garden spots, remove sod with a spade before tilling. You can use the sod to patch your lawn or put it in a compost pile to decay. Next, plow, spade, or rotary till the soil when soil moisture conditions are right. To test, pick up a handful of soil and squeeze it. If it stays in a ball, it is too wet. If it crumbles freely, it should be about right. Excessively dry soil is powdery and clumpy and may be difficult to work. Take samples at the surface and at a 4- to 6-inch depth in several locations in the garden plot. If soil sticks to a shovel, or if when spading the turned surface is shiny and smooth, it is still too wet. Working soils when excessively wet can destroy soil structure, which may take years to rebuild. Plowing with a tractor when the soil is wet is especially damaging, causing the formation of a compaction layer that will inhibit root growth. Soils with adequate humus levels generally allow more leeway because of their improved structural qualities.

Just prior to planting, break up large clods of soil and rake the bed level. Small-seeded vegetables germinate best in smooth, fine-surfaced soil. Do not pulverize the seedbed soil. This destroys the structure and promotes crusting and erosion problems.

Tilling the Soil

The type of equipment used to prepare your garden will depend on the size of the garden, your physical ability, time, and budget. Options include hand-digging with a spade or shovel, tilling with a power rotary tiller, and using a small garden tractor or a full-sized farm tractor. Rotary tilling (rototilling) is sufficient for most home gardens, as long as plant debris accumulation is not out of hand. Rotary tilling mixes the upper layers of soil rather than completely turning the soil over, and the effects produced are generally desirable. One possible harmful effect of rototilling is the formation of a compaction layer just beyond the reach of the tines. Use of deep-rooted cover crops or double-digging can do much to prevent or alleviate this problem when it exists. Small gardens can be designed using raised beds which may be worked entirely by hand if the area is small enough.

Gardeners often wonder whether to plow/till in the spring or fall. Working the soil in fall has several advantages over the traditional, spring plowing. It allows earlier spring planting, since the basic soil preparation is already done when spring arrives. Turning under large amounts of organic matter is likely to result in better decomposition when done in the fall, since autumn temperatures are higher than those of early spring, and there is more time for the process to take place. Insects, disease organisms, and perennial weeds may be reduced by killing or inactivating them through burial or exposure to harsh winter weather. The physical condition of heavy clay soils may be improved by the alternate freezing and thawing, which breaks up tightly aggregated particles. Also, snow is trapped between the hills of roughly plowed soil, so more moisture is retained than on flat, bare ground. Incorporation of limestone in the fall gives it time to become integrated with the soil and influence spring plant growth.

Fall plowing alone is not recommended for hillside or steep garden plots, since soil is left exposed all winter, subject to erosion when spring rains come. If a winter cover crop is grown to improve soil and prevent erosion, the ground will have to be tilled in the fall to prepare the soil for seed and again in spring to turn under the green manure. Spring plowing is better for sandy soils and those where shallow tilling is practiced. Generally, most gardens must be disked or rotary tilled in the spring to smooth the soil for planting.

Soil Amendments

Any addition to the soil that improves its physical or chemical condition is considered a soil amendment. Many types of amendments are valuable to the home gardener.

Amendments to change pH and nutrient levels:
Lime, sulfur, and gypsum are common amendments used to change soil pH. The correct soil pH is essential for optimum plant growth. Dolomitic limestone adds calcium and magnesium while also raising soil pH (lowering acidity). Gypsum adds calcium and some sulfur but does not enhance the structure of Eastern U.S. clay soils as it does soils in western states. Agricultural sulfur is used to acidify alkaline soil. The amount to add depends on the current and desired pH, which is one good reason to have garden soil checked every three years.

Wood ashes can be used as a soil amendment to raise soil pH. They contain potash (potassium), phosphate, boron, and other elements. Wood ashes can be used to raise soil pH. Apply twice as much ash as limestone to achieve the similar desired effect. Ashes should not come into contact with germinating seedlings or plant roots as they may cause root burn. Spread in a thin layer over the winter, and incorporate into the soil; check pH yearly if you use wood ashes. Never use coal ashes or large amounts of wood ash (no more than 20 lbs. per 1000 square feet), as toxicity problems may occur.

Amendments to improve soil qualities:
In special cases, perlite is sometimes added to clays to attempt to improve soil structure. However, inert materials such as perlite can be expensive and extremely large quantities are needed to do any good. Compost, manures, and other amendments usually serve the purpose better and are more economical at improving the structure or way the soil binds together.

Organic matter is a great soil improver for both clay and sandy soils. Good sources of organic matter include manures, leafmold, sawdust, straw, and others. These materials are decomposed in the soil by soil organisms. Various factors, such as moisture, temperature, and nitrogen availability, determine the rate of decomposition through their effects on these organisms. Adequate water must be present, and warm temperatures will increase the rate at which the microbes work. Proper balance of carbon and nitrogen (C to N ratio) in the material is needed to ensure adequate nutrient availability both to growing plants and decomposing organisms. Adding nitrogen may be necessary if large amounts of undecomposed leaves, straw, sawdust, or other high-carbon substances are used. Nitrogen is used by the soil organisms to make proteins for their own bodies, and if it is not present in sufficient amounts, the microbes have no qualms about stealing the plant's share. Generally, fresh green wastes, such as grass clippings, are higher in nitrogen than dry material.

The use of compost is one way to get around the decomposition problem. Compost is usually made by the gardener from plant and/or animal wastes. Correct composting is an art that can result in a valuable nutrient and humus source for any garden. The basis of the process is the microbial decomposition of mixed, raw, organic materials to a dark, fluffy product resembling rich soil, which is then spread and worked into the garden soil (refer to Chapter 3: Soils for more information).

Animal manures are commonly used as a garden soil amendment. The value of manure in terms of the nutrients it contains varies. Fresh horse, sheep, rabbit, and poultry manures are quite high in nitrogen and may even burn plants if applied directly to a growing garden. They are best applied in the fall and tilled under. Manure usually has fewer total nutrients than synthetic fertilizers in terms of N, P, and K, but is a valuable soil builder. Unfortunately, manures may be a source of weed seeds; if this is a problem, composting in a hot pile may help. In urban areas, manure may be hard to come by, but country dwellers usually find it plentiful.

Another source of inexpensive soil improvement that should not be underestimated is the cover crop. Green manures, or cover crops, such as annual rye, ryegrass, and oats, are planted in the garden in the fall for incorporation in the spring. For best results, seed should be sown a month before the first killing frost. In a fall garden, plant cover crops between the rows and in any cleared areas. Cover cropping provides additional organic matter, holds nutrients that might have been lost over the winter, and helps reduce erosion and loss of topsoil. Legume cover crops can increase the amount of nitrogen in the soil and reduce fertilizer needs. A deep-rooted cover crop allowed to grow for a season in problem soil can help break up hardpan and greatly improve tilth. Incorporate green manures at least two weeks before planting vegetables; they should not be allowed to go to seed before incorporation.

The regular addition of manure, compost, cover crops, and other organic materials can raise the soil nutrient and physical level to a point at which the addition of synthetic fertilizers is greatly reduced. This comes about not only through the intrinsic fertilizing value of the amendment, but also through the increased action of microorganisms on soil and humus particles; humic acid (and other acids)

helps to release previously locked-up nutrients naturally present in the soil, and the extra surface area provided by humus serves as a reserve, holding nutrient elements until they are needed by plants. This highly desirable soil quality does not come about with a single or even several additions of organic material, but rather requires a serious, long-term, soil-building program. Information is widely available in books and magazine articles on this subject.

Remember, your soil is alive and constantly changing. By keeping it fertile and rich, many gardening problems may be diminished. Soil is the base for plant growth, and much attention should be paid to getting and keeping it in the best condition.

Study Questions

1. _____ is the best time to plan your garden.
2. Vegetables grow best in an area where they receive an ideal of _____ hours of sun per day.
3. Soil should be tested for fertility and pH:
   a) once a month; b) every winter; c) once every three years; d) only when planting crops
4. Soil moisture conditions are right for tilling:
   a) when soil is powdery; b) if soil crumbles freely when balled; c) when soil is shiny and smooth; d) any time
5. The best time to plow or till the garden is in the _____.
6. Clay and sandy soils can be improved by adding _____.

Answers: 1 - winter; 2 - eight to ten; 3 - c; 4 - b; 5 - fall; 6 - organic matter

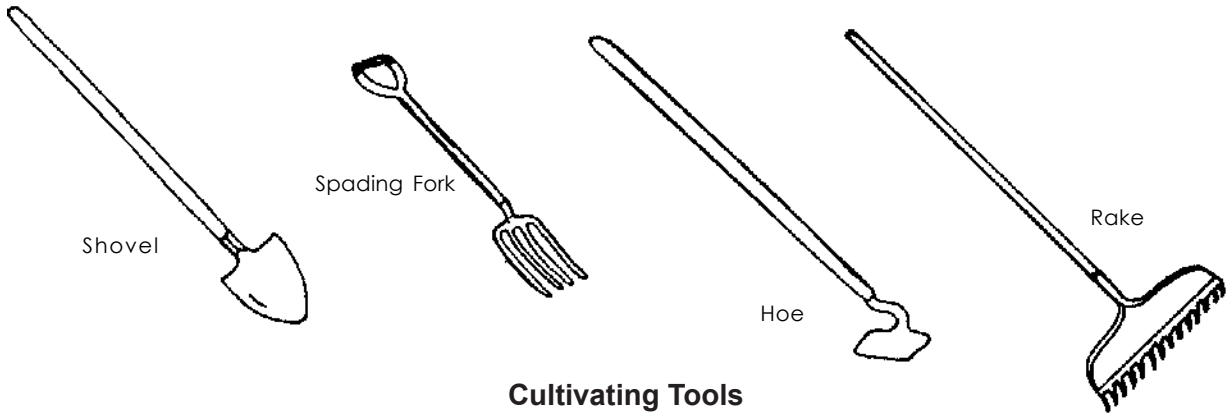
Selecting Gardening Equipment

Garden catalogs and stores are full of gardening tools, many highly specialized; some are very useful, others are nice but not necessary, and some are gimmicks. The gardening equipment you need depends on the size of your garden, your age and strength, and whether you want to get the job done in a hurry or prefer to take your time. The minimum equipment needed by most gardeners includes a shovel or spade, a hoe, a rake, and a trowel. A wide selection of styles is available in each of these tools, and the choice is really one of personal preference and price range. You can get the best value for the price range you choose by knowing each tool's uses and particular qualities to look for when comparison shopping. Buy at the end of the gardening season when prices are reduced.

Selecting Tools For Cultivating

A garden shovel with a pointed blade is lighter and smaller than most other shovels and is well suited for use in the garden. Shovels are earth movers with dish-shaped blades mounted to the handle at an angle. A spade has a flat blade and is designed for cutting rather than lifting or moving soil. Spades are excellent for shaping straight-sided trenches and for edging beds. For general-purpose digging, lifting, and moving, a long-handled shovel is ideal. Both shovels and spades come with long or short handles in standard or D-shaped styles. Choice of handle style will depend on personal preference; long handles offer greater leverage and are less tiring to use in many cases. Short handles are often thicker and stronger than long ones.

A **spading fork** is another useful digging tool. It is ideal for breaking and turning heavy soils and for loosening subsoil layers when double digging a bed. Turning coarse compost, spreading mulches, and digging root crops are other jobs suitable for a spading fork.



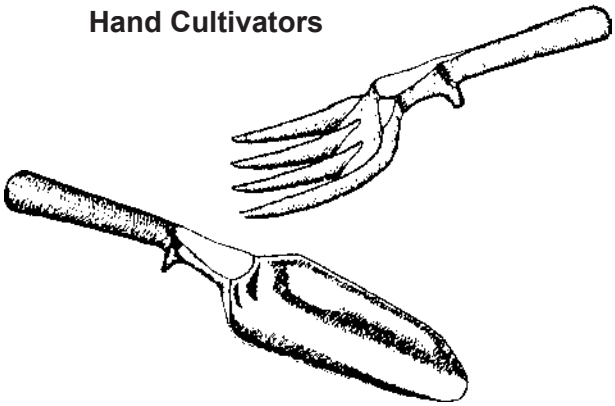
Cultivating Tools

A **hoe** is essential in any garden for preparing the seed bed, removing weeds, and breaking up encrusted soil. Several different hoe styles are available. The pointed hoe with a heart-shaped blade is lightweight and useful for opening seed furrows and cultivating between plants. The hula, or action hoe, is a type of scuffle hoe which is very lightweight and maneuverable. Pushing and pulling it just under the soil surface eliminates newly emerging weeds and breaks up any crust on the soil surface. This type of hoe is most easily used on soil which is not compacted, since the blade is relatively thin and lacks the clod-breaking capabilities of a heavier hoe; it is also less effective in cases where weeds have gotten a good start. Other types of scuffle hoes are somewhat more sturdy and are used with a pushing motion rather than pushing and pulling. Probably the most commonly used hoe is the square-bladed hoe, which lends itself well to many garden tasks.

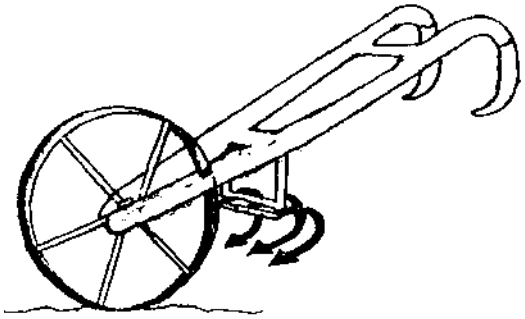
A sturdy **rake** is useful in clearing the garden of rocks and debris. It is also helpful in spreading mulches and smoothing seedbeds. The size of the rake right for you depends on your size and strength and the uses you intend to put it to. As the number of tines increases, the rake weight also increases; avoid choosing a rake so heavy it will tire you after a short period of use. The length of the rake handle is important too; the tip of the handle should come up to your ear when standing upright. A handle that is too short will make your work harder, causing excess bending and back strain.

Especially in the spring, a **trowel** will be in constant use for those many digging jobs that need not be done with full-sized tools. The trowel is perfect for transplanting seedlings and bulbs or digging shallow-rooted weeds. Small hand cultivators, often sold in sets with trowels, are good for weeding in small areas and between closely spaced plants. Another useful, small digging tool is appropriately named a digger (a.k.a. weeder, cultivator, asparagus knife). This tool is available from most hardware or discount stores inexpensively. It is useful for digging up weeds with long taproots, such as dandelions or Queen Anne's lace, or for prying out Johnson grass rhizomes. It consists of a long (10 to 14 inch), solid-metal rod with a two-pronged blade at one end and a handle at the other. This tool is practically indestructible and well worth the small investment of its price for people with strong hands and arms or extremely loose, friable soil.

Hand Cultivators



Some other tools that may have a place in the garden tool shed include the pickax, mattock, and wheel cultivator. Pickaxes are used to break up extremely hard-packed or stony soil. Mattocks are for the same purpose, but are equipped with a cutting blade for areas where larger roots need to be removed. A mattock may also be used to chop up debris for composting. A wheel cultivator has a number of attachments for soil preparation and weed control and may prove a good investment for those with larger gardens.



Power Tools For Cultivating

The power **rotary tiller** is probably the power tool most commonly purchased by gardeners. Whether or not a gardener needs a rotary tiller depends on the size of the garden, the gardener's capabilities, and the intended uses of the tiller. Renting a tiller or hiring someone to till the garden meets the needs of most gardeners. If a tiller is to be purchased, tiller selection may be based on the nature of the work to be done, the quality of the machine and ease of repair, as well as personal preference. The tiller's engine powers rotating blades, or tines, which can make garden soil loose and fluffy, ready for planting. It can also chop up plant debris and mix it into the soil. Incorporating organic matter and manures into the garden is easily accomplished with a tiller, reducing the tendency to procrastinate this necessary chore. The ability of the tiller to do these jobs effectively is a function of its

weight, strength, design, and type of tines, as well as the type of soil. A heavy, powerful tiller is most effective on stony, clay soils, while in a small garden or one with light soil, a smaller tiller is more appropriate. Very lightweight tillers, known as soil blenders, are designed mainly for raised-bed gardening.

Rotary tillers are available with front-mounted or rear-mounted tines. Rear-tined tillers are generally better able to self-propel on all but the rockiest soils. They travel straight and can produce a footprint-free seedbed. Rear-tined tillers often have a number of attachments available for a variety of uses, such as hilling potatoes, making raised beds, even plowing snow! The price of a rear-tined rototiller is considerably higher, in most cases, than that of the front-tined type; consideration should be given to the payback time necessary for such a large investment.

If gardening is simply a hobby, or if the garden is small, a front-tined tiller may be suitable. Front-tined tillers are usually light in weight, but may require considerable strength to guide them through the soil. Operating this type of tiller is comparable to handling a large floor polisher, such as those used in schools and hospitals; mainly, leverage is required for control. New gardeners are sometimes scared away from these tillers because of the initial experience of having a tiller run away from them. The front-tined tiller may not make as straight a pass as the heavier, rear-tined type, but it is much easier to turn. Due to this increased maneuverability, the front-tined tiller is easy to use in small gardens and in corner areas.

The purchase of a tiller is a major investment. Features to look for include heavy cast-iron, steel plate and tubing, heavy bearings, strong welds used in construction, and easily operable controls. Ask to look at the operator's manual and try to determine how simply a tune-up can be performed; you may save yourself a great deal of trouble and money if you can replace plugs and points yourself, particularly, if you have no truck on which to load the tiller. Also consider the locations of service centers and parts dealers. Careful attention to your needs, abilities, and price range is important. Talk to people who have the types of tillers in which you are interested. If possible, borrow or rent various types of machines and send for information before buying.

If you are considering the purchase of a rotary tiller, plan to do so well ahead of time so you will not be rushed into a purchase. A good tiller is a long-term investment, so plan carefully before you buy.

Other Power Tools

There are few other power tools needed in the vegetable garden. Cordless tools come with various cultivating attachments. Most are rechargeable and can make garden chores more pleasurable; these tools are especially useful to those with physical disabilities that limit strength. However, these tools only work effectively in a bed high in organic material and free of coarse debris.

A garden shredder may be useful for a large garden with a lot of plant wastes. There are hand-operated shredders that are slow but useful if wastes become available in small quantities and are not too coarse. Gasoline shredders are quite expensive and may be disappointing to the gardener who wants to chip branches and other large materials. They are best used for shredding leaves, small branches, and other plant wastes (though sunflower stalks would probably be too much for one). A chipper, on the other hand, will chip large branches and other coarse material, but the cost of $1000 or more makes the chipper uneconomical for the home gardener. Wear ear protection when using power tools.

Carts/Wheelbarrows

A wheelbarrow or cart is very handy to have in and around the garden area. Select one that is easy to handle when full, with good maneuverability. Durable construction is well worth paying for to ensure a long, useful life. Be sure to choose the size appropriate for your physical abilities and garden needs. A wheelbarrow generally requires more strength and control than do most garden carts, but many of the small carts generally available are made of relatively flimsy metal and, though inexpensive, are not particularly long lasting or suitable for heavy items such as rocks. Again, consider your needs. If you plan to haul only light straw, leaves, sawdust, and such materials, then

one of the small carts may be suitable. For heavier jobs, you may need a wheelbarrow; or investigate some of the newer garden carts, especially those with bicycle-size tires, which make easy work of hauling. They are made of heavy plywood and metal, but are well balanced and easy to maneuver. These carts do, however, involve a sizeable investment (up to several hundred dollars) and a large storage space. Therefore, only serious gardeners or those with other uses for such a cart find them economical.

Watering Equipment

Watering is an essential garden job for most gardeners. An adequate water supply makes a big difference in garden yields. Purchase of watering equipment depends on available facilities, water supply, climate, and garden practices. If there is no outdoor spigot near the garden, the expense of having one installed may be greater than the benefits gained except in very drought-prone areas or in the case of a gardener who is fully dependent on the season's produce. Where rainfall is adequate except for a few periods in the summer, it is wise to keep watering equipment simple; a garden hose with a fan-type sprinkler will suffice. A water breaker for small seedlings is useful. But, in areas where there are extended periods of hot weather without precipitation, the local water supply is likely to be short. Overhead sprinklers are wasteful of water, so in this case, a drip irrigation system may be in order. Drip irrigation puts water right at the roots and doesn't wet plant leaves, helping to prevent disease. Timers are available that allow automatic watering with drip and some other systems. However, this type of system is relatively expensive and may be considered a nuisance by some gardeners because of maintenance and placement requirements. Cultural practices, such as mulching, close plant spacing, shading, cultivar selection, and wide bed planting, will significantly reduce water needs. See Chapter 19: Water Quality and Conservation for more information.

Soil testing equipment

Soil test kits can be purchased in various sizes and levels of sophistication. These are handy, but not always necessary; soil testing does not have to be done more frequently than once a year for most gardening purposes. If inexpensive garden soil tests are offered through the Extension offices or private labs, it is often preferable to have them do the tests, as results are likely to be more accurate. Some gardeners like to monitor the soil quality frequently, though, making a soil test kit a worthwhile purchase. An electronic pH tester is on the market for those who like gadgets.

Soil Thermometer

Soil temperature is critical for many vegetable and food crops. Soil thermometers measure soil temperature and the internal temperature of a compost pile. Seeds planted in soil that is too cold will often rot, and seedlings planted in cold soil will delay growth until the ground temperature gets warmer and will likely result in stunted plants. A soil thermometer will assist the gardener in determining the proper time to plant seeds and seedlings. Optimal soil temperatures for seeds of early vegetables are between 45 and 50ºF and 50 to 55ºF for seedlings. Soil temperatures for warm weather species should be at least 65ºF.

Other Environmental Monitoring Equipment

Serious gardeners often invest in various types of equipment that allow them to monitor the microclimate around the garden or indoors. A rain gauge is an inexpensive device that helps the gardener determine if enough rain has fallen for garden plants. A minimum-maximum thermometer is a costly, but often useful, device to measure nightly lows and daytime highs within an area; these are especially valuable in a greenhouse. Light and watering meters can be purchased for indoor plant monitoring.

Seeding and Planting Tools

Depending on the size of your garden and your physical abilities, you may want to consider a row seeder. Seeders with wheels make easy work of sowing long rows of corn or beans or other vegetables. Seeders are available which make a furrow, drop the seeds properly spaced, and close up the furrow behind the seed - all in one pass. They do not perform quite as well on small-seeded crops, and it is not really worth the effort of setting up a seeder for small areas. A hand-held seeder is probably a better choice for this type of work. Broadcast seeders are available for sowing seeds, such as rye or wheat, for a cover crop, but are generally not necessary for the average home gardener since broadcasting is easily done by hand once the proper technique is learned.

Pruning Tools

Please refer to the Pruning chapter for details on pruning tools.

Trellises/Cages

Trellises and cages for vining plants save space and keep fruits off the ground, reducing the amount of stooping required for harvest and damage to plants. Look for heavy-duty materials and sturdy design that will stand

up to rain, wind, and drying. Wire should be of a heavy gauge, and wood should be treated with non-phytotoxic (i.e., not toxic to plants) materials. Metal parts should be rustproof or at least rust-resistant. If you build your own, you will probably save a considerable amount of money and get better quality for the price.

Composting Equipment

If you wish to make compost regularly, it will be helpful to have compost bins in some form. See Chapter 3: Soils for more information on composting equipment options.

Season Extenders

Your annual harvest can be greatly increased by extending the growing season, starting earlier in the spring and harvesting past frost. (see "Season Extenders" section later in this chapter).

Harvesting and Processing Equipment

Harvesting equipment varies depending on the size and type of garden, whether or not food is to be stored, and the way in which it is to be processed. Baskets are useful to most gardeners. They may be purchased at garden or farm supply stores or sometimes may be scrounged from local grocery stores or fruit stands. Berry baskets for small fruits, baskets with handles for carrying vegetables, and peck or bushel baskets for storage are all useful. Fruit pickers are nice and easy to use for tall fruit trees. A sharp knife for cutting vegetables off plants is handy and helps prevent plant damage.

Food processing equipment includes canners, blanchers, dehydrators, and sealers for frozen food packages. There is even a home vacuum-packer available. A food mill is inexpensive and very useful for making sauces and juices; a blender or food processor is also useful to the gardener with extra food. More specialized tools include corn cutters which remove kernels from the cob, bean Frenchers and shellers, cherry pitters, strawberry cappers, apple corers and peelers, jelly strainers and thermometers, and many more. For canning, a large kettle or pot is indispensable for preparing food prior to canning. A jar lifter will prevent burned fingers; a funnel for transferring food to jars reduces messiness. As always, choices depend on individual needs.

Purchasing and Maintaining Tools

When purchasing tools, buy for quality rather than quantity. Your tools will be in frequent use throughout the garden season. Cheap tools tend to break or dull easily and may end up making a job unnecessarily difficult and frustrating. Quality tools will last and tend to increase in value with time if well kept. Tools should be lightweight for easy handling, but heavy enough to do the job properly. Metal parts should be of steel, which will stay sharp, keep its shape, and outlast softer metals. Wooden handles may split or splinter; fiberglass handles are more durable.

Keeping a tool clean and sharp will increase its usefulness and lengthen its life. Learn the techniques of sharpening each tool, and practice them frequently. Professional gardeners often carry sharpening stones or files while working and sharpen after every hour or so of use. Clean your tools after each use and oil the blades.

The last and perhaps most important step in tool care is to put tools in their proper places. Tools left in the garden will rust and break and can be a safety hazard. Some gardeners paint handles with a bright color to make their tools easy to spot. And, if each tool has its own place in the storage area, it is simple to determine if tools are missing before closing up for the day.

Before winter sets in, sharpen tools, then coat metal parts lightly with oil and rub wooden handles with boiled linseed oil. Drain power tools of gasoline, and obtain filters, mufflers, and tune-up parts so a fall or late-winter tune-up can get the machine ready for early spring jobs. Have maintenance done, if needed, in the winter, when demand is lowest and you can afford to let the repairer take his or her time.

In fall, any trellises or cages that have been outdoors should be cleaned and stored inside if possible. Traps and other pest control devices should also be stored if the pest season is over. Cold frames and other season extenders should be protected from damage by ice and snow or high winds, and once their job is done, should be repaired if necessary and put away if possible. Tools with wheels, like cultivators, seeders, and carts, should be oiled and stored. Thoughtfully selected and cared for, your tools will give many years of service. This extra help in the garden will pay for itself in time.

Treated Wood in the Vegetable Garden

Some home gardeners have been concerned with the safety of pressure-treated landscape timbers in the garden, specifically when used to build raised bed vegetable gardens. On February 12, 2002, the Environmental Protection Agency (EPA) announced a voluntary decision by the wood preserving industry to phase out

the use of wood preservatives that contain arsenic for any wood products destined for consumer use. The phaseout was completed by December 31, 2003. This transition affects virtually all residential uses of wood treated with chromated copper arsenate, also known as CCA, including wood used in play structures, decks, picnic tables, landscaping timbers, residential fencing, patios, and walkways/boardwalks. Since January 2004, the EPA has not allowed CCA products for any of these residential uses.

The EPA has not concluded that there is unreasonable risk to the public from CCA lumber, but believes that any reduction in exposure to arsenic is desirable. More information on this action can be found on the EPA Web site.

CCA has been replaced with two other formulations in pressure-treated wood - ACQ and copper azole (CA-B). Information on ACQ and CA-B can be found at https://www.epa.gov/ingredients-used-pesticide-products/overview-wood-preservative-chemicals-0

Study Questions

7. A tool with a flat blade designed for cutting rather than lifting or moving soil is the:
   a) shovel; b) spade; c) spading fork; d) trowel

8. Optimum soil temperatures for seedlings of early/cool vegetables are:
   a) 35-40ºF; b) 50-55ºF; c) 65-70ºF; d) 80ºF

9. _____ seeders are used to sow cover crops such as wheat and rye.

10. _____ is the best time to do maintenance on your garden tools.

11. When buying lumber for the garden, always look for the _____ on the wood to determine if it is safe to use.

Answers:
7 - b; 8 - b; 9 - broadcast; 10 - winter; 11 - quality stamp

Seed for the Garden

Choosing and purchasing vegetable seeds is one of the most enjoyable gardening pastimes. Thumbing through colorful catalogs and dreaming of the season's harvest is one way to make winter seem a little warmer. Seed purchased from a dependable seed company will provide a good start toward realizing that vision of bounty. Keep notes about the seeds you purchase - their germination qualities, vigor of plants, tendencies toward insects and disease, etc. From this information, you can determine whether one seed company is not meeting your needs, or whether the varieties you have chosen are unsuitable for your area or gardening style. For example, if powdery mildew is a big problem on squash family plants in your area, the next year, you may want to look for mildew-resistant varieties.

Saving Seed

Saving your own vegetable seed is another pleasurable activity. It offers a sense of self-sufficiency and can save money. You can maintain a variety that is not available commercially, which helps to perpetuate a broad genetic base of plant materials. Breeders often search for old-time varieties when attempting to improve commercial plants, since the heirloom vegetables (as they are sometimes called) often have disease and pest resistance or cold hardiness. Participation in a seed-saver's exchange can be a rewarding experience. You may find unusual varieties available for trade in an exchange that are otherwise hard to find.

You can find many seed-saver organizations, such as Seed Savers Exchange, on the internet. SSE's URL is: http://www.seedsavers.org

There are certain considerations to be kept in mind when saving seed. Seeds from hybrid varieties will not produce plants that are the same as the parent plants; therefore, only open-pollinated varieties should be used for home seed production. Some seed dealers have responded to the increasing interest in seed saving by clearly marking open-pollinated varieties in their catalogs. Another consideration in saving seed is the possibility of carrying seed-borne diseases into the next year's crop. Many commercially grown seeds are grown in dry areas unsuitable to fungal, viral, and bacterial diseases that may be present in your region. Take care to control diseases that can be carried in seed. Another weather-related factor is the speed of drying of seeds, which can be adversely affected by frequent rains and/or humidity. Finally, if you've ever saved squash seed during a season in which you had more than one type of squash planted, you have probably seen the weird results that may be obtained from cross pollination! Saving seeds from cross-pollinated crops is not generally recommended for the novice because of problems with selection,

requirements for hand pollination and isolation, biennial habits, and genetic variability. Failure to let the seed mature adequately on the plant also leads to nonviable seed. Common, self-pollinated, annual plants from which seed may be saved include lettuce, beans, peas, herbs, and tomatoes.

Beans and peas: Allow seed pods to turn brown on the plant. Harvest pods, dry for one to two weeks, shell, then store in a cool (below 50ºF), dry environment in a paper bag.

Lettuce seed: Cut off seed stalks when fluffy in appearance, just before all the seeds are completely dried. Seeds will fall off the stalk and be lost if allowed to mature on the plant. Dry the harvested seed stalk further; shake seeds off; then store in a cool, dry environment in an envelope or small glass jar.

Herb seeds: Herbs vary in the way their seeds are produced. In general, allow herb seeds to stay on the plants until they are almost completely dry. Some seed heads, such as dill, will shatter and drop their seeds as soon as they are dry. Watch the early ripening seeds; if they tend to fall off, harvest the other seed heads before they get to that point, leaving several inches of stem attached. Hang several stems upside down, covered with a paper bag to catch falling seed, in a warm, dry place until the drying is complete. Remove seeds from the seed heads, and store in envelopes or small glass jars. Some herb seeds (dill, celery, anise, cumin, coriander, and others) are used for flavoring and are ready to use once dry.

Tomato seeds: Pick fruit from desirable plants when ripe. Cut fruit and squeeze out pulp into a container. Add a little water, then let ferment two to four days at room temperature, stirring occasionally. When seeds settle out, pour off pulp and spread seeds thinly to dry thoroughly. Store in an envelope or glass jar in a cool, dry place.

Saving Purchased Seed

Properly stored seed remains viable for different lengths of time depending on the type of seed. Be aware that seed companies may store seeds up to the number of years of their viability prior to selling them. To ensure maximum viability of purchased seed after its package has been opened, remaining seed should be sealed in airtight containers and stored in a cool, dark location. Glass jars with rubber seals, such as baby food jars or canning jars, or tightly sealed plastic bags stored inside jars are good choices. Be sure to label all stored seed with the species name and original package date.

For all kinds of saved seeds, be sure to mark the storage containers clearly with permanent (preferably waterproof) ink, indicating the variety and date saved. Seeds will remain viable for some time if properly stored. To test for germination, sprout seeds between moist paper towels; if germination is low, either discard the seed or plant enough extra to give the desired number of plants. Excellent books are now available for more details.

Viability of Vegetable Seeds
(Average number of years seeds may be saved)

Vegetable	*Years*	*Vegetable*	*Years*
Asparagus	3	Leek	2
Bean	3	Lettuce	6
Beet	4	Muskmelon	5
Broccoli	3	Mustard	4
Brussels sprouts	4	Okra	2
Cabbage	4	Onion	1
Carrot	3	Parsley	1
Cauliflower	4	Parsnip	1
Celery	3	Pea	3
Chinese cabbage	3	Pepper	2
Collards	5	Pumpkin	4
Corn, sweet	2	Radish	5
Cress, water	5	Rutabaga	4
Cucumber	5	Spinach	3
Eggplant	4	Squash	4
Endive	5	Tomato	4
Kale	4	Turnip	4
Kohlrabi	3	Watermelon	4

Depth for Planting Vegetable Seeds

The depth to cover seeds when you plant them depends on a number of factors, such as the size of the seed, the type of soil you have, and the season of the year. As a general rule, vegetable and flower seeds should be covered about four to five times their lateral diameter or width (not their length). Most seeds should be planted from 1/4 to 1/2 inch deep. There are exceptions, however, so read the packet directions. Small seeds, such as celery, should be planted only 1/8 inch deep. Vine crops, sweet corn, and beans can be planted 1 inch or deeper. Some seeds require light for germination and should not be covered at all. These instructions apply to seeds planted both inside and out.

Starting Seeds Indoors

To start seeds indoors, it is important to have enough light. More homegrown seedlings are probably lost to

Plant Production Data Chart			
Crop	*Days to Emergence from Seeding*	*Optimum Soil Temperature (°F) Range for Germination*	*Number of Weeks to Grow Transplants*
Beans	5-10	65°- 85°	*
Beets	7-10	50°- 85°	*
Broccoli	3-10	50°- 85°	5-7
Cabbage	4-10	50°- 85°	5-7
Carrots	12-18	50°- 85°	*
Cauliflower	4-10	50°- 85°	5-7
Celery	9-21	50°- 85°	10-12
Chard, Swiss	7-10	65°- 85°	*
Corn, sweet	5-8	65°- 85°	*
Cucumber	6-10	65°- 85°	4 (peat pots)
Eggplant	6-10	65°- 85°	6-9
Lettuce	6-8	50°- 85°	3-5
Melons	6-8	65°- 85°	3-4 (peat pots)
Okra	7-10	65°- 85°	*
Onion	7-10	65°- 85°	8
Parsley	15-21	50°- 85°	8
Peas	6-10	50°- 85°	*
Pepper	9-14	65°- 85°	6-8
Potatoes, sweet	(slips)	65°- 85°	5-6
Radish	3-6	50°- 85°	*
Spinach	7-12	50°- 85°	*
Squash	4-6	65°- 85°	3-4 (peat pots)
Tomato	6-12	65°- 85°	5-7
Turnip	4-8	50°- 85°	*
** Transplants not recommended*			

this one factor than to any other. Vegetable seedlings grown under low-light conditions are likely to be leggy and weak, and many will fall over under their own weight after they are 3 to 4 inches tall. If you do not have a sunny room or back porch with a southern exposure, you will probably need supplemental lights. A simple, fluorescent, shop light with one warm-white and one cool-white bulb (or with grow lights) will suffice.

It is probably easiest to use a soilless or peat-lite mix to start seedlings, since garden soil contains disease organisms that can be highly destructive to small plants. Soil can be sterilized in the oven by baking it at 200ºF until the internal soil temperature is 180ºF. It should be held at that temperature for 30 minutes. This is a smelly process, but it works. Garden soil for use in containers should be conditioned with compost and perlite to prevent excess moisture retention and/or shrinkage. You can mix your own peat-like mix if you prefer; 50% vermiculite and 50% fine sphagnum peat is excellent for starting seeds. Fertilizer at half the normal strength may be added to the mixture. Mix well before using.

Many types of containers can be used to start seeds. Flats or other large containers may be used; plant in rows, and grow seedlings until they have one or two sets of true leaves, then transplant into other containers for growing to the size to transplant outdoors. Seedlings may also be started in pots, old cans, cut-off milk cartons, margarine tubs, egg cartons, or other throwaways. The pop-out trays found at garden centers are easy to use and reusable after cleaning. Peat pots are nice, especially for large seeds. Sow one or two large seeds directly in each peat pot. Thin to one seedling per pot. Peat pots may be planted

directly in the garden; do not allow the edges of the pot to stick out above the soil since they will act as a wick and moisture will evaporate from this exposed surface. Many seed starting kits are now available and provide everything you will need, but remember that these are used as part of a hobby and not as a way to save money instead of buying plants at a nursery.

Regardless of the type of container chosen, fill it three quarters full with seed-starting mixture and sow the seeds. Cover to the specified depth, and water the mix. It may help to cover the containers with plastic wrap to maintain a steadier moisture level. Seeds and seedlings are extremely sensitive to drying out. They should not be kept soaking wet, however, since this condition is conducive to damping-off, a fungus disease deadly to seedlings. Damping-off can be prevented or diminished by sprinkling milled sphagnum moss, which contains a natural fungicide, on top of the soil.

Another option is to use peat pellets or cubes, which are preformed and require no additional soil mix. The pellets or cubes are soaked until thoroughly wet, then seeds are planted in the holes provided. The whole pellet or cube may then be planted without disturbing the roots. The only disadvantage to this method is the expense.

Starting Seed Outdoors

Many seeds may be sown directly in the garden. If garden soil is quite sandy or is mellow (with a high content of organic matter), seeds may be planted deeper. Young seedlings can emerge quite easily from a sandy or organic soil. If garden soil is heavy with a high silt and/or clay content, however, the seeds should be covered only two to three times their diameter. In such soils, it may be helpful to apply a band of sand, fine compost, or vermiculite, 4 inches wide and 1/4 inch thick, along the row after seeds are planted. This will help retain soil moisture and reduce crusting, making it easier for seedlings to push through the soil surface.

Soil temperature has an effect on the speed of seed germination. In the spring, soil is often cold, and seeds of some plants will rot before they have a chance to sprout. The chart on the next page gives optimum soil temperatures.

When planting the fall garden in midsummer, the soil will be warm and dry; therefore, cover the seeds six to eight times their diameter. They may need to be watered each day with a sprinkler or a sprinkling can to promote germination. Moisture can also be retained with a shallow mulch or by covering the row with a board until the seeds have sprouted. Shading the area may be helpful to keep the soil cooler for seed germination, especially when planting cool-weather crops in summer. Seed that requires a lower germination temperature may benefit from being kept in the refrigerator for two weeks before planting or from pre-sprouting indoors. Pre-sprouting is a useful technique for planting in cold soils, as well. However, seed must be handled very carefully once sprouted to prevent damaging new root tissue.

Row Planting

A string stretched between stakes will provide a guide for nice, straight rows, if desired. Use a hoe handle, a special furrow hoe, or a grub hoe to make a furrow of the appropriate depth for the seed being planted. Sow seed thinly; it may help to mix very small seed with coarse sand to distribute the seeds more evenly. Draw soil over the seed, removing stones and large clods. Firming soil so that it is in direct contact with seeds improves uptake of soil moisture by the seed, hastening germination. When plants have grown to 4 to 6 inches tall, thin according to seed packet instructions to provide adequate room for growth.

Wide Row or Banded Planting

Many crops may be sown in wide rows or bands instead of in long, single rows. Crops of spinach, bean, pea, beet, lettuce, and carrot are especially suited to this type of culture. Sow seed evenly over the area, then rake it in, firming soil over the seeds. Thin young plants to allow room for growth (See section "Intensive Gardening Methods" for more information).

Hill Planting

Larger vegetables, such as melons, squash, sweet corn, and cucumbers, may be planted in hills or groups of seed. Soil is mounded to a foot or so in diameter, at the recommended spacing. Plant four to six seeds per hill, firming the soil well. Thin the seedlings to three to five plants per hill.

Study Questions

12. Only _____ seed varieties should be used for home seed production.

13. In general, vegetable and flower seeds should be planted _____ times their diameter or width in a loam soil.

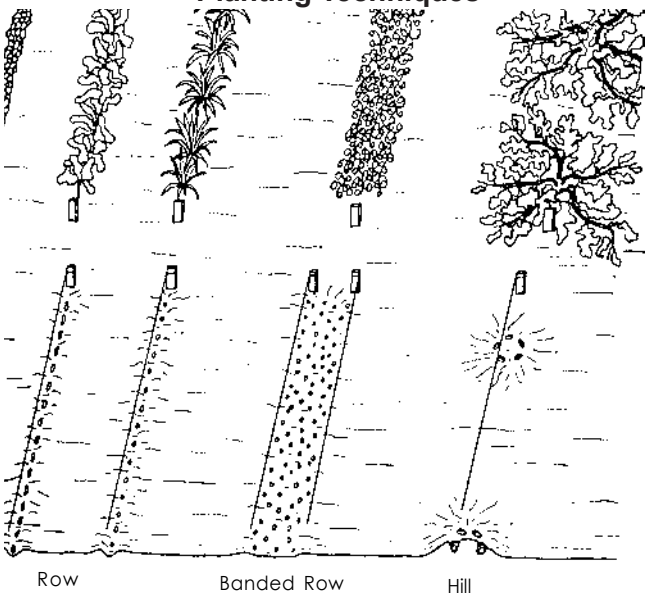
14. To promote germination of cool-weather crops planted in summer, one can:
    a) provide shade; b) water each day; c) plant seeds a bit deeper; d) all of the above

15. To aid evenness in distribution of small seed, mix seed with _____.

16. Hill planting can be used for: a) carrots;
    b) tomatoes; c) melons; d) all of the above

Answers: 12 - open-pollinated; 13 - 4 to 5; 14 - d; 15 - coarse sand; 16 - c

Planting Techniques



Transplants for the Garden

Most gardeners use transplants in the garden at some time or another to give long-season plants a chance to grow to maturity under their preferred weather conditions or just to lengthen the harvest season. Cool-season crops, such as head lettuce, broccoli, and celery, would not have a chance to reach their prime harvest stage in most places in Virginia in spring if not given those extra weeks indoors to get a head start. Tomatoes would certainly have a short harvest period in all but southeastern Virginia if started from seed in the ground, and peppers and eggplants might not produce at all if not grown from transplants.

Due to the amount of time, attention, and need for controlled growing conditions, many gardeners prefer to purchase plants for their gardens. However, for a larger choice in varieties and the control of plant production from seed to harvest, others choose to start their own transplants.

Annual Plants

Transplants of annual vegetables and flowers should be stocky, healthy, free from disease, and have good roots. They should not be too small or too mature (tomatoes will transplant all right with fruits already on them, but many other plants will drop flowers or fruit after transplanting). Be sure plants have been hardened-off so that they will easily adapt to environmental change, but they should not be so hardened that they are woody and yellow otherwise they will not resume active vigorous growth. Successful transplanting is achieved by interrupting plant growth as little as possible so younger plants that do not have dense roots growing out of the pot will usually become established fastest.

Have garden soil prepared before transplanting. All additives that require time to break down, such as manure, limestone, fertilizer, and green manure, should be incorporated the autumn before planting if at all possible. Quicklime (hydrated) fertilizers and well-decayed compost may be added just before planting.

Transplant on a shady day, in late afternoon, or in early evening to prevent wilting. It helps to water the plants several hours before transplanting; when using bare-root plants, such as plants from an old-time farm supply store, soak the roots thoroughly an hour or two before setting them out in the garden. They should not be allowed to dry out completely at any time. Handle plants carefully. Avoid disturbing the roots or bruising the stems. Dig a hole large enough to hold the roots of the plants. Set the plants slightly deeper than previously planted and at recommended intervals. Tomatoes are an exception to the rule of how deep to plant; they will develop roots all along the stems, and you can plant deep enough to leave only two or three sets of leaves exposed. Press soil firmly around the roots of transplants. Pour about a cup of starter solution in the hole around the plant. Use a solution of about half the strength recommended for that type of plant during the normal growing season. Fish emulsion or dilute manure tea may also be used. In cold weather, various season extenders are useful (see "Season Extenders" section). Water the plants once or twice during the next week if there is insufficient rain.

Transplant Production Data (Ease of transplanting)		
Easily Survive Transplanting	Require Care in Operation	Not Successfully Transplanted by Usual Methods
Broccoli	Celery	Bean
Brussels sprout	Eggplant	Carrot
Cabbage	Melon	Corn, sweet
Cauliflower	Onion *(tends to bolt)*	Cucumber *(tends to stop growth)*
Chard	Pepper	Orka
Chinese cabbage		Pea
Lettuce		Squash
Sweet potato slips		
Tomato		

Perennial Plants

When buying small fruit plants and perennial crowns, such as asparagus, order early or buy from reliable local outlets. Occasionally stores allow plants to dry out, so watch for this, especially if you are buying sale plants. Select varieties that will do well in your growing conditions. For perennial plants, it will pay to do some research to find out what the major disease and insect pests are and buy resistant varieties. Dormant, bare root plants, and 1- or 2-year-old crowns are preferred. Look for roots that are full, slightly moist, and have color. Roots that are dry brown or soggy black are indicative of poor storage and will probably not give good results. Check crowns for signs of viable buds. Inspect plants for signs of insects or disease. If you receive plants by mail that are not satisfactory, do not hesitate to send them back.

Once you have the plants, keep the roots moist (but not soaking wet) by misting occasionally, and do not allow them to freeze or be exposed to high temperatures. If it is necessary to keep the crowns for more than a few days, place in cold storage (not freezing) or else heel in a trench of moist soil in a shaded location. Pack soil firmly against roots to eliminate any air pockets.

Transplant crowns according to directions, digging holes large enough to give the roots plenty of room to spread. Remove any discolored or dried out roots. Perennial plants appreciate a dose of compost mixed into the bottom of the hole. Once transplanted, shade the plants if necessary and water when needed. Extra care at the beginning of their growth will result in productive, healthy plants.

Study Questions

17. Plants that should be started from transplants to be harvested in Virginia do NOT include:
    a) tomatoes; b) corn; c) peppers; d) eggplant

18. Transplants that have been _____ will more easily adapt to environmental changes.

19. To help prevent wilting, transplanting should be done: a) on a shady day; b) in late afternoon; c) in early evening; d) all of the above

20. Fish emulsion, dilute manure tea, or a starter solution should be applied at transplanting:
    a) at half the recommended strength; b) at twice the recommended strength; c) only in late fall; d) only for leguminous crops

21. Perennial roots that indicate poor storage conditions: a) are full; b) are slightly moist; c) are soggy black; d) have color

Answers:
17 - b; 18 - hardened off; 19 - d; 20 - a; 21 - c

Irrigating the Home Garden

Adequate soil moisture is essential for good crop growth. A healthy plant is composed of 75 to 90% water, which is used for the plant's vital functions, including photosynthesis, support (rigidity), and transportation of nutrients and sugars to various parts of the plant. During the first two weeks of growth, plants are becoming established and must have water to build their root systems.

During the growing season of April through September, vegetable crops need enough water each week to wet the soil down 5 to 6 inches. In most soils, this means that about 1 inch of water needs to be applied each week in the form of rainwater, irrigation water or a combination of both. Keep a rain gauge near the garden or check with the local weather bureau for rainfall amounts, then supplement rainfall with irrigation water, if needed. There are ways, however, to reduce the amount of water you have to add.

During dry periods, one thorough watering each week of 1 to 2 inches of moisture (65 to 130 gallons per 100 square feet) at one time is usually enough for most soils. Soil should be wetted to a depth of 5 to 6 inches each

time you water and not watered again until the top few inches of soil begin to dry. A trickle irrigation system will be much more efficient in use of water. It utilizes more frequent or continuous application of water in smaller amounts to prevent soil dryness. If there is any doubt, dig down 6 inches into the soil to check for moisture but take care not to damage any roots.

Reducing Water Demands

All of the water you apply may not be available to plants, particularly if the soil is a heavy clay. Clay particles hold soil moisture tightly. If, for example, there are four and one-half inches of water per foot of this type of soil, there may be as little as one and one-half inches available for plants. A relatively high level of humus in the soil, brought about by the addition and breakdown of organic matter, can improve this proportion to some extent. By causing clay particles to form aggregates or large clumps of groups of particles, humus also adds air spaces to tight clays, allowing moisture to drain to lower levels as a reserve, instead of puddling and running off the top of the soil.

The moisture-holding capacity of sandy soils is also improved by addition of organic matter. Though most soil water in sandy soil is available, it drains so quickly that plants are unable to reach water after even a few days following a rain. Humus in sandy soil gives the water something to cling to until it is needed by plants. Addition of organic matter is the first step in improving the moisture holding capacity of the soil.

Mulching is a cultural practice that can significantly decrease the amount of water to be added to the soil. A 2- to 3-inch (6 to 8 inches of loose straw or leaves will compact to 2-3 inches of mulch) organic mulch can reduce water needs by as much as half by reducing evaporation of moisture directly from the soil. Organic mulches themselves hold some water and increase the humidity level around the plant. If they become dry it may be necessary to add an extra 1 or 2 inches of water when overhead watering to soak through the mulch. Plastic mulch also conserves moisture, but may increase soil temperatures dramatically during the summer (to the detriment of some plants and the benefit of others) if not covered by other mulch materials or foliage.

Shading and the use of windbreaks are other moisture-conserving techniques. Plants that wilt in very sunny areas can benefit from partial shade during the afternoon in summer. Small plants, in particular, should be protected. Air moving across a plant carries away the moisture on the leaf surfaces, causing the plant to need more water. In very windy areas, the roots often cannot keep up with leaf demands, and plants wilt. Temporary or permanent windbreaks can help tremendously.

During those times when cultural practices simply aren't enough, when rainfall is sparse, and the sun is hot, watering can benefit the garden with higher yields or may save the garden altogether in severe drought years.

By knowing the critical watering periods for selected vegetables, you can reduce the amount of supplemental water you add. This can be important where water supplies are limited. In general, water is most needed during the first few weeks of development, immediately after transplant, and during development of fruits.

Specifically, the critical watering periods for selected vegetables are:

* Asparagus - Spear production, fern development
* Beans - Pod filling
* Broccoli - Head development
* Cabbage - Head development
* Carrot - Seed emergence, root development
* Cauliflower - Head development
* Corn, sweet - Silking, tasseling, ear development
* Cucumber - Flowering, fruit development
* Eggplant - Flowering, fruiting
* Lettuce - Head development; moisture should be constant
* Melons - Flowering, fruit development
* Peas - Pod filling
* Tomato - Flowering, fruiting

In areas prone to repeated drought, look for drought-resistant varieties when buying seed or plants.

Irrigation practices, when properly used, can benefit the garden in many ways:

* Aid in seed emergence
* Reduce soil crusting
* Improve germination and plant stand

* Reduce wilting and checking of growth in transplants
* Increase fruit size of tomato, cucumber, and melon
* Prevent premature ripening of peas, beans, and sweet corn
* Maintain uniform growth
* Improve the quality and yields of most crops

Irrigation Methods

The home gardener has several options for applying water to plants. Most gardeners either use overhead watering (a watering sprinkler can, a garden hose with a fan nozzle or spray attachment, portable lawn sprinklers), or a drip application (a perforated plastic soaker hose, drip or trickle irrigation, or a semiautomatic drip system). When properly cared for, quality equipment will last for a number of years.

Some basic techniques and principles for overhead watering:

Adjust the flow or rate of water application to about 1/2 inch per hour. A much faster flow than this will cause runoff, unless the soil has exceptionally good drainage. To determine the rate for a sprinkler, place small tin cans at various places within the sprinkler's reach, and check the level of water in the cans at 15 minute intervals.

When using the oscillating type of lawn sprinklers, place the sprinkler on a platform higher than the crop to prevent water from being diverted by plant leaves and try to keep the watering pattern even by frequently moving the sprinkler, overlapping about half of each pattern.

Do not get foliage wet in the evening; this can encourage diseases. Morning watering is best. Watering in the morning, which is usually the least windy time of day, also helps to decrease evaporation.

It is best to add enough water to soak the soil to a depth of 5 to 6 inches. It takes approximately 2/3 gallon of water for each square foot or 65 to 130 gallons for 100 square feet of garden area. This varies with the nature of the soil. Frequent, light waterings will only encourage shallow rooting which will cause plants to suffer more quickly during drought periods, especially if mulches are not used. On the other hand, too much water, especially in poorly drained soils, can be as damaging to plant growth as too little water. A good rule to remember is to water "deeply and infrequently."

Several types of drip or trickle equipment are available. The soaker hose is probably the least expensive and easiest to use. It is a fibrous hose that allows water to seep out all along its length at a slow rate. There are also hoses with holes in them that do basically the same thing; water drips out the holes. With the latter type, a flow regulator usually has to be included with the system so water can reach the end of the hose, yet not be sprayed out at full force. A special, double-wall type of irrigation hose has also been developed that helps maintain an even flow. Finally, there is the emitter-type system, best used for small, raised-bed or container gardens, in which short tubes, or emitters, come off a main water supply hose; emitters put water right at the roots of the desired plants. This is generally the most expensive form of irrigation and the most complex to set up, but it has the advantage that the weeds in the area are not watered, and evaporation from the soil is minimized. This type of system is best used in combination with a coarse mulch or black plastic. Drip systems generally have some problems with clogging from soil particles and/or mineral salts from water taken from springs or wells. New designs take into consideration the clogging problem; some include filters and self-flushing emitters. It is wise to make a complete investigation and comparison before purchasing a drip irrigation system.

Perforated plastic hoses or soaker hoses should be placed with holes down (if there are holes) along one side of the crop row or underneath mulch. Water is allowed to soak or seep into the soil slowly.

Study Questions

22. Growing vegetables need approximately _____ of water at one time per week from April to September supplied by irrigation, rain, or both.
23. A soil type that hold moisture tightly is _____.
24. Practices that significantly decrease the need to water include: a) mulching; b) shading; c) using windbreaks; d) all of the above
25. A windbreak helps to reduce watering needs by reducing _____.
26. Two common irrigation practices for the home gardener are _____ and _____.

Answers:
22 - 1 ½; 23 - clay; 24 - d; 25 - transpiration; 26 - overhead watering, drip application

Fertilizing the Garden

The amount of fertilizer to apply to a garden depends on the natural fertility of the soil, the amount of organic matter present, the type of fertilizer used, and the crop being grown. The best way to determine fertilizer needs is to have the soil tested. Soil testing is available through your local Extension agent, through private labs, and with soil test kits that can be purchased from garden shops and catalogs.

Weed Control in the Garden

Vegetables fall into three main categories according to their fertilizer requirements: heavy feeders, medium feeders, and light feeders. It may be advantageous to group crops in the garden according to their fertilizer requirements to make application easier. (For a complete discussion of fertilizers, refer to Chapter 3: Soils).

The old saying, "One year's weed - seven years' seed," contains more truth than myth, as most gardeners soon learn. Weeds (some native and some introduced) are remarkably adapted to conditions in the area where they grow, usually much more so than the imported cultured vegetables we prize so highly for food. Many weeds that would otherwise not be growing in a lawn or natural area appear to spring up as if by magic when the soil is cultivated. Weed seeds may remain viable for those seven (or more) years when conditions are not right for their growth. Then, brought to the surface by tilling and uninhibited by sod, shade, or other factors, they germinate and become pests that take water, nutrients, sunlight, and space from vegetable plants. Weeds are "plants out of place" and while useful in other settings, "weeds" can create many problems in the garden, including shading, competition for nutrients and water, and harboring insects and disease.

Beneficial Weeds

Many plants considered weeds in the garden have positive attributes. Some, such as morning glory and even thistles, have flowers that rival those intentionally planted in flower beds. In fact, seeds of some "weeds" are sold by seed companies as flowering plants and wildflower gardening has become a very popular pastime.

Weeds are often a habitat for various insects, some of which are beneficial to the garden. They provide shelter, pollen, and nectar for bees and predators of garden pests, such as praying mantis. Wild plants also have other virtues. Parts of some plants are used in natural dyes and other homemade products. Weeds can be a good source of nitrogenous materials for the compost pile if pulled before flowering. Finally, the presence of specific weed species can indicate certain soil problems (e.g., deficiencies, pH changes, soil compaction, etc.). A small number of books are available with detailed information on this subject.

Control Methods

Most gardeners won't tolerate weeds in their vegetable plots. Perhaps it is an overreaction to an earlier garden allowed to go completely to weeds or perhaps it's the unruly appearance of weeds. This may be a sensible approach. If one doesn't have time to ruthlessly destroy morning glory vines after enjoying the first few flowers and before they go to seed, the garden will soon become one glorious display of morning glories and little else.

Cultivation: There are several ways to rid the garden of most problem plants. Since mature weeds extract large quantities of moisture and nutrients from the soil, it is more beneficial (and easier) to remove weeds when they are young and tender. Hand pulling and digging are okay for small gardens and raised beds. Those with larger spaces usually prefer at least a hoe. There are manual-powered rotary cultivators that do a good job on long rows and pathways as long as the soil is not too wet or dry and the weeds are small. In large gardens, a rotary tiller of appropriate size makes the work easy and fast. Manual and powered rotary cultivators are usually unable to turn under weeds very close to vegetable plants without damaging the vegetables. Hand pulling or hoeing with a light touch are best for removing weeds near vegetable plants. Deep cultivation with any instrument is likely to damage roots or stems of crop plants, reducing yield and increasing disease problems.

Turning under weeds provides organic matter to the soil but many plants with heavy roots or rhizomes may survive. Hand-pulled weeds, except for rhizomatous grasses, may be laid on top of the soil to dry out after shaking them free of soil and will eventually have the same effect of adding organic matter to the soil. However, if rain is predicted in the area within a day or two, it's best to collect the weeds and add them to the compost pile; rain will wash soil

around the roots and some weeds will survive. If weeds have started to go to seed, leaving them in the garden is not a good idea. Composting may not destroy weed seeds if the pile doesn't heat up enough after the weeds are added. Grasses that spread by rhizomes or stolons also present a problem if not dried up completely. In these cases, despite their potential value as organic material, it's better to either: let the trash collectors take the weeds; burn the weeds and spread the ashes in the garden (if local ordinances permit); or maintain a "pit" compost pile (where the organic material is actually buried in the soil) for these items, kitchen scraps, and other problematic materials. Reducing weed growth around the garden by mowing, especially before seed head production, will also help prevent the spread of weeds and seeds into the garden area.

Cultivation is best done when the soil is somewhat moist, but not wet. Working wet soil will change the structure, especially of heavy soils. When it is too dry, weeds are difficult to pull and hoeing is also hard. A day or two after a rain or irrigation is probably the best time to cultivate. If you have a choice, remember that the work will be much more pleasant in the cool temperatures of early morning or evening. On hot, summer afternoons, you are likely to fatigue more easily; get a sunburn; or suffer from sun poisoning, sunstroke, or worse. Wear protective clothing if you must work when it's sunny, and stop frequently for rest and water.

Mulching: Mulching can be an alternative to weeding if you have a reliable source of mulching materials. Thick layers of organic mulch will not allow most annual weeds to poke through, and those that do are usually easily pulled. Weeds with runners are often not so easily controlled, and black plastic may be a better choice where these prevail. For paths, newspaper, cardboard, or other such materials, covered with mulch, will provide excellent weed suppression. However, sawdust is not recommended for use right around plants because of its tendency to crust and because bacteria take nitrogen from the soil, thus from the vegetables, to break down the sawdust.

Close spacing: Once vegetable plants are established, if they have been planted close enough to each other, they will shade the soil and prevent the growth of many weed seedlings. This is the effect achieved by a well-planned raised bed in which plants are spaced so that the foliage of adjacent plants touches and forms a closed canopy at a mature growth stage.

Cover crops: The use of cover crops over several seasons or years in a particularly weedy section can also reduce weed problems. However, this method requires leaving that part uncultivated, reducing gardening space. Cover crops must also be mown or harvested regularly, which can be time-consuming and/or difficult without appropriate tools.

Herbicides: As mentioned before, herbicides may be used in and around the home garden, but it can be a risky business. They should always be used according to label instructions and only for crops listed on the label. The wrong herbicide can destroy a garden's productivity for years. Even when used properly, drift from herbicide sprays used on lawns or in areas surrounding the garden can cause damage to vegetable plants, so take care to spray on windless days and erect barriers to protect plants if necessary. Drift from preemergent herbicides does not damage growing plants, but may prevent seeds from germinating. Be aware that treatment with an herbicide for one type of weed may result in the area being colonized by other weeds that are tolerant to the chemical. Finally, never use an herbicide in the same sprayer used for insect and disease control. Keep a separate sprayer for plant killers only.

Insect Control for the Garden

Home gardeners sometimes think that if a little pesticide is good, then more will be better, and then they use more pesticides per square foot in their garden than farmers do in their fields. This may be a serious violation of many pesticide labels, not to mention a waste of money. Overuse of pesticides has a number of adverse effects. It makes food less safe to eat, especially if residues remain at harvest. It may make the plants dangerous to handle. It may harm or kill beneficial insects, earthworms, birds, or other animals. Gardeners are exposed to toxins by inhalation or absorption through the skin each time they spray pesticides. Pesticides may leach through the soil into ground water, contaminating water supplies. Pesticides used near ponds may kill fish. Continuous use of certain pesticides may induce resistance in insect pests, then requiring the use of other toxins. Some pesticides break down slowly and can remain in the environment for years.

Concern over the use and misuse of pesticides has led many home gardeners to seek means of natural pest

control. There are many cultural practices that help reduce plant injury due to insects. Insecticide use can be minimized with a little research and effort. Proper soil preparation, careful plant selection, and good garden practices can be combined with biological and mechanical control measures to reduce the need for pesticides. Home gardeners should consider accepting some small visible blemishes on a tomato instead of growing perfect produce that fits market standards.

Mechanical Controls

Handpicking

Inspect plants for clusters of eggs, caterpillars, bean beetle larvae, and other insects as often as possible. Handpick and destroy these when found to reduce pest populations mechanically. Knocking the pests into a container of plain soapy water is an effective control measure, too.

Traps

Use appropriate insect traps to reduce certain pest populations. Japanese beetle traps are effective in attracting the adult beetles, but they may draw in more adults from surrounding areas than what is already present in your yard. Place traps at least 40 feet away from the beetles' favorite food plants and remove dead beetle frequently.

Other effective traps include upside-down flower pots, flat boards, sheets of newspaper, and similar items that attract earwigs, sowbugs, and slugs who collect underneath when the sun comes up in the morning. Collect these pests and destroy them each morning. In greenhouses, use yellow sticky traps to control whiteflies and thrips. These traps can be made from boards painted yellow and lightly coated with oil or petroleum jelly, or they can be purchased commercially.

Light traps, particularly those known as "bug zappers" that use special blacklight or bluelight bulbs that emit a higher proportion of ultra violet light that is highly attractive to nocturnal insects, are generally useless in protecting a garden. While they usually attract and kill a large number of insects, many of those insects are beneficial or harmless species drawn into the area by the blacklight. Some of the insects killed are harmful pests, but the light may draw more into the area than are killed by the bug zapper itself, and these may find the garden and become pests there. Light traps also do not kill wingless or flightless species, or any insects that are active during the day instead of at night when the light is turned on.

Baits

A shallow dish of stale beer sunk at ground level will attract and control slugs.

Repellents

Aluminum foil and other reflective mulch may repel aphids, but can be expensive. Crushed egg shells can be used against slugs, but iron phosphate bait pellets are more effective.

Exclusion or Barriers

Various materials can be used to physically block or repel insects from plants. Place wood ash, cardboard tubes, and orange juice cans around the stems of young plants to discourage cutworms. Bands of copper foil around plant stems will discourage slugs. Put paper bags over ears of developing corn to protect them from birds and insects, but only after pollination is completed. Cages of netting or mesh screening will protect plants from insect, bird, and rabbit damage. Floating row covers are effective in excluding pests from cole crops, strawberries, cucumbers, melons, and squash.

Biological Control

Predators, Parasitoids, and Parasites

Healthy gardens should have many beneficial organisms present. Take advantage of the biological control already present in your garden by encouraging natural predators such as lacewings, ladybugs, preying mantises, and ground beetles. Learn to recognize the eggs and larvae of the beneficial insects so you can avoid harming them. Learn more about the likes and dislikes of these helper insects regarding their preferences for food and habitat. Studies have shown that providing a diversity of flowering plants will attract a wide variety of beneficial insects. Understand that even spiders and toads are also beneficial in the garden and eat unwanted pests.

Purchasing natural enemies such as ladybugs from commercial suppliers is not recommended for several reasons. If they were collected in the wild, the insects could introduce unwanted parasites or diseases into new areas when released. Also, these insects instinctively disperse when released, and may not remain in the area you want them for very long. Purchased natural enemies are more effective when released in closed areas such as greenhouses.

Learn to recognize beneficial parasites and their life stages. For example, tomato hornworm caterpillars are often found with white cocoons on their backs. These cocoons are about the size of a grain of rice and are made by beneficial wasps that have already parasitized the caterpillar. By the time the wasp grubs have spun their cocoons, the tomato hornworm has ceased feeding and will soon die. It is to the gardener's advantage to leave the infested caterpillar in the garden so that the adult wasps can emerge and parasitize more hornworms.

Insecticides

Reduced use of pesticides is always suggested for the following reasons: to avoid environmental contamination; protect valuable pollinators and other desirable species; delay the development of pesticide resistance in pests; and limit unnecessary exposure to humans and other vertebrate animals. However, there are times when insecticide use is appropriate and justified to control insect pests. When insecticide use is warranted, choose the least toxic material available. Check that the equipment used to apply the insecticide is in good working condition and is calibrated correctly. Wear appropriate clothing as directed on the insecticide label. Follow the label directions regarding how much material should be applied and in what manner. Failure to follow the insecticide label directions is a violation of Federal law.

Many gardeners are interested in organic pesticides as an alternative to synthetic insecticides. Organic pesticides are derived from naturally occurring sources, whereas conventional or synthetic pesticides are synthesized from chemicals and may include chemical structures not found in nature. Be aware that even organic or "natural" insecticides are still toxic chemicals. If they weren't toxic then they would not be effective in killing insects. Organic pesticides usually have a lower toxicity to warm-blooded animals, but not always. Organic pesticides usually don't persist in the environment as long as synthetic pesticides, so they are referred to as being "softer" on the environment. Some "softer" insecticide choices include botanical products such as pyrethrins, neem, and rotenone; biopesticides such as spinosad and Bt (Bacillus thuringiensis); horticultural or dormant oils; and insecticidal soaps.

See the Pesticides chapter for more information. Refer to the current Virginia Cooperative Extension Pest Management Guide for Home Grounds and Animals for the latest recommendations for all types of insecticides approved for use in Virginia, including organic controls, application rates, and proper timing of application.

Vegetable Planting Guide

And Recommended Planting Dates

Planting Map/Guide/Dates

The Planting Area Map that follows can be used to determine the average date of last frost in your area. Actual dates will vary due to local conditions and yearly temperature fluctuations. The average date of last killing frost in the spring can be used to adapt the Recommended Planting Dates Chart to your particular area. This chart can be used to tell the approximate earliest and latest dates for a spring planting of each crop and the average length of harvest for each crop. This is particularly important in making maximum use of garden space by following one crop with another as soon as the first harvest is complete.

The Vegetable Planting Guide can be used to determine the approximate proper amount of crop to plant for the desired yield, the amount of seed or transplants required for that amount of crop, and proper spacing between plants in a row. In intensive, raised-bed gardens, use the in-row figures between all plants; i.e., use equidistant spacing between plants. Sow seeds to a depth three to five times the diameter of the seed. For midsummer plantings, sow up to twice this depth.

Frost Dates

The planting date for vegetables depends on the hardiness of the particular crop. Most planting directions are based on the average frost date. Average frost date refers to the expected dates of the last frost in the spring and the first frost in the fall for a geographic location. The difference between the two average frost dates determines the average number of frost free days for crop production.

Study Questions

27. The best way to determine the soil's fertilization needs is to _____.

28. Problems created by weeds in the garden do NOT include: a) shading; b) competition for water and nutrients; c) harboring insects and disease;

d) increased erosion

29. A mulch that is recommended for controlling perennial weeds with runners is _____.

30. Even when used properly, _____ from herbicides can cause damage to vegetable plants in other parts of the garden.

31. Most planting dates are based on the average _____.

Answers:
27 - soil test; 28 - d; 29 - black plastic; 30 - drift; 31 - frost date

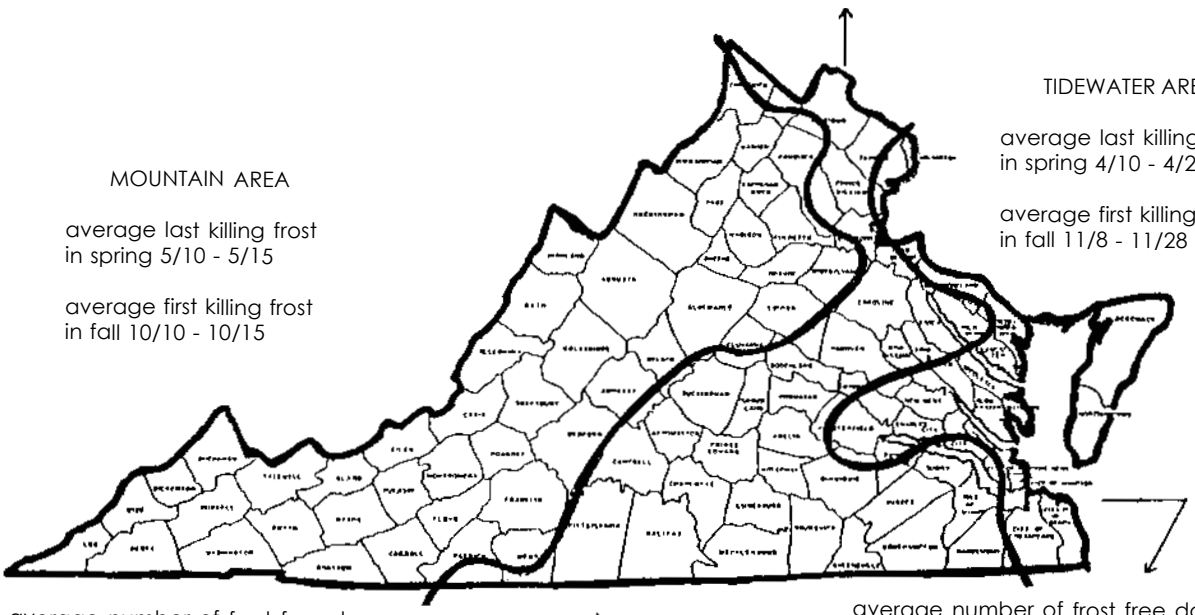
Intensive Gardening Methods

The purpose of an intensively grown garden is to harvest the most produce possible from a given space. More traditional gardens consist of long, single rows of vegetables spaced widely apart. Much of the garden area is taken by the space between the rows. An intensive garden reduces wasted space to a minimum. The practice of intensive gardening is not just for those with limited garden space; rather, an intensive garden concentrates work efforts to create an ideal plant environment, giving better yields with less labor.

Though its benefits are many, the intensive garden may not be for everyone. Some people enjoy the sight of long, straight rows in their gardens. Others prefer machine cultivation over hand weeding; though there is often less weeding to do in intensive plantings. Because of fewer pathways and closely spaced plants, the weeding that must be done is usually done by hand or with hand tools. Still other gardeners like to get their gardens planted in a very short period of time and have harvests come in all at once. The intensive ideal is to have something growing in every part of the garden at all times during the growing season.

A good intensive garden requires early, thorough planning to make the best use of time and space in the garden.

Planting Areas Map



Spring Vegetable Planting Dates

Instructions: *To use this chart, write in the day of your average last spring frost on the line above the 00 column. From there, fill in the dates before that frost, to the left of the 00 column, each 10 days prior to the last. For example, if your average last frost date is April 15, write April 15 on the line above 00. Then write April 5 above the column marked 10 to the left of the 00 column, March 26 in the next column to the left, etc. To the right of the 00 column, write April 25, May 5, May 15, etc. Also make note of the approximate first frost date in the fall so you will know dates of the end of harvest for tender crops. This will vary for different areas. To plan for a fall garden, use the fall planning calendar in extension publication 426-334.*

Crop	60	50	40	30	20	10	00	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200
Asparagus	P	P	P	P	P	H	H	H	H	H	H	H															
Beans, bush							P	P	P	P	PH	PH	PH	PH	PH	H	H	H	H	H	H	H					
Beans, pole							P	P	P	P	P	P	P	H	H	H	H	H	H	H	H	H					
Beans, lima									P	P	P	P	P	P		H	H	H	H	H	H	H	H				
Beans, wax							P	P	P	P	P	P	PH	PH	PH	H	H	H	H	H	H	H					
Beets			P	P	P	P	P		H	H	H	H	H	H													
Broccoli*				P	P	P	P	P			H	H	H	H	H	H											
Brussels sprouts				P	P	P	P	P				H	H	H	H	H	H	H									
Cabbage*			P	P	P	P	P		H	H	H	H	H	H													
Chinese cabbage*				P	P						H	H	H	H													
Carrots			P	P	P	P			H	H	H	H	H	H													
Cauliflower				P	P	P			H	H	H	H															
Chard, Swiss			P	P	P	P	P	P	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
Collards	P	P	P	P	P				H	H	H	H	H														
Corn, sweet							P	P	P	P	P	P		H	H	H	H	H	H	H	H						
Cucumbers							P	P	P			H	H	H	H	H	H	H									
Eggplant*							P	P	P						H	H	H	H	H	H	H	H					
Leeks		P	P	P	P	P									H	H	H	H	H	H	H	H	H	H	H	H	H
Lettuce, bibb			P	P	P	P	P			H	H	H	H														
Lettuce, leaf			P	P	P	P	P	H	H	H	H	H															
Muskmelons							P	P	P	P					H	H	H	H	H	H							
Mustard		P	P	P	PH	H	H	H	H	H																	
Okra								P	P	P	P					H	H	H	H	H	H	H					
Onion (set)	P	P	P	P	PH	PH	PH	PH	PH	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
Peas, garden	P	P	P	P			H	H	H	H	H																
Peas, southern									P	P	P	P	P			H	H	H	H	H	H	H	H	H			
Peppers*							P	P	P					H	H	H	H	H	H	H	H	H	H				
Potatoes		P	P	P	P						H	H	H	H	H	H	H	H	H	H	H	H	H	H			
Potato, sweet							P	P	P	P									H	H	H	H					
Pumpkins							P	P	P	P				H	H	H	H	H	H	H	H	H	H	H			
Radish	P	P	PH	PH	PH	PH	H	H	H	H																	
Rutabaga			F	A	L	L		P	L	A	N	T		O	N	L	Y										
Spinach	P	P	P	P	H	H	H	H	H	H																	
Squash, summer							P	P	P	P	P	PH	H	H	H	H	H	H	H	H	H						
Squash, winter									P	P	P						H	H	H	H	H	H	H				
Tomatoes							P	P	P	P			H	H	H	H	H	H	H	H	H	H	H				
Turnips	P	P	P	P	H	H	H	H	H	H	H																
Watermelon								P	P	P						H	H	H	H	H	H						

Key: P = PLANT, H = HARVEST; PH = PLANT & HARVEST

** Transplants*

Vegetable Planting Guide

Crop	Planting Distance (ft or in)		Approximate Yield per 10' of row (lb)	Approximate of row feet to plant per person	Transplant Required	Or seed per 10' Row
	In Rows	*Between Rows*			*# of Plants*	*Amount of Seed*
Asparagus	18"	48-60"	3-4	15-20'	7-8 crowns	
Beans, bush	1-2"	24-30"	3-5	20-50'		1 oz.
Beans, pole	4-12"	36-48"	6-10	10-30'		1 oz.
Beans, lima	3-4"	24-36"	3-5	20-30'		1 oz.
Beans, wax	2"	24-36"	3-5	20-50'		1/8 oz.
Beets	2-3"	12-24"	8-10	10'		1/8 oz.
Broccoli	15-24"	24-36"	4-6	10-20'	5-8 or	1/10 oz.
Brussels Sprouts	18-24"	30-36"	3-4	10'	5-7 or	1/10 oz.
Cabbage	15-18"	30-36"	10-25	10-15'	5-8 or	1/10 oz.
Chinese Cabbage	12-24"	18-30"	20-30	10-15'	8-12 or	1/5 oz.
Carrots	1-2"	15-30"	7-10	10-20'		1/5 oz.
Cauliflower	14-24"	24-36"	8-10	10-15'	5-8 or	1/10 oz.
Chard, Swiss	6-12"	18-30"	8-12	5-10'		1/5 oz.
Collards	18-24"	24-36"	8-15	10-15'	5-7 or	1/10 oz.
Cucumbers	12-18"	48-72"	8-10	15-20'		1/10 oz.
Eggplant	18-24"	30-42"	10-12	3-6'	5-7 or	1/40 oz.
Endive	9-12"	18-30"	3-6	5-10'	5-10 or	1/40 oz.
Kale	10-18"	18-36"	4-8	10-15'	6-10 or	1/10 oz.
Kohlrabi	4-6"	12-36"	4-8	5-10'		1/10 oz.
Leeks	3-6"	12-30"	10-20	3-6'		1/10 oz.
Lettuce (Bibb)	6-10"	14-24"	4-8	15-20'		1/40 oz.
Lettuce (Leaf)	4-6"	12-18"	5-10	10-15'		1/40 oz.
Muskmelons	24-36"	60-90"	15-25	8-12'	3-5 or	1/8 oz.
Mustard	3-4"	18-30"	3-6	5-10'		1/10 oz.
Okra	12-18"	36-48"	5-10	10-15'	7-10 or	1/5 oz.
Onions (sets)	2-4"	12-24"	7-10	15-25'	30-60	1 lb.
Peas (English)	1-3"	12-30"	2-6	40-60'		1/2 oz.
Peppers	18-24"	30-36"	5-18	5-10'	5-7	N/A
Potatoes, Irish	10-21"	24-36"	10-20	75-100		1 lb.
Pumpkins	4-7'	6-8'	10-20	10'		1/20 oz.
Rutabaga	3-6"	15-30"	8-12	5-10'		1/8 oz.
Southern Peas	2-4"	24-30"	5-18	25-30'		1 oz.
Sweet Corn	9-12"	24-36"	7-10	40-60'		1/2 oz.
Spinach	3-6"	15-30"	4-6	30-40'		1/8 oz.
Squash, summer	24-36"	36-60"	20-80	5-10'		1/10 oz.
Squash, winter	3-7'	3-10'	10-80	10'		1/10 oz.
Sweet Potatoes	12-18"	36-48"	8-12	75-100'	7-10	N/A
Tomatoes	18-36"	36"	15-45	10-15'	3-7	N/A
Turnips	2-3"	12-24"	8-12	10'		1/8 oz.
Watermelons	6-8'	7-10'	8-40	10-15'	1-2 or	1/2 oz.

Vegetables Recommended for Virginia

Vegetable Variety	*Remarks*	*Resistant to the Following*
Asparagus		
Jersey Giant F1 (2-3 years)		fusarium crown and root rot, rust
Jersey Gem F1 (2-3 years)		
Beans, Bush		
Roma II (59)		mosaic, mildew mosaic
Dwarf Horticultural (65)	shell beans	
Derby (55)		NY 15 and common mosaic
Slenderette (55)	canning	mosaic
Kentucky Wonder 125 (60)	bush, with pole bean flavor	mosaic, mildew
Beans, Lima		
Bridgeton (65)		downy mildew
Jackson Wonder (65)		heat ad drought
Fordhook 169 (75)		downy mildew (races A, B, &D)
Beet		
Ruby Queen (65)		
Detroit Dark Red (60)		
Broccoli		
Packman (60)	for early crop	heat
Windsor (66)	for fall crop (and spring in mountains)	heat, downy mildew
Green Goliath (80)	bears over long period	
Brussels Sprouts		
Jade Cross (110)		
Cabbage		
Gourmet (70)		yellows
Stonehead (75)		yellows
Dynamo AAS (68)	longstanding	bacterial spot (2# dwarf heads)
Guardian (80)		black rot
Two Season (85)	Chinese cabbage	
Carrots		
*Gold King (72)	nearly coreless	
Danvers (72)		
Imperator (78)		
Cauliflower		
Candid Charm (65)	early spring or fall, self-blanching (wrap-per leaves protect head)	more heat tolerant
White Sails (55)		
Corn, Sweet		
Silver Princess (73)	early maturing	
Breeders Choice (68)	good husk protection	
Silver King (82)	earlier white, tough husk	birds
Argent (86) “Improved Silver Queen”		

Vegetables Recommended for Virginia

Vegetable Variety	*Remarks*	*Resistant to the Following*
Golden Queen (95)		
Cucumber		
Dasher II (60)	slicing	anthracnose, leaf spot, mosaic mildew, scab
Everslice (60)	slicing	same as Dasher II
Bush Whopper (68)	slicing	anthracnose, leaf spot, mildew
Sweet Slice (65)	slicing	mosaic, downy mildew
County Fair (55)	pickling and slicing	anthracnose, leaf spot, mosaic, scab, mildews, cucumber beetles/bacterial wilt
Eggplant		
Mission Bell (95)	oval shape	
Black Knight (110)		
LIttle Fingers	slender, oriental type	
Kale		
Vates Dwarf Blue (55)	spring or fall	
Dwarf Siberian (80)	overwinter	
Lettuce		
Salad Bowl (50)	leaf	
Summer Time (72)	head	heat tolerant
Mission (80) (trial)		
Dark Green Boston (70)	loose heading	heat tolerant
Parris Island Cos (75)	Romaine	heat tolerant
Buttercrunch (65)	Bibb-type	
Muskmelon		
Ambrosia (82)	fine flavor	powdery & downy mildew, fusarium wilt
Apollo		tolerates powdery mildew & fruit spot
*Short’n Sweet (85)	very dwarf vines	
Athena (87)	unique sweet taste, good keeper, large	fusarium wilt. powdery mildew tolerant
Mustard		
Tendergreen F1 (40)		
Southern Giant Curled (45)		
Okra		
Annie Oakley (50)	spineless	
Clemson Spineless (45)		
Onion		
White Portugal (100)	white	
Sweet Sandwich (105)	start seed in Jan; Vidalia-type brown	

** These varieties have been specifically bred for minimum space require-ments, as for urban or high density plantings. Your Extension agent can advise you of sources of supply for new varieties.*
***Numbers in parentheses indicate growing time, in days (unless otherwise stated) until beginning of harvest period*
Table information from VCE publication 426-480, Vegetables Recommended for Virginia, Charles R. O’Dell, Extension Specialist, Horticulture, and Diane Relf, Extension Specialist, Horticulture, Virginia Tech

Vegetables Recommended for Virginia

Vegetable Variety	Remarks	Resistant to the Following
Ebenezer (110)	brown, stores well after curing	
Mustang (110)		
Peas		
Knight (56) (early)	tolerates heat, stringless	fusarium wilt
Sugar Snow (70) (snap)	tolerant of downy mildew	fusarium wilt
Wando (68)	edible pod, flat, snow pea	
Green Arrow (70)		
Dwarf Gray Sugar (68)		fusarium wilt
Peas, Southern		
Queen Anne (56)		
Purple Hull Crowder (60-70)		
Pepper		
Lady Bell (110)	sweet	drought, mosaic
Boydton Bell	sweet, early compact plant, green bell turns bright red	bacterial leaf spot (Races 1, 2, &3)
Mucho-Nacho (100)		
Huge Jalapenos	hot	viruses
Red Cayenne (110)	hot	
Potato, Irish		
Steuben (eastern VA) (100)	red	
Superior (eastern VA) (100)	high flavor	mosaic, late blight
Pontiac (100)	stores well	
Yukon Gold (western VA) (112)	western VA on S or SE slopes	uses 1/2# gypsum per lb seed potatoes in furrow to Black Heart
Potato, Sweet		
Centennial (120)		
Jewel (120)		
Baker (120)		
Pumpkin		
Magic Lantern (100)	12-15” carving	powdery mildew
Merlin (100)	12-15” carving	powdery mildew
Howden Biggie	large, uniform to 5#	
We-Be-Little	small, uniform for preschoolers	
Jack-Be-Little	very small, ornamental	
Radish		
Cherry Belle (24)	round red	
Icicle (30)	long, white	
Spinach		
Melody (50)	tolerates heat	
Vienna (80)	seed late Sept for overwintering, for March/April harvests	

Vegetables Recommended for Virginia

Vegetable Variety	Remarks	Resistant to the Following
Squash, summer		
Butterbar (50)	yellow	
Superpik (50)	yellow, early, heavy, crown set	multiple viruses
Goldrush (50)	yellow zucchini	
Puma Fi (50)	green zucchini	multiple viruses
Squash, winter		
*Table Ace (80)	acorn	
*Butterbush (96)	butternut	
Waltham Butternut (96)	white	
Buttercup (100)	white	squash borer
Swiss Chard		
Rhubarb (50)	red	
Lucullus (45-55)	green	
Tomato		
Big Beef (AAS) (73)	excellent flavor, large, early	fusarium wilt, veric, leaf spots, TMV virus
Mountain Spring	concentrated set, good canning, excellent flavor	verticillium, fusarium wilt
Celebrity (70)		verticillium, fusarium wilt
Better Boy VFN (105)		
Sweet 100 (65)	cherry tomato	verticillium, fusarium wilt
Plum Dandy (Roma type)	plum, top flavor, yields	
Turnip		
Tokyo Cross (40)	white, fall	
Purple Top White Globe (55)	fall crop only	
All Top F1 (45)	for greens only	
Watermelon		
Petite Sweet (80)	8 lbs	
*Sugar Bush (75)	10 lbs	anthracnose, fusarium wilt
Starbrite (90)	25-30 lbs	
Chifton Seedless Yellow (86)	12 lbs, extra flavor	anthracnose, fusarium wilt
The Heart Series (Jack, Queen, & King of Hearts) (80)	10-18 lbs, seedless, crisp, extra sweet (Jack of Hearts is smallest)	anthracnose, fusarium wilt, hollow heart (OK)

** These varieties have been specifically bred for minimum space requirements, as for urban or high density plantings. Your Extension agent can advise you of sources of supply for new varieties.*
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Interrelationships of plants must be considered before planting, including nutrient needs, shade tolerance, above- and below-ground growth patterns, and preferred growing season. Using the techniques described below, anyone can develop a high-yielding intensive garden.

The Raised Bed

The raised bed or growing bed is the basic unit of an intensive garden. A system of beds allows the gardener to concentrate soil preparation in small areas, resulting in effective use of soil amendments and creating an ideal environment for vegetable growth. Some people like to use frames for their beds but it is not necessary and traditional cultures throughout the world do not.

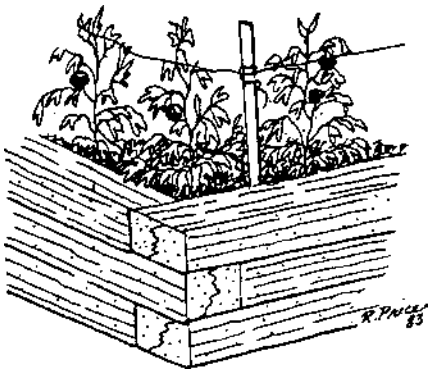
Beds are generally 3 to 4 feet wide and as long as desired. The gardener works from either side of the bed, reducing the incidence of compaction between plants caused by walking on the soil.

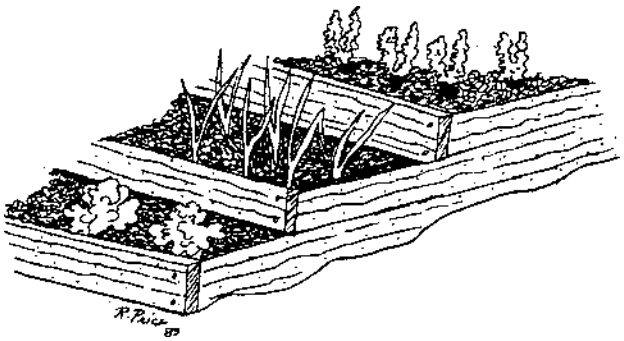
Soil preparation is the key to successful intensive gardening. To grow so close together, plants must have adequate nutrients and water. Providing extra synthetic fertilizers and irrigation will help, but there is no substitute for deep, fertile soil high in organic matter. Humus-rich soil will hold extra nutrients, and existing elements that are "locked up" in the soil are released by the actions of earthworms, microorganisms, and acids present in a life-filled soil, making them available for plant use.

If your soil is not deep, double-dig the beds for best results. Remove the top 12 inches of soil from the bed. Insert a spade or spading fork into the next 10 to 12 inches of soil, and wiggle the handle back and forth to break up compacted layers. Do this every 6 to 8 inches in the bed. Mix the removed topsoil with a generous amount of compost or manure, and return the mixture to the bed. It should be somewhat fluffy and may be raised slightly. To create a true raised bed, take topsoil from the neighboring pathways and mix it in as well.

This is a lot of work! Try it in one or two beds for some of your most valuable plants; if you like the results, you can proceed to other beds as you have time. One nice thing about raised bed gardening is that it breaks work into units. Instead of gazing desperately at a garden full of weeds, thinking you'll never have time to clean it up, you can look at each bed and say, "I can do that in half an hour today!" Other chores are accomplished with the same ease.

Raised Beds





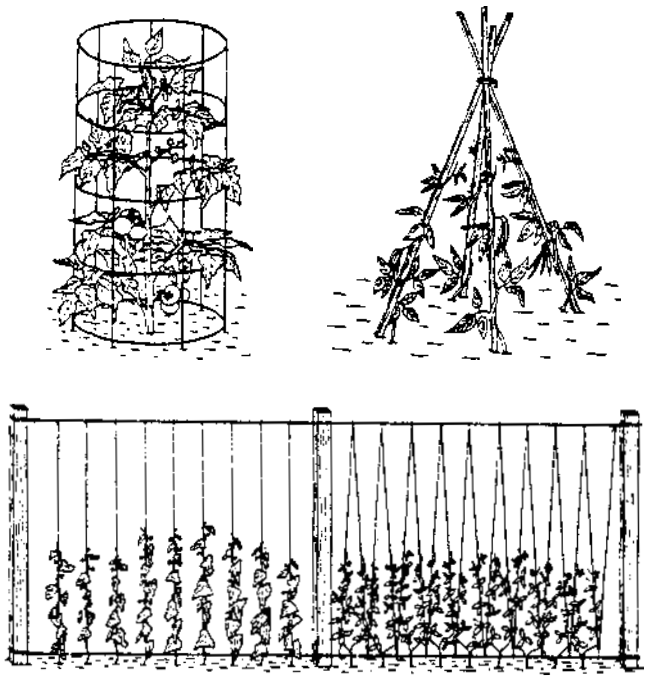
By their nature, raised beds are a form of wide-bed gardening, a technique by which seeds and transplants are planted in wide bands of several rows or broadcast in a wide strip. In general, the goal is to space plants at equal distances from each other on all sides, such that leaves will touch at maturity. This saves space, and the close plantings reduce moisture loss from surrounding soil.

Vertical Gardening

The use of trellises, nets, strings, cages, or poles to support growing plants constitutes vertical gardening. This technique is especially suited, but not limited, to gardeners with a small garden space. Vining and sprawling plants, such as cucumbers, tomatoes, melons, and pole beans, are obvious candidates for this type of gardening. Some plants entwine themselves onto the support, while others may need to be tied. Remember that a vertical planting will cast a shadow, so beware of shading sun-loving crops, or take advantage of the shade by planting shade-tolerant crops near the vertical ones. Plants grown vertically take up much less space on the ground, and though the yield per plant may be (but is not always) less, the yield per square foot of garden space is much greater. Because vertically growing plants are more exposed, they dry out faster and may need to be watered more frequently than if they were allowed to spread over

the ground. This fast drying is also an advantage to those plants susceptible to fungus diseases. A higher rate of fertilization may be needed, and soil should be deep and well-drained to allow roots to extend vertically rather than compete with others at a shallow level.

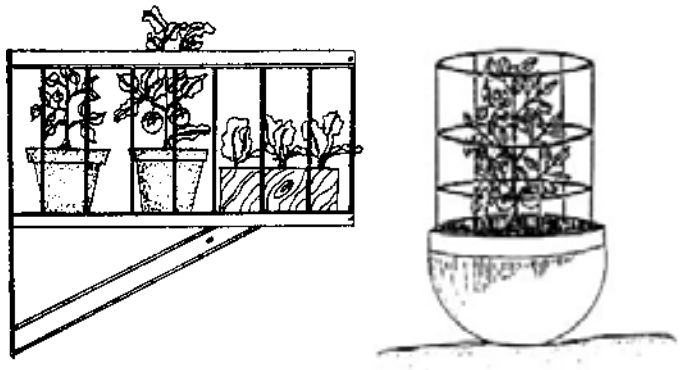
Vertical Gardens



Interplanting

Growing two or more types of vegetables in the same place at the same time is known as interplanting. Proper planning is essential to obtain high production and increased quality of the crops planted. This technique has been practiced for thousands of years and is gaining widespread support in this country. To successfully plan an interplanted garden, the following factors must be taken into account for each plant: length of the plant's growth period; its growth pattern (tall, short, below or above ground); possible negative effects on other plants (such as the allelopathic effects of sunflowers and Jerusalem artichokes on nearby plants); preferred season; and light, nutrient, and moisture requirements. Interplanting can be accomplished by alternating rows within a bed (plant a row of peppers next to a row of onions), by mixing plants within a row, or by distributing various species throughout the bed. For the beginner, alternating rows may be the easiest to manage at first.

Container Gardens



Long-season (slow to mature) and short-season (quick to mature) plants like carrots and radishes, respectively, can be planted at the same time. The radishes are harvested before they begin to crowd the carrots. An example of combining growth patterns is planting smaller plants close to larger plants, radishes at the base of beans or broccoli. Shade tolerant species, like lettuce, spinach, and celery, may be planted in the shadow of taller crops. Heavy feeders, such as cabbage family crops, should be interplanted with less gluttonous plants.

Interplanting may reduce insect and disease problems. Pests are usually fairly crop-specific; that is, they prefer vegetables of one type or family. Mixing families of plants helps to break up large expanses of the pest-preferred crop, helping to contain early pest damage within a small area, thus giving the gardener a little more time to deal with the problem. One disadvantage is that when it does come time to spray for pests, it's hard to be sure that all plants are protected.

Wide Row Planting

Individual plants are closely spaced in a raised bed or interplanted garden. An equidistant spacing pattern calls for plants to be the same distance from each other within the bed; that is, plant so that the center of one plant is the same distance from plants on all sides of it. In beds of more than two rows, this means that the rows should be staggered so that plants in every other row are between the plants in adjacent rows. The distance recommended for plants within the row is the distance from the center of one plant to the center of the next. This results in an efficient use of space and leaves less area to weed and mulch. The close spacing tends to create a nearly solid leaf canopy, acting as a living mulch, decreasing water loss, and keeping down weed problems. However, plants should not be crowded to the point that disease problems arise or competition causes stunting.

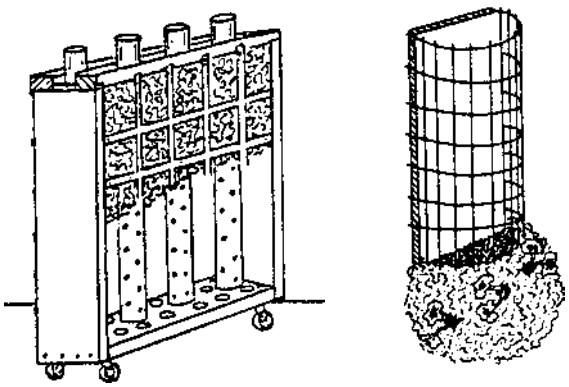
Succession and Relay Planting

Succession planting is an excellent way to make the most of an intensive garden. To obtain a succession of crops,

plant something new in spots vacated by spent plants. Planting corn after peas is a type of succession. This following of early crops with new ones provides for a gradual change from a spring garden to summer and fall gardens. Cool-season crops (broccoli, lettuce, pea) are followed by warm-season crops (bean, tomato, pepper), and where possible, these may be followed by more cool-season plants or even a winter cover crop. It is extremely important to avoid using members of the same family in succession cropping. For example, do not follow peas with beans. Insects and disease populations from the first crop will still be present, causing greater problems on the next.

Relaying is another common practice, consisting of overlapping plantings of one type of crop. The new planting is made before the old one is removed. For instance, sweet corn may be planted at two-week intervals for a continuous harvest. This requires some care, though; crops planted very early are likely to get a slower start because of low temperatures. In the case of sweet corn, it can be disastrous to have two varieties pollinating at the same time, as the quality of the kernels may be affected. Give early planted corn extra time to get started, for best results. Another way to achieve the same result is to plant, at once, various varieties of the same vegetable; for example, you can plant an early season, a mid-season, and a late-season corn at the same time and have a lengthy harvest.

Vertical Planters



Using Transplants

Starting seeds indoors for transplanting is an important aspect of intensive gardening. To get the most from the garden plot, a new crop should be ready to take the place of the crop being removed. Several weeks may be gained by having 6-inch transplants ready to go into vacated areas. Don't forget to recondition the soil for the new plants.

Planning an Intensive Garden

Begin planning your garden early. In January or February, when the cold days of winter seem never-ending, pull out last year's garden records and dig into the new seed catalogs. As with any garden, you must decide what crops you want to grow based on your own likes and dislikes, as well as how much of each you will need. An account of what cultivars were most successful or tasted best is helpful in making crop choices. Use the charts below and your own experience to determine what crops are likely combinations.

Good gardening practices, such as watering, fertilizing, crop rotation, composting, and sanitation, are especially important in an intensive garden. An intensive garden does require more-detailed planning, but the time saved in working the garden and the increased yields make it well worthwhile.

Study Questions

32. _____ is the key to successful intensive gardening.

33. An intensive garden method good for plants that are susceptible to fungus diseases would be:
a) raised beds; b) vertical gardens;
c) interplanting; d) succession or relay planting

34. Close plant spacing does NOT:
a) decrease soil water loss from evaporation;
b) keep down weeds; c) cause stunting due to competition; d) decrease disease

35. Planting corn after peas is an example of _____ planting.

Answers:
32 - good soil preparation; 33 - b; 34 - d; 35 - succession

Intensive Spacing Guide

Note: To determine spacing for interplanting, add the inches for the two crops to be planted together, and then divide the sum by 2. For example, if radishes are planted next to beans, add 2 inches + 4 inches = 6 inches; then divide 6 inches by 2 = 3 inches. The radishes should be planted 3 inches away from the beans.

Plant	*Inches*	*Plant*	*Inches*
Asparagus	15-18	Leeks	3-6
Beans, lima	4-6	Lettuce, head	10-12
Beans, pole	6-12	Lettuce, leaf	4-6

Intensive Spacing Guide

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Plant	*Inches*	*Plant*	*Inches*
Beans, bush	4-6	Melons	18-24
Beets	2-4	Mustard	6-9
Broccoli	12-18	Okra	12-18
Brussels sprouts	15-18	Onion	2-4
Cabbage	15-18	Pea, garden	2-4
Cabbage, Chinese	10-12	Pea, southern	3-4
Carrots	2-3	Peppers	12-15
Cauliflower	15-18	Potatoes	10-12
Cucumber	12-18	Pumpkins	24-36
Chard, Swiss	6-9	Radishes	2-3
Collards	12-15	Rutabaga	4-6
Corn, Sweet	15-18	Spinach	4-6
Endive	15-18	Squash, summer	18-24
Eggplant	18-24	Squash, winter	24-36
Kale	15-18	Tomatoes	18-24
Kohlrabi	6-9	Turnip	4-6

Container Gardening

If you don't have space for a vegetable garden or if your present site is too small, consider raising fresh, nutritious, homegrown vegetables in containers. A window sill, patio, balcony, or doorstep can provide sufficient space for a productive container garden. Problems with soil-borne diseases, nematodes, or poor soil can also be overcome by switching to container gardening.

Grow vegetables that take up little space, such as carrots, radishes and lettuce, or crops that bear fruits over a period of time, such as tomatoes and peppers, for best use of space and containers. Dwarf or miniature varieties often mature and bear fruit early, but most do not produce as well overall as standard varieties. With increasing interest in container gardening, plant breeders and seed companies are working on vegetables specifically bred for container culture. These varieties are not necessarily miniature or dwarf and may produce as well as standard types if properly maintained.

The amount of sunlight that your container garden spot receives may determine what crops can be grown. Generally, root crops and leaf crops can tolerate partial shade, but vegetables grown for their fruits generally need at least six hours of full, direct sunlight each day and perform better with eight to ten hours. Available light can be increased somewhat by providing reflective materials around the plants (e.g., aluminum foil, white-painted surfaces, marble chips).

Container gardening lends itself to attractive plantscaping. A dull patio area can be brightened by the addition of barrels of cherry tomatoes or a colorful herb mix. Planter boxes with trellises can be used to create a cool, shady place on an apartment balcony. Container gardening presents opportunities for many innovative ideas.

Containers

There are many possible containers for gardening. Clay, wood, plastic, and metal are some of the suitable materials. Containers for vegetable plants must (1) be big enough to support plants when they are fully grown, (2) hold soil without spilling, (3) have adequate drainage, and (4) never have held products that would be toxic to plants or people. Consider using barrels, cut-off milk and bleach jugs, window boxes, clothes baskets lined with plastic (with drainage holes punched in it), even pieces of drainage pipe or cement block. If you are building a planting box out of wood, you will find redwood and cedar to be the most rot-resistant, but bear in mind that cedar trees are much more plentiful than redwoods. Wood for use around plants should never be treated with creosote or pentachlorophenol (Penta) wood preservatives. Penta is a restricted-use chemical, not available to non-licensed individuals; however, you may still find it on some pretreated woods. Penta and creosote may be toxic to plants as well as harmful to people. The chemicals in pressure-treated wood should not leach out if handled properly (see "Treated wood in the vegetable garden" earlier in this chapter).

Some gardeners have built vertical planters out of wood lattice lined with black plastic, then filled with a light-weight medium; or out of welded wire, shaped into cylinders, lined with sphagnum moss, and filled with soil mix. Depending on the size of your vertical planter, 2-inch diameter perforated, plastic pipes may be needed inside to aid watering.

Whatever type of container you use, be sure that there are holes in the bottom for drainage so plant roots do not stand in water. Most plants need containers at least 6 to 8 inches deep for adequate root growth.

As long as the container meets the basic requirements

described above it can be used. The imaginative use of discarded items or construction of attractive patio planters is a very enjoyable aspect of container gardening. For ease of care, dollies or platforms with wheels or casters can be used to move the containers from place to place. This is especially useful for apartment or balcony gardening so that plants can be moved to get maximum use of available space and sunlight and to avoid destruction from particularly nasty weather.

Media

A fairly lightweight potting mix is needed for container vegetable gardening. Soil straight from the garden usually cannot be used in a container because it may contain too much clay. Clay soil consists of extremely small (microscopic) particles. In a container, the bad qualities of clay are exaggerated. It holds too much moisture when wet, resulting in too little air for the roots, and it pulls away from the sides of the pot when dry. It is also extremely heavy! Container medium must be porous to support plants, because roots require both air and water. Packaged potting mix available at local garden centers is relatively lightweight and, if of high quality, may make a good container medium. Soilless mixes, such as peatlite mix, are generally too light for container vegetable gardening, not offering enough support to plant roots. If the container is also lightweight, a strong wind can blow plants over, resulting in major damage. Also, soilless mixes are sterile and contain few nutrients, so when fertilizers are added, trace elements must be included. If you wish to use a sterile mix you may add garden soil for weight and better water holding capacity but remember it will introduce insects, weeds, and diseases. For a large container garden, the expense of prepackaged or soilless mixes may be quite high. Try mixing your own with one part peat moss; one part garden loam; one part clean, coarse (builder's) sand or perlite; and a slow-release fertilizer (14-14-14) according to container size. Lime may also be needed to bring the pH to around 6.5. In any case, a soil test is helpful in determining nutrient and pH needs, just as in a large garden.

Information for Growing Vegetables in Containers

*Vegetable**	*Light** Requirement*	*Minimum Container Size*	*Distance Between Plants in Containers*	*Days from Seed to Harvest*	*Comments*
Beans, bush	FS	2 gal.	2-3	45-60	Several plantings, 2-week intervals
Beets	FS/PS	1/2 gal.	2-3	50-60	Thin plants when 6-8" tall
Carrots	FS/PS	1 qt.	2-3	65-80	Several plantings, 2-week intervals
Cabbage	FS/PS	5 gal.	12-18	65-120	Requires fertile soil.
Chard, Swiss	FS/PS	1/2 gal.	4-6	30-40	Harvest leaves.
Cucumbers	FS	5 gal.	14-18	70-80	Require hot weather, support vines.
Eggplant	FS	5 gal.	1 plant per container	75-100	Requires fertile soil.
Kale	FS/PS	5 gal.	10-15	55-65	Harvest leaves
Lettuce, leaf	PS	1/2 gal.	4-6	30-35	Harvest leaves
Mustard greens	PS	1/2 gal.	4-5	35-40	Several plantings, 2-week intervals
Onions, green	FS/PS	1/2 gal.	2-3	70-100	Require moisture
Peppers, bell	FS	2 gal.	1 plant per container	110-120	Require hot weather
Squash, summer	FS	5 gal.	1 plant per container	50-60	Plant bush type only
Tomatoes	FS	5 gal.	1 plant per container	55-100	Stake/prune or cage
Tomatoes, cherry	FS	1 gal.	1 plant per container	55-100	Stake and prune
Turnips	FS/PS	3 gal.	2-3	30-60	Harvest leaves and roots

** Consult seed catalog for varieties adapted to container culture.*
*** FS = full sun; FS/PS = full sun, tolerates part shade; PS = partial shade.*

Planting

Plant container crops at the same time you would if you were planting a regular garden. Fill a clean container to within 1 to 2 inches of the top (depending on the size of the container) with the slightly damp soil mixture. Peat moss in the mix will absorb water and mix much more readily if wetted before putting the mix in the container. Sow the seeds or set transplants according to instructions on the package. Put a label with the name, variety, and date of planting on or in each container. After planting, gently soak the soil with water, being careful not to wash out or displace seeds. Thin seedlings to obtain proper spacing when the plants have two or three true leaves. If cages, stakes, or other supports are needed, provide them when the plants are very small to avoid root damage later.

Watering

Pay particular attention to watering container plants. Because the volume of soil is relatively small, containers can dry out very quickly, especially on a concrete patio in full sun. Watering daily or even twice daily may be necessary. Apply water until it runs out the drainage holes. On an upstairs balcony, this may mean neighbor problems, so make provisions for drainage of water. Large trays filled with coarse marble chips work nicely. However, the pot should never be in direct contact with the drainage water as it will be absorbed and keep the soil too wet. The soil should never be soggy or have water standing on top of it. When the weather is cool, container plants may be subject to root rots if maintained too wet. Clay pots and other porous containers allow additional evaporation from the sides of the pots, and watering must be done more often. Small pots also tend to dry out more quickly than larger ones. If the soil appears to be getting excessively dry (plants wilting every day is one sign), group the containers together so the foliage creates a canopy to help shade the soil and keep it cooler. On a hot patio, you might consider putting containers on pallets or other structures that will allow air movement beneath the pots and prevent direct contact with the cement. Check containers at least once a day and twice on hot, dry, or windy days. Feel the soil to determine whether or not it is damp. Mulching and windbreaks can help reduce water requirements for containers. If you are away a lot, consider an automatic drip emitter irrigation system.

Fertilizing

If you use a soil mix with fertilizer added, then your plants will have enough nutrients for eight to ten weeks. If plants are grown longer than this, add a water-soluble fertilizer at the recommended rate. Repeat every two to three weeks. An occasional dose of fish emulsion or compost will add trace elements to the soil. Do not add more than the recommended rate of any fertilizer, since this may cause fertilizer burn and kill the plants. Container plants do not have the buffer of large volumes of soil and humus to protect them from over-fertilizing or over-liming. Just because a little is good for the plants does not guarantee that a lot will be better.

General Care

Vegetables grown in containers can be attacked by the various types of insects and diseases that are common to any vegetable garden. Plants should be periodically inspected for the presence of foliage-feeding and fruit-feeding insects as well as the occurrence of diseases. Protect plants from very high heat caused by light reflected from pavement. Move them to a cool spot or shade them during the hottest part of the day. Plants should be moved to a sheltered location during severe rain, hail, or wind storms and for protection from early fall frosts.

Indoor Container Gardening With Vegetables

If you want fresh, homegrown vegetables over the winter, or if you don't have an outdoor space in which you can place containers, it is worth trying some indoor container gardening. Of course, you cannot have a full garden in the house, but a bright, sunny window can be the site for growing fresh food all year. Some small-fruited tomatoes and peppers, several types of lettuce, radishes, and many herbs are among the plants you can include in the indoor garden.

Follow directions given above for preparing pots and for watering, fertilizing, etc. However, note that plants will dry out less quickly indoors and will also grow more slowly, needing less fertilizer. To make watering easy it is wise to set the pots in large trays with an inch or two of decorative stones in them. Not only will this eliminate the need to move the plants in order to water them, which may discourage you from watering when you should, but it will also provide humidity, which is a major requirement, especially during winter when the house is warm and dry.

As mentioned before, a sunny, south-facing window is a must for indoor vegetable growing. Fruiting vegetables, such as tomatoes and peppers, will also need supplemental light, such as a combination warm-white/cool-white fluorescent light during winter months. Insufficient light will result in tall, spindly plants and failure to flower and set fruit.

Herbs are a First Choice for Many Indoor Gardeners

Many herbs are less demanding than vegetable plants, and cooks find it pleasant to be able to snip off a few sprigs of fresh parsley or chop up some chives from the windowsill herb garden. Chives grow like small onions with leaves about 6 inches tall. These plants prefer cool conditions with good light, but will grow quite well on a windowsill in the kitchen. One or two pots of chives will provide leaves for seasoning salads and soups. Plant seeds in a 6-inch pot. The plants should be about 1 inch apart over the entire surface area. It will require about 12 weeks from the time seeds are planted until the first leaves can be cut. For variety, try garlic or Chinese chives, which grow in a similar fashion, but have a mild garlic flavor.

Parsley seeds can be planted directly into 6-inch pots, or young, healthy plants can be transplanted from the garden. One vigorous plant per pot is enough. Standard parsley develops attractive, green, curly leaves about 6 or 8 inches tall. Italian, or flat-leaved, parsley has a slightly stronger flavor and is a favorite for pasta dishes. Leaves can be clipped about 10 to 12 weeks after planting the seeds.

Cilantro, or the leaves of the young coriander plant, can be grown in the windowsill garden. Cilantro is used in Oriental and Mexican dishes and must be used fresh. Grow cilantro as you would parsley. Thyme and other herbs will also grow well indoors if given the right conditions.

The small-fruited varieties of tomatoes, such as Tiny Tim, Small Fry, and Roma (a paste tomato), may be raised quite satisfactorily in the home. They will challenge your gardening ability and supply fruits that can be eaten whole, cooked, or served with salad. The Tiny Tim tomato grows to a height of about 12 to 15 inches. Small Fry, which is about 3 feet tall, and Roma will need more space and should be located on an enclosed porch or in a sun room. It may also be worth experimenting with varieties developed for hanging baskets. Some of the small-fruited peppers may be grown as indoor plants. Like tomatoes, they require warm, bright conditions to grow well indoors. Fruits will be ready to harvest from peppers and tomatoes about ten weeks after planting.

Whiteflies and aphids may present a problem on indoor tomato and pepper plants. Keep a close watch for these pests so they do not get a good start in your planting. Yellow sticky traps, either purchased or homemade, are effective in trapping whiteflies. Insecticidal soap or other pesticides approved for vegetable plants can be used to control aphids. Fortunately, you will be less likely to experience problems with outdoor pests, such as tomato hornworm, corn earworm (in peppers), and late blight, than you would if plants were outside.

For a quick-growing crop, try radishes. These must be grown very rapidly if they are to be crisp and succulent. Scatter radish seeds on moist soil in a 6-inch pot. Cover with 1/4-inch of soil, and place a piece of glass or plastic wrap over the pot to conserve moisture until the seeds germinate. Carrots are slower, but can be grown in the same way; use the small-rooted varieties, such as Little Finger, for best results indoors.

Experiment with various types of lettuce. Leaf lettuce and the miniature Tom Thumb butterhead are some to try. Space them according to package directions. Keep lettuce moist and in a very sunny spot.

If light is limited, an old standby for fresh taste and high food value is sprouted seeds. Almost any seeds can be sprouted: corn, barley, alfalfa, lentil, soybean, rye, pea, radish, mung bean, sunflower, etc. Use seeds that have not been treated with pesticides. Organic seeds are commonly available by mail order or at health food or specialty stores. Use any wide-mouthed container, such as a Mason or mayonnaise jar. Soak seeds overnight, drain, and place in the container. Cover with a double cheesecloth layer held with rubber bands or a sprouting lid. Set the container in a consistently warm spot, and rinse and drain seeds two or three times daily. In three to five days, sprouts will be 1 to 3 inches long and ready for harvesting.

Study Questions

36. Container gardens do NOT prevent/solve problems such as: a) small space; b) soil-borne diseases; c) poor soil; d) insect pests

37. Considerations that should be kept in mind when selecting a container for gardening include: a) size; b) capacity; c) drainage; d) all of the above

38. The best media for containers is: a) lightweight potting mix; b) garden soil; c) soilless media; d) sand

39. _____ containers allow for additional evaporation from the sides of the pots, and

therefore require more water.

40. Compared to outdoor container vegetable gardens, vegetables grown indoors:
a) dry out quicker; b) need less sun; c) grow more slowly; d) need more fertilizer

41. _____ and _____ are pest problems on indoor tomatoes and peppers.

Answers:
36 - d; 37 - d; 38 - a; 39 - clay; 40 - c; 41 - whiteflies, aphids

Vegetable Gardening in the Fall

Planning for a Fall Harvest

By planning and planting a fall vegetable garden it is possible to have fresh vegetables up to and even past the first frosts. At the time when retail vegetable prices are on the rise, you can be reaping large and varied harvests from your still-productive garden site.

Many varieties of vegetables can be planted in midsummer to late summer for fall harvests. Succession plantings of warm-season crops, such as corn and bean, can be harvested until the first killing frost. Cool-season crops, such as kale, turnip, mustard, broccoli, and cabbage, grow well during the cool fall days and withstand light frosts. Timely planting is the key to a successful fall garden. The table on p. 272 can be used to determine the appropriate date for planting.

To calculate the time to plant a particular vegetable for the latest harvest in your area, you need to know the average date of the first killing frost and the number of days to maturity for the variety grown. Choose earliest maturing varieties for late plantings. The formula below for determining the number of days to count back from the first frost will help determine when to start your fall garden.

Number of days from seeding or
transplanting outdoors to harvest
+
Number of days from seed to
transplant if you grow your own
+
Average harvest period
+
Fall Factor (about two weeks)
±
Frost Tender Factor (if applicable); 2 weeks
=
Days to count back from first frost date

The **Frost Tender Factor** is added only for those crops that are sensitive to frost (corn, bean, cucumber, tomato, squash), as these must mature two weeks before frost in order to produce a reasonable harvest. The **Fall Factor** takes into account the slower growth that results from cooler weather and shorter days in the fall and amounts to about two weeks. This time can be reduced two to five days by presprouting seeds. Almost any crop that isn't grown for transplants can benefit from presprouting. Sprout seeds indoors, allowing them to reach a length of up to an inch. Sprouted seeds may be planted deeper than normal to help prevent drying out, and they should be watered well until they break the soil surface. Care should be taken not to break off the sprouts when planting them.

When planting fall crops, prepare the soil by restoring nutrients removed by spring and summer crops. A light layer of compost or aged manure or a small application of a complete fertilizer will boost soil nutrients in preparation for another crop.

Dry soil may make working the soil difficult and inhibit seed germination during the midsummer period. Plant fall vegetables when the soil is moist after a rain, or water the area thoroughly the day before planting. Seeds may be planted in a shallow trench to conserve moisture. Cover the seeds about twice as deeply as you do in the spring. An old-time trick for germinating seeds in midsummer is to plant the seeds, water them in well, then place a board over the row until the sprouts just reach the soil surface; at that time, remove the board. An organic mulch on top will help keep the soil cool and moist but should not be deep enough to interfere with germination. Mulching between rows can also help keep soil cool and decrease soil drying. In severe hot weather, a light, open type of mulch, such as loose straw or pine boughs, may be placed over the seeded row. This must be removed as soon as seedlings are up so they receive full sun. Starting transplants in a shaded cold frame or in a cool indoor area is another possibility.

The fall garden gives you a chance to try again any spring failures you might have encountered. Some crops, in fact, grow well only in the fall in certain areas. Cauliflower and long-season Chinese cabbage are two examples of crops that do not produce well in mountain areas in spring because they cannot reach maturity before the cool weather ends. Protection of vegetable plants during

Fall Vegetable Planting Guide

Instructions: To use this chart, write in the day of your average first fall frost on the line above the 00 column. From there, fill in the dates before that frost, to the left of the 00 column, each 10 days prior to the last. For example, if your average first frost date is October 25, write October 25 on the line above 00. Then write October 15 above the column marked 10 to the left of the 00 column, October 5 in the next column to the left, etc. To the right of the 00 column, write November 4, 14, 24, etc. To plan for a spring garden, use the spring planning calendar in Extension publication 426-332.

Crop	160	150	140	130	120	110	100	90	80	70	60	50	40	30	20	10	00	10	20	30	40	50	60	70	80	90	100
Beans, bush				P	P	P	P			H	H	H	H	H	H	H	H										
Beans, wax				P	P	P	P			H	H	H	H	H	H	H	H										
Beets						P	P	P	P		H	H	H	H	H	H	H										
Broccoli					P	P						H	H	H	H	H	H	H									
Brussels Sprouts[1,2]				P	P	P						H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
Cabbage[1]					P	P	P					H	H	H	H	H	H	H									
Chinese Cabbage[1]						P	P						H	H	H	H	H	H	H								
Carrots							P	P	P	P		H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
Cauliflower								P	P						H	H	H	H	H								
Chard, Swiss							P	P	P	P				H	H	H	H	H	H	H	H						
Collards							P	P	P						H	H	H	H	H	H	H						
Cucumbers							P	P	P	P		H	H	H	H	H											
Endive									P	P							H	H	H	H	H						
Kale								P	P	P	P		H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
Kohlrabi										P	P	P	P			H	H	H	H	H	H	H					
Leeks		P	P	P	P	P									H	H	H	H	H	H	H	H	H	H	H	H	H
Lettuce, bibb										P	P	P			H	H	H	H	H								
Lettuce, leaf										P	P	P	P		H	H	H	H	H								
Mustard											P	P	P	P		H	H	H	H	H	H						
Onion seed[3]											P	P	P		*S*	*P*	*R*	*I*	*N*	*G*	*H*	*A*	*R*	*V*	*E*	*S*	*T*
Peas, garden[4]									P	P				H	H	H	H	H	H								
Potatoes, Irish[3]								P	P								H	H	H	H	H	H	H	H	H	H	H
Radish											P	P	PH	PH	H	H	H	H	H								
Rutabaga[3]									P	P	P						H	H	H	H	H	H	H	H	H	H	H
Spinach									P	P	P	P	H	H	H	H	H	H	H	H	H						
Turnips									P	P	P	PH	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
Crop	160	150	140	130	120	110	100	90	80	70	60	50	40	30	20	10	00	10	20	30	40	50	60	70	80	90	100

Key: P = PLANT, H = HARVEST; PH = PLANT & HARVEST

[1]TRANSPLANTS [2]USE SPECIAL TWO-SEASON VARIETIES ONLY [3]TIDEWATER & PIEDMONT ONLY [4]MOUNTAINS ONLY

cold periods may extend your season even further (see section "Season Extenders"). Although in the hot days of summer, the last thing you want to think about is planting more crops to take care of, look ahead to the fall garden which offers its own satisfaction through prolonged harvest of fresh vegetables, savings in food costs, and the knowledge that you're making full use of your gardening space and season.

Care of Fall Crops

The beginning of fall garden care comes when the weather and the radio station announce the first arrival of frost. Your main concern then should be to harvest all ripe, tender crops. Tomato, summer squash, melon, eggplant, cucumber, pepper, and okra are some of the crops that cannot withstand frost and should be picked immediately. Store the vegetables in a place where they can be held

until needed for eating or processing. If the frost warning is mild, predicting no lower than 30ºF, try covering tender plants in your garden that still hold an abundance of immature fruit. Baskets, burlap, boxes, blankets, row covers, or buckets help protect them from the frost. Warm days after the frost will still mature some of the fruit as long as the plants have this nightly frost protection. Much will depend on the garden's microclimate. If your spot is low and unsheltered, it is likely to be a frost pocket. Gardens sheltered from winds and on the upper side of a slope are less susceptible to early frost damage.

When using a cold frame to extend the harvest season, be sure to close the top on frosty nights to protect the plants from the cold. When the sun comes out the next morning and the air warms, open the cold frame again; leave it closed if daytime temperatures are low.

Cool-season crops, such as cabbage, cauliflower, broccoli, spinach, and Brussels sprouts, can withstand some cold. In fact, their flavor may be enhanced after a frost. They cannot stay in the garden all winter, but do not need to be picked immediately when frost comes. Kale, spinach, evergreen bunching onion, lettuce, parsley, parsnip, carrots, and salsify are some crops that may survive all winter in the garden. Mulch these overwintering vegetables with 8 inches of mulch to prevent heaving of the soil. Most of these vegetables can be dug or picked as needed throughout the winter or in early spring.

Care of Perennial Vegetables

Prepare perennial vegetables for winter around the time of first frost also. Most will benefit from a topdressing of manure or compost and a layer of mulch, which reduces damage from freezing and thawing of the soil. Dead leaf stalks of perennial vegetables, such as asparagus and rhubarb, should be cut to the ground after their tops are killed by frost, though some people prefer to leave asparagus stalks until late winter to hold snow over the

Cover Crops

Type	*Legume/ Non-Legume*	*Amount to Sow / 1000 ft² (oz.)*	*When to Sow*	*When to Turn Under*	*Effects*	*Notes*
Alfalfa	L	1/2	Spring Late summer	Fall Spring	Fixes 150-250 lbs. N/ac./yr; deep roots break up hard soil, trace elements to surface.	Loam, fairly fertile soil; needs warm temps for germination. In mountains sow by Aug 10. Drought tolerant. Inoculate.
Barley	N	4	Fall Spring	Spring Fall	Adds organic matter; improves soil aggregation.	Prefers medium-rich, loam soil. Lime if pH is low. Not as hardy as rye. Tolerates drought.
Buckwheat	N	2 1/2	Spring Summer	Summer Fall	Mellows soil; rich in potassium.	Must leave part of the garden in cover crop during season. Grows quickly. Not hardy.
Crimson Clover	L	1/3	Spring Fall	Fall Spring	Fixes 100-150 lbs. N/ac./yr.	Not reliably hardy. Sow before mid-Sept in piedmont and mountains. Not drought tolerant. Lime if pH is low. White clover is a bit hardier.
Fava Beans	L	Plant 8" apart	Early spring Late summer	Early summer Fall	Some types fix 70-100 lbs. N/ac./yr. in as little as 6 weeks. Use small seeded rather than large seeded table-types.	Will grow on many soil types. Medium N/ac. in drought tolerance. Likes cool growing weather. Good for mountain areas. If planted in early spring can grow late vegetables. Inoculate with same bacteria as hairy vetch.
Oats	N	4	Spring Fall	Summer Spring	Adds organic matter; improves soil aggregation.	Needs adequate manganese. Not hardy; tolerates low pH.
Rye, winter	N	3 1/2	Fall	Spring	Adds organic matter, improves soil aggregation.	Very hardy. Can plant until late October.
Vetch, hairy	L	2 1/2	Early fall	Spring	Fixes 80-100 lbs. N/ac/yr.	Inoculate; slow to establish. Fairly hardy. Till under before it seeds; can become a weed.
Wheat, winter	N	4	Fall	Spring	Adds organic matter, improves soil aggregation.	Prefers medium-rich loam soil. Lime if pH is low. Not as hardy as rye. Tolerates drought.

bed. Don't forget strawberry beds. Remove weeds that you let grow when you were too busy last summer. You can transplant some of the runner plants if you have had no disease problems and the plants are vigorous. Carefully dig a good-sized ball of soil with the roots. Mulch the bed well with a light material. Old raspberry canes can be cut back at this time or late in the winter (see Chapter 14: Fruits in the Home Garden).

When tender crops have been harvested and overwintering crops cared for, pull up all stakes and trellises in the garden except those stakes that are clearly marking the sites of overwintering plants. Clean remnants of plant materials and soil from stakes and trellises. Hose them down and allow to dry. Tie stakes in bundles, and stack them so that they won't get lost over the winter. If possible, roll up wire trellises and tie them securely. Store these items inside your attic, barn, or shed in an area where they are out of the way and where rodents and other animals cannot get to them to use as winter nests.

Preparing Soil for Winter

After caring for perennial vegetables, you are ready to prepare the soil for winter. Pull up all dead and unproductive plants, and place this residue on top of the soil to be tilled under or in the compost heap. Remove any diseased or insect infested plant material from the garden that may shelter overwintering stages of disease and insect pests. If this plant material is left in the garden, you are leaving an inoculum of diseases and insects that will begin to reproduce next spring and add to your pest problems.

Clean-up also gives you the chance to add compost to the garden. Compost contains highly nutritious, decomposed plant material and beneficial organisms and is an excellent soil builder. By spreading compost and other wastes on the soil and plowing them in, you are adding nutrients to the soil for next year's crop. The beneficial insects and microorganisms in the compost will help integrate the compost with the soil, and the added humus will improve soil structure.

Don't overlook other excellent sources of organic material available during the fall. Leaves are abundant, and neighbors will usually be glad to give their leaves away. Put some on the garden now, and store some for next year's mulch. Leaves will mat if put on in too thick a layer and will not decompose quickly. You can help leaves break down more easily by running a lawn mower back and forth over the pile. Put the shredded leaves directly onto the garden or compost them. Farms and stables often want to get rid of manure piles before winter.

If you wait until spring to add organic material to the garden, it may not have time to decompose and add its valuable nutrients to the soil by the time you are ready to plant, and you may have to delay planting to a later date. Hot (very fresh) manure can also burn young seedlings. By adding these materials in the fall, you give them plenty of time to decompose and blend into the soil before planting time. If you don't have enough organic material for the entire garden, try to cover those areas that you want especially rich for next summer's crop.

Check with your county recycling center for mulch or compost but keep in mind that it may contain weed seed or disease.

If possible, plow or rotary till in the fall. Turning under vegetation in the fall allows earlier planting in the spring and is especially good for heavy soils, since they are exposed to the freezing and thawing that takes place during the winter. This helps to improve soil structure. If you have a rainy fall or if the garden is steep and subject to erosion, you may decide you'd rather plant a cover crop for winter garden protection. A cover crop decreases erosion of the soil during the winter, adds organic material when it is incorporated in the spring, improves soil tilth and porosity, and adds valuable nutrients. Winter cover crops can be planted as early as August 1, but should not be planted any later than November 1. They should make some growth before hard frost. Where you have fall crops growing, you can sow cover crop seed between rows a month or less before expected harvest. This way, the cover crop gets a good start, but will not interfere with vegetable plant growth.

Prepare the soil for cover crop seed by tilling under plant wastes from the summer. Broadcast the seed, preferably before a rain, and rake it evenly into the soil. Spring planting may be delayed somewhat by the practice of cover cropping, since time must be allowed for the break down of the green manure. If you have crops that need to be planted very early, you may prefer to leave a section of the garden bare or with a stubble mulch.

When time or weather conditions prohibit either tilling or cover cropping, you may wish to let your garden lie under a mulch of compost, plant wastes, or leaves all winter

to be plowed or tilled under in the spring. However, if you want to plant early the next spring, a mulch of heavy materials, such as whole leaves, may keep the soil cold long enough to delay planting. In this case, chop them fine enough so they will break down over the winter. The addition of fertilizer high in nitrogen will also help break down organic matter more quickly.

Care of Garden Equipment

Clean-up of tools and equipment is another important practice related to the garden that should be completed in the fall. Proper clean-up of tools now will leave them in top shape and ready to use when spring comes. Clean, oil, and repair all hand tools. Repaint handles or identification marks that have faded over the summer. Sharpen all blades, and remove any rust. Power tools should be cleaned of all plant material and dirt. Replace worn spark plugs, oil all necessary parts, and sharpen blades. Store all tools in their proper place indoors, never outdoors where they will rust over the winter.

Unless you are lucky enough to live in a warm area where a cold frame will protect vegetables all winter, you will need to clean up the frame when all vegetables have been harvested. Remove all remaining plant material, and spread it on the cold frame soil. Spade the plant refuse and any other organic material into the soil in the cold frame as thoroughly as possible. Do not leave the top on the cold frame over the winter as the cold air or the weight of snow may crack or break the glass. Remove the top, wash it thoroughly, and store it on its side in a protected indoor area where it will not get broken.

Study Questions

42. When calculating time to plant a fall vegetable crop, the _____ factor is added only to crops sensitive to frost.

43. A crop that should be harvested with the threat of first frost is:
a) tomato; b) kale; c) spinach; d) carrots

44. Preparing perennial vegetables for winter does NOT include: a) topdressing; b) removing mulch; c) removing dead stalks; d) removing weeds

45. The best thing to do with infested plant material is to: a) leave it to overwinter on the soil surface; b) turn it 6” under the soil surface; c) mulch over it; d) burn it, where legal

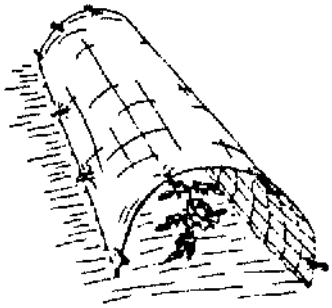
46. Using a/an _____ can decrease erosion, add organic matter, improve soil tilth, and add valuable nutrients.

Answers:
42 - frost tender; 43 - a; 44 - b; 45 - d; 46 - cover crop

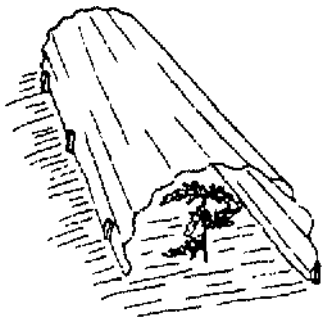
Season Extenders

To get the most out of a garden, you can extend the growing season by sheltering plants from cold weather both in early spring and during the fall. Very ambitious gardeners harvest greens and other cool-weather crops all winter by providing the right conditions. There are many ways to lengthen the growing season, and your choice depends on the amount of time and money you want to invest.

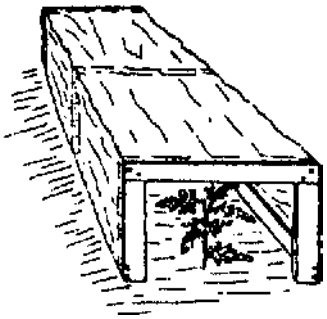
Tunnel Row Covers



Bend wire frame over plants and secure in soil. Drape clear plastic over wire and fasten with clothes-pins. Fold plastic back on hot days.



Bend fiberglass panel over the row and secure it with stakes.

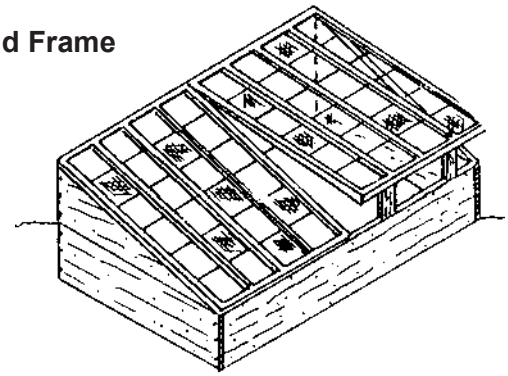


Build a wood frame and cover it with clear plastic.

Cold Frames and Hot Beds

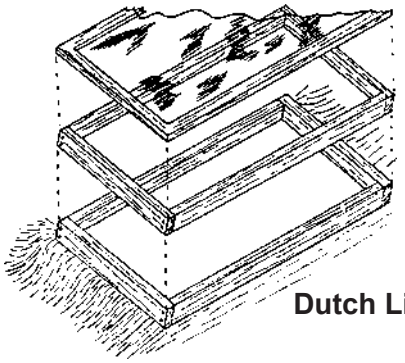
Cold frames, sun boxes, and hot beds are relatively inexpensive, simple structures providing a favorable environment for growing cool-weather crops in the very early spring, the fall, and even into the winter months. Some are elaborate and require a large investment, but are reasonable for those who are serious about having home grown fresh vegetables during the winter.

Cold Frame



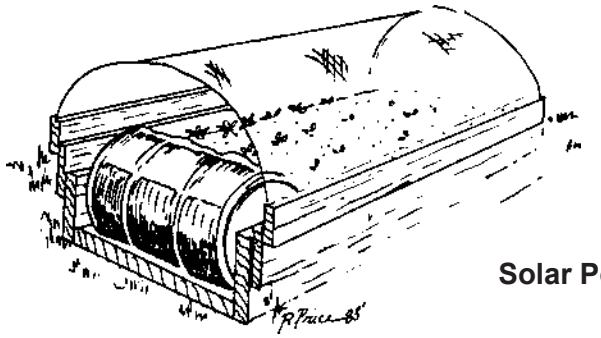
Cold frames and sun boxes have no outside energy requirements, relying on the sun for their source of heat. Hot beds are heated by soil-heating cables; steam-carrying pipes; or fresh, strawy manure buried beneath the rooting zones of the plants. Heat is collected by these frames when the sun's rays penetrate the sash, made of clear plastic, glass, or fiberglass. The ideal location for a cold frame is a southern or southeastern exposure with a slight slope to ensure good drainage and maximum solar absorption. A sheltered spot with a wall or hedge to the north will provide protection against winter winds. Sinking the frame into the ground somewhat will also provide protection, using the earth for insulation. To simplify use of the frame, consider a walkway to the front, adequate space behind the frame to remove the sash, and perhaps weights to make raising and lowering of glass sashes easier. Some gardeners make their cold frames lightweight enough to be moved from one section of the garden to another.

Another possibility is the Dutch light, which is a large, but portable, greenhouse-like structure that is moved around the garden.



Dutch Light

New designs in cold frames include passive solar energy storage. For example, barrels painted black and filled with water absorb heat during the day and release it at night. The solar pod, shown below, is one design that provides for this type of heat storage. Other new cold frames are built with a very high back and a steep glass slope and insulated very well; these may also include movable insulation that is folded up during the day and down at night or during extremely cold weather.



Solar Pod

In early spring, a cold frame is useful for hardening-off seedlings that were started indoors or in a greenhouse. This hardening-off period is important as seedlings can suffer serious setbacks if they are moved directly from the warmth and protection of the house to the garden. The cold frame provides a transition period for gradual adjustment to the outdoor weather. It is also possible to start cool-weather crops in the cold frame and either transplant them to the garden or grow them to maturity in the frame.

Spring and summer uses of the cold frame center around plant propagation. Young seedlings of hardy and half-hardy annuals can be started in a frame many weeks before they can be started in the open. The soil in a portion of the bed can be replaced with sand or peat moss or other medium suitable for rooting cuttings and for starting sweet potato slips. Fall is also a good time for sowing

some cool-weather crops in frames. If provided with adequate moisture and fertilization, most cool-season crops will continue to grow through early winter in the protected environment of the cold frame. Depending on the harshness of the winter and whether or not additional heating is used, your frame may continue to provide fresh greens, herbs, and root crops throughout the cold winter months.

Growing frames can be built from a variety of materials; wood and cement block are the most common. If you use wood, choose wood that will resist decay, such as a good grade of cypress or cedar. Wood frames are not difficult to build. Kits may also be purchased and easily assembled; some kits even contain automatic ventilation equipment.

There is no standard-sized cold frame. The dimensions of the frame will depend on amount of available space, desired crops, size of available window sash, and permanency of the structure. Do not make the structure too wide for weeding and harvesting; 3 to 4 feet is about as wide as is convenient to reach across. The sash of the frame should be sloped to the south to allow maximum exposure to the sun's rays.

Insulation may be necessary when a sudden cold snap is expected. A simple method is to throw burlap sacks filled with leaves over the sash on the frame at night to protect against freezing, or bales of straw or hay may be stacked against the frame. Ventilation is most critical in the late winter, early spring, and early fall on clear, sunny days when temperatures rise above 45ºF. The sash should be raised partially to prevent the buildup of extreme temperatures inside the frame. Lower or replace the sash each day early enough to conserve some heat for the evening. In summer, extreme heat and intensive sunlight can damage plants. This can be avoided by shading with lath or old bamboo window blinds. Watering should be done early so that plants dry before dark, to help reduce disease problems.

You may convert your cold frame to a hotbed. For a manure-heated bed: dig out to 2 feet deep (deeper to add gravel for increased drainage); add an 18-inch layer of strawy horse manure; and cover with 6 inches of good soil.

Cloches and Tunnels

The cloche (pronounced klosh) was originally a bell-shaped glass jar set over delicate plants to protect them from the elements. The definition has expanded, however, to include many types of portable structures that shelter plants from drying winds and cold air.

The idea is to provide a greenhouse-like atmosphere for seeds and small plants in order to get an early start on the season or to extend the fall garden as long as possible. Cloches are set out over individual plants or are made into tunnels for whole rows. They trap solar radiation and moisture evaporating from the soil and plants. The hotcap is a simple form. More elaborate ones are fiberglass tunnels, special plastic cloches, row covers with slits in them to allow some aeration, and panes of glass connected by specially designed hinges to form a tent. There is a variety of forms on the market now, some work, some don't, and some are easily constructed from materials around the home. Cloches are generally lightweight, portable, and reusable. It is preferable to have a design that can be closed completely at night to prevent frost damage and opened or completely removed during the day for good air circulation. Cloches should be anchored or heavy enough that they don't blow away.

Floating Row Covers

Row covers are a more recent development in extending vegetable production past frost dates. They are simple devices, pieces of material (in spunbonded polyesters) laid over transplants in the field. As the plants grow taller, the material is pushed up by the plants. Row covers retain heat and protect against frost so crops can be planted earlier in the spring and harvested later in the fall. They have demonstrated insect and vertebrate pest protection while also protecting plants from wind damage. Row covers generally provide 4 to 5 degrees of frost protection, so cool-season crops can be planted in air temperatures as low as 28ºF. Covers should be removed from the crops when air temperatures beneath the cover reach 80ºF. Problems associated with row covers are lower light transmission, as nonwoven materials allow 75 to 80% transmission of light to the crop. The fabric covers can be extended through two seasons if treated with care. If used in conjunction with other season-extending techniques, row covers can mean earlier harvests with greater yields in addition to extended harvests.

Hotcaps

Hotcaps function as miniature greenhouses, trapping the heat from solar radiation. An effective hotcap transmits sufficient solar energy for photosynthesis and for warming the air inside, but not so much that the plant is damaged by overheating. Hotcaps also must retain sufficient heat throughout the night to protect plants

against low temperature injury. Hotcap designs vary from wax paper cones to water-filled, plastic tepees (Wall-O-Water™). All hotcap designs are most effective during sunny weather and have little effect on temperature during cloudy periods. The greatest temperature differences occur during sunny days and clear nights.

However, hotcaps transmit less than 70% and 50% of the available solar energy and photosynthetic photon flux, respectively. The reduced light transmittance contributes to poor plant development inside hotcaps. Low light transmittance may lead to stunted and/or chlorotic plants. Using hotcaps, the mean time to first ripe fruit can be decreased by as much as five to ten days.

Although the Wall-O-Water™ is reusable, cleaning is time consuming, and the Wall-O-Water™ is quite expensive compared to other hotcaps. However, research has shown them to be more effective than other materials and can add several weeks growth to the early part of the season. Wax paper hotcaps are easy to install and disposable. Plastic jugs may be difficult to secure in the field and can only protect small plants; they do not retain sufficient heat to provide frost protection. They can delay fruit development unless ventilation is provided and can become hot enough to kill plants. For most gardens, simply cover plants overnight if there is a danger of frost. Be sure to remove the covering during the day.

Greenhouses

There is an almost overwhelming selection of greenhouses on the market, and plans for building even more types are available. If you intend to purchase or build a greenhouse, it is wise to investigate the alternatives thoroughly, preferably visiting as many operating home greenhouses as possible. List your needs and wants ahead of time, and determine how you will use your greenhouse. Then compare on that basis. Many companies will send free specifications and descriptions of the greenhouses they offer; look in gardening magazines for their ads. The conservation-minded person may find a solar greenhouse desirable. The initial cost is generally higher for a solar greenhouse than for the simpler, free-standing, noninsulated types, but for maximum use with lower heating bills, one can insulate north and side walls, provide liberal glass area for winter sun-catching, and make use of some type of solar radiation storage. When attached to a house, these greenhouses can be used for supplementary household heating, but there is a trade-off between heating the home and growing plants (especially heat-loving ones) in the greenhouse. Some researchers have concluded that a good compromise is to forget winter tomatoes and grow cool-weather crops during the winter in a solar attached greenhouse. In addition, they may retain excessive amounts of heat from late spring to fall and can make cooling the home more difficult.

Shading

It is not always easy to start seeds or young plants for fall crops in the hot and dry conditions of August. One simple way to provide shade in otherwise exposed conditions is to build a portable shade frame for placing over rows after seeds are sown or transplants are set out. This can be the same type of frame used for starting early seeds, but using lath strips or an old bamboo shade instead of plastic.

Study Questions

47. _____ are season extenders heated by soil-heating cables, steam carrying pipes, or fresh manure buried beneath the rooting zone.

48. The ideal location for a cold frame has a _____ exposure.

49. A portable, reusable, lightweight structure that provides a greenhouse-like atmosphere is a: a) hot bed; b) cold frame; c) cloche; d) floating row cover

50. All hotcap designs are most effective during _____ weather.

51. To maximize efficiency of a solar powered greenhouse, one can:
a) insulate the north and side walls; b) provide liberal glass for sun-catching; c) use some type of solar radiation storage; d) all of the above

Answers:
47 - Hot beds; 48 - south/southeast; 49 - c; 50 - sunny; 51 - d

Selected Vegetable Crops

Notes on the culture of individual plants have been developed to provide an easy-to-use guide, a summary of a wide range of information concerning the culture, nutritional value, harvest, and storage of specific food crops. These are not intended to be comprehensive references, and you may need to consult other materials to obtain very detailed information. In most cases, though, the culture notes should provide enough know-how to get a crop from seed to harvest.

The following key will help to explain the various terms found in the notes for selected vegetable crops.

Environmental Preferences

Light: Sunny - requires direct light at least 6 hours per day for any production; prefers 10 hours per day for maximum production.

Tolerates partial shade - will do well with fewer than 8 hours of sunshine per day, but probably needs at least 5 hours per day.

Prefers shade - more than 6 hours of direct sunlight may be harmful; prefers filtered light, probably needs at least 3 to 4 hours of light per day.

Soil: Well-drained - water does not stand or remain puddled for more than 24 hours after a hard rain.

Deep - at least 8 to 12 inches of topsoil or loose subsoil; no shallow hardpan.

Loam - soil composed roughly of equal portions of clay and sand, with a reasonable amount of humus; good garden soil.

Fertility: Results of soil tests can be used to indicate the basic fertility level of soils. Soil testing does not indicate nitrogen levels, due to variability. Soil is often described in terms of being rich, medium, or poor. These terms relate to the amount of organic matter in the soil and availability of nutrients to plants as well as to other soil conditions.

pH: Refers to the acidity or alkalinity of the soil.

7.0 is neutral. Below 7.0 is acidic. Above 7.0 is alkaline.

Temperature: Approximate ranges of daily mean temperature preferred for optimum growth.

Moisture: Amount of rainfall or supplemental watering needed for optimum growth; more for sandy soils, less for clay. Average - roughly 1 inch of water per week.

Moist - roughly 1 to 2 inches water per week at one time; soil should be well-drained.

Culture

Planting: Specific information needed to get plants started, such as when to seed, whether to start plants indoors, best transplant time, etc.

Spacing: Optimum distances between plants and rows for traditional gardens.

Hardiness: Very hardy perennial - can withstand winter extremes in most parts of Virginia with only slight protection.

Hardy perennial - can withstand winters with protection in colder areas.

Hardy annual - can withstand frosts in spring and fall; may need protection from heavy frosts or freezing.

Half-hardy annual - can withstand light frosts, but not heavy frosts or freezing.

Tender annual - frost will seriously damage plant tissue.

Very tender annual - frost will destroy tissues; needs warm weather for growth.

Fertilizer Needs: Refers to relative levels of nutrient uptake from the soil. This information can be used to group similar types of plants, so that fertilizers may be applied to sections of the garden according to plant needs. The terms high, medium, and low are used to describe the amount of fertilizer plants need and extract from the soil. In general, if a fertilizing regime includes initial broadcasting at a higher level of N and/or banding and one or more side dressings, the plants are “heavy feeders.” If only broadcasting and one side dressing is needed during the season, the plants are “medium feeders.” If only the initial broadcasting is needed, the plants are “light feeders.”

Cultural Practices

Gives general growing information. Includes proven methods for increasing production and/or decreasing pest problems. Unique growing suggestions may be included.

Common Problems

Gives a general list of the most common diseases, insects, and cultural problems of the crop in the state of Virginia. Identify the cause of the problem, review non-chemical and preventative control information, then if chemical control is needed, refer to current Pest Management Guides or contact your Extension agent for specific chemical control information.

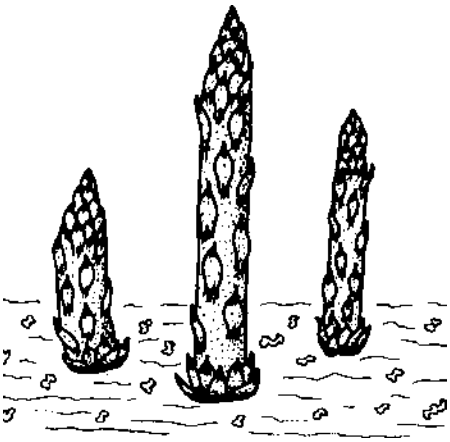
Harvesting and Storage

Approximate yields: These figures vary according to the variety, local environmental conditions, planting designs, and cultural practices.

Amount to Raise: These figures are average ranges per person. Specific amounts will vary depending on projected usage, whether fresh or processed, and according to personal preferences.

Preservation: Suggestions for preserving the crop over an extended period. See Extension publications on food preservation for specific methods.

Asparagus



Environmental Preferences

Light: Sunny.

Soil: Well-drained, deep sandy loam.

Fertility: Medium-rich.

pH: 6.0 to 6.7

Temperature: Cool (60 to 65ºF).

Moisture: Average; a flush of spears often follows a soaking rain.

Culture

Planting: 1-year crowns, early spring.

Spacing: 18 inches by 4 to 5 feet; or in wide beds of three rows with plants 18 inches apart in all directions.

Hardiness: Hardy perennial, should be mulched in autumn.

Fertilizer Needs: Medium-heavy feeder, high phosphorus and potassium and organic matter at planting; annual nitrogen in late winter or very early spring; may sidedress after harvest; benefits from early topdressing of compost.

Cultural Practices

Asparagus is a perennial vegetable that will live from 12 to 15 years or longer. It is one of the most valuable of the early vegetables and is well adapted to freezer storage. During the harvest period (traditionally spring, but see below for summer harvest instructions), the spears develop daily from underground crowns. Asparagus does well where winters are cool and the soil occasionally freezes at least a few inches deep; it is considered very hardy. Start asparagus either from seed or from 1- to 2-year-old crowns. For fastest results, crowns purchased from a reputable nursery are recommended. There is risk of disease from less reputable dealers' asparagus. Starting plants from seed requires an extra year before harvest. Seed may be started in peat pots; they are slow to germinate, so be patient. Seedlings may be transplanted in June. Crowns are usually shipped and set out in March or April.

Choose a site with good drainage and full sun. The tall ferns of asparagus may shade other plants, so plan accordingly. Prepare the bed as early as possible and enrich it with additions of manure, compost, bone or blood meal, leaf mold, wood ashes, or a combination of several of these. In heavy soils, double-digging is recommended. To double-dig, remove the top foot of soil from the planting area. Then, with a spading fork or spade, break up the subsoil by pushing the tool into the next 10 to 12 inches of soil and rocking it back and forth. Do this every 6 inches or so. Double-digging is ideal for the trench method of planting asparagus since a 12-inch-deep trench is usually dug anyway. The extra work of breaking up the subsoil will be well worth the effort, especially in heavy soil. The trench is dug 12 to 18 inches wide, with 4 to 5 feet between trenches. The same method may be used in wide-bed plantings, with plants staggered in three rows. Mix the topsoil that has been removed with organic matter, and spread about 2 inches of the mixture

in the bottom of the trench or bed. Set the plants 15 to 18 inches apart, mounding the soil slightly under each plant so that the crown is slightly above the roots. Crowns should be of a grayish-brown color, plump and healthy-looking. Remove any rotted roots before planting. Spread the roots out over the mound of soil and cover the crown with 2 to 3 inches of soil. Firm well. As the plants grow, continue to pull soil over the crowns (about 2 inches every two weeks) until the trench is filled. Water if rainfall is inadequate. According to recent research, total yield is unaffected by asparagus planting depth; however, deeper plantings produced larger spears, but fewer of them. Shallow plantings send up shoots earlier in spring, thus are subjected to possible frost damage.

Asparagus shoots or spears should not be harvested the first season after crowns are set. Research plots harvested one year after planting crowns had a 23% smaller cumulative yield after five years than did plots harvested for the first time two years after planting. Harvest lightly for three to four weeks the second year. The fleshy root system needs to develop and store food reserves to produce growth during subsequent seasons. Plants harvested too heavily too soon often become weak and spindly, and the crowns may never recover. An extra year is added to the above schedule for asparagus started from seed; i.e., do not harvest at all the first TWO seasons, and harvest lightly the third. When the asparagus plants are in their fourth season, they may be harvested for eight to ten weeks per year.

Weed the bed each spring before the first shoots come up, to avoid accidentally breaking off spears. During the production period, it is best to pull rather than hoe weeds if possible. Harvest spears daily during the eight- to ten-week harvest period. The 6- to 8-inch spears are best and should be snapped off just below the soil surface. If the asparagus is allowed to get much taller, the bases of the spears will be tough and will have to be cut; cutting too deeply can injure the crown buds which produce the next spears. Blanched asparagus is a gourmet item; to blanch (whiten) the spears, mound soil around them or otherwise exclude light from them so that chlorophyll is not formed in the stalks.

When harvest is over (after eight to ten weeks), allow the spears to grow. Asparagus has an attractive, fern-like foliage that makes a nice garden border. Some gardeners prefer to support the growing foliage with stakes and strings to keep them tidy. In high-wind areas, it is a good idea to plant the rows parallel to the prevailing winds so that the plants support each other to some extent.

There are several ways to extend the harvest period of your asparagus planting. One method is to plant at different depths (3 inches, 4 to 6 inches, 6 to 8 inches, 8 to 10 inches). The shallow plantings will come up first and can be harvested while the deeper plantings are just forming. This method will result in a slightly longer harvest, but may result in some plants being less vigorous than others. Another way to extend the harvest for a few weeks is to remove mulch from half of the asparagus bed. Leave the mulch on the other half. The exposed soil will warm up more quickly, and the crowns will sprout earlier. This process may be speeded up even further using black plastic, but be careful not to encourage growth too early, as heavy frost can make spears inedible. Remove mulch from the second bed when spears begin to appear.

A third technique for extending asparagus harvest has been the subject of university research and is recommended for home gardeners who have plenty of space. Plant double the amount of asparagus needed for your household. Harvest half of the plants as you normally would in spring and early summer, then allow the foliage to grow for the rest of the season. During the early harvest period, allow the ferns to grow in the other half of the asparagus planting. Then, cut the ferns in the second half in late July. This causes the crowns to send up new spears, which can be harvested till late in the season. If rainfall is short in summer, it will help to water this bed for good spear production. A light mulch will help keep the soil surface from becoming too hard for the shoots to break through easily. If using this method, harvest the spring bed only in spring and the fall bed only in fall! Otherwise, you risk weakening the crowns.

In all asparagus plantings, cut the foliage down to 2-inch stubs after frost when the foliage yellows, before the red berries fall off to reduce overcrowding caused by sprouting of self-seeding. A layer of 4 to 6 inches of mulch of compost, manure, leaves, or other material added at this time will help control weeds and add organic matter and nutrients.

Common Problems

Diseases: Rust - use resistant varieties; Fusarium root rot.

Insects: Asparagus beetles, cutworms.

Cultural: Weak, spindly plants and/or too few spears from too early or too heavy a harvest; crown rot or poor production from inadequately prepared,

heavy soil; moles/voles can be a problem.

Harvesting and Storage

Days to Maturity: Two to three years.

Harvest: Third year spears; snap off just under soil surface when 6 to 8 inches tall, before tips begin to separate; use or refrigerate immediately.

Approximate Yields: 3 to 4 pounds per year, per 10-foot row.

Amount to Raise: 6 pounds per person.

Storage: Process or refrigerate immediately in plastic bag.

Preservation: Can or freeze.

Beans

Environmental Preferences

Light: Sunny.

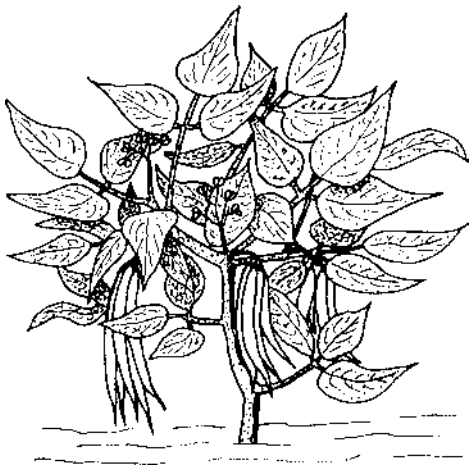
Soil: Well-drained, deep sandy loam.

Fertility: Medium-rich.

pH: 5.8 to 7.0

Temperature: Warm (65 to 80ºF), except fava beans - cool (60 to 65ºF).

Moisture: Average.



Culture

Planting: Seed after danger of frost is past; inoculating seeds with nitrogen-fixing bacteria may increase yields on land newly planted with beans.

Row Spacing: 2 inches by 24 to 30 inches for bush snap beans; 4 inches by 18 to 30 inches for bush lima beans; 4 to 8 inches by 24 to 36 inches for pole beans.

Hardiness: Tender annual, except fava - semi-hardy annual.

Fertilizer Needs: Beans are medium feeders. Since beans are legumes, they will fix nitrogen once a good root system is established; inoculation will speed the process. Excess nitrogen will delay flowering, so sidedress only after heavy bloom and setting of pods, using 3 tablespoons of 10-10-10 per 10-foot row.

Cultural Practices

Snap beans grown for the pod are the most common. Some beans, like lima, soybean, and dried beans, are grown primarily for the seed itself and not the pod. The bush snap bean is the most popular because of its early maturity and because trellising is not required. Varieties include standard green, yellow wax, and purple-pod types, giving the gardener a larger choice than is generally available in supermarkets. Though wax beans are yellow and waxy in appearance, their flavor is only subtly different from that of regular green snap beans. The purple pod beans are different in appearance while growing, but the pods turn green when cooked. Flat-pod green snap beans are somewhat different in flavor and texture than the round-pod ones and are preferred by many gardeners. These are available in both bush and pole types.

First plantings of bush beans should be made after danger of frost is past in the spring and soil is warmed since seed planted in cold soils germinate slowly and are susceptible to rotting. Also, seedling growth may be slow in cool temperatures. Plant several crops of bush beans two to three weeks apart until August 1 for a continuous harvest. Snap beans should be kept picked to keep plants producing heavily. Most will give two large flushes of beans and can then be removed from the garden.

Half-runner beans have a growth habit between that of bush and pole beans, producing beans usually used as snap beans. Though they have runners about 3 feet long, half-runners are generally grown like bush beans. Trellising, however, may increase production of these already heavy yielders.

Pole type beans come in many varieties, generally bearing over a longer period than bush types. They require trellising, and for that reason, generally yield more in the same amount of space. Pole beans are natural climbers, but require vertical supports as they will not interweave themselves through horizontal wires. A tripod

support can be made with three wooden poles or large branches that are lashed together at the top. Five to six seeds are planted in a circle 6 to 8 inches from each pole. Many types of homemade trellises work well as long as they provide the needed support. Trellises should be 6 to 8 feet tall and sturdy enough to withstand strong winds and rain. See illustrations under vertical gardening in this chapter for examples of bean trellises. Interplanting pole or half runner beans with corn is a historic practice more suitable to field corn than sweet corn. Scarlet runner beans are a type of pole bean that is quite ornamental as well as productive and delicious. The vines grow rapidly, producing beautiful red flowers and beans that may be harvested as snap beans when young and as green shell beans later. Beans are ready to pick in 75 to 85 days, and several pounds are produced per plant. The value of scarlet runner beans is mainly ornamental, though - the lush 6- to 15-foot vines can be used to cover arbors, trellises, or fences. An added feature is that the flowers are attractive to hummingbirds. According to some catalogs, the scarlet runner bean grows best in cooler weather than standard beans prefer; in some very hot areas, the vines may not keep producing all summer, as they will in cooler regions. Keeping maturing beans picked off will prolong the life of the vines.

Lima beans are available in bush or pole types. Bush limas mature about 10 to 15 days earlier than pole limas. Pole type limas have better yields and produce longer than the bush forms. Soil temperature must be 65ºF for five days in order for the beans to germinate well. Because the large seeds store considerable amounts of carbohydrates, limas are quite susceptible to soil fungi and bacteria. Pregermination or starting indoors helps if care is taken not to damage the shoots when planting and if soil remains moist for several days; seed treated with anti-fungal agents also have improved germination rates. Soil should be kept moist (but not soaking wet) until the seedlings come through the ground; do not allow a crust to form on the soil, since the seedlings will have trouble pushing through. Prevent crusting and conserve moisture by spreading 1/4 inch of sand, sawdust, or a light mulch over the seeded row. A cold, wet spell can cause lima flowers to drop, as can excessively hot and dry periods, reducing yields. Baby limas or butter beans are less susceptible to blossom drop problems.

Southern peas are not actually beans or peas, but are in a separate genus. However, they are grown and used in the same ways as beans. There are three commonly grown types, black-eyed pea, cream pea, and crowder pea. They are available in both pole and bush forms. Southern peas may be harvested in the green shell or in the dried pea stage.

The yard-long or asparagus bean is related to black-eyed peas and has similar flavor, but the entire pod may be eaten. On trellised vines, pods may be produced which are 1-1/2 to 2 feet long. Yard-long is stretching it a bit. Asparagus beans need warm temperatures and a long growing season to do well. Look for the seeds in novelty, gourmet, Oriental, or children's sections of seed catalogs.

Soybeans are increasing in popularity because of their high nutritional value and their versatility. Catalogs often list them as edible soybeans; all soybeans are actually edible, but those in garden catalogs have been bred to do well under ordinary garden conditions, requiring a shorter season and not growing as tall as the field types. There is also a difference in flavor and texture, as there is between sweet and field corn. Soybeans are less sensitive to frost and may have fewer problems with Mexican bean beetles than standard beans. Soybeans are quite delicious when harvested as green shell beans, but may also be allowed to dry on the vine. The pods of soybeans are quite difficult to open; cook for a few minutes to soften the pod before removing the beans.

Beans used primarily as **dried beans** are many and varied. Many can be used green, but dry well for easy storage. In the small garden, growing dry beans is somewhat impractical, since the amount of space required to raise a large enough quantity for storage is great. Many types of dry beans may be purchased in supermarkets at a very low cost, so it may be more worthwhile to grow higher-value crops in the limited space. However, if you have a very large garden area and a desire to sit on the front porch rocking away and shelling beans in the fall, they are worth a try. Some varieties available to gardeners are either rare or completely unavailable in the supermarket.

The horticultural bean, or October bean, is very widely grown in parts of the state and is called a "Virginia delicacy" by one Extension Specialist. The colorful pods and beans of the October bean make it an attractive addition to the garden and kitchen. The seeds of pinto beans look similar to those of the horticultural beans, but are smaller. They are widely used as brown beans and as refried beans in Mexican dishes. Black beans or black turtle beans make an unusual, delicious, black-colored soup. They are easy to grow if given plenty of air movement to prevent disease problems to which they

are susceptible. Kidney beans are the popular chili and baking bean, available in deep red or white types. Navy pea and Great Northern beans are used in soups and as baked beans. Cranberry and yellow-eyed beans are heirloom varieties again gaining favor among gardeners.

Mung beans, native to India, have enjoyed a rise in popularity because of their use as sprouts in Oriental dishes and salads, and gardeners now find seeds available for home production. Mung beans require 90 days of warm weather for good yield in the garden. Garbanzos, or chickpeas, produce plants that do not look like other bean plants. Garbanzos are actually neither true beans nor peas, but are leguminous. The fine-textured foliage is an attractive addition to the garden. Plant many seeds; the meaty seeds, like limas, tend to rot if they don't germinate and grow rapidly. Also, each pod contains only one or two seeds. The nutty-flavored beans of unusual texture are good roasted, in salads, and in soups. Garbanzos also require a warm climate and long (100 day) growing season.

Fava beans, or broad beans, are quite hardy. In cool climates, they are often substituted for limas. Favas are sown early in spring and are the exception to the rule, as they do not grow well in warm weather; in fact, if sown in April, they may be ready as green shell beans in late June or early July. It should be noted that some people of Mediterranean origin have a genetic trait that causes a strong allergic reaction to fava beans. People of this descent should sample the beans in small quantities at first.

Common Problems

Diseases: Mosaic - use resistant varieties; Anthracnose; Bacterial blight - use disease-free, western-grown seed; Seed rot - do not plant in cold, moist soils; Root and stem rots.

Insects: Mexican bean beetles and larvae, corn earworm, mites.

Cultural: Large plants with few beans (excess nitrogen); blossom drop (excessive heat, dry winds).

Harvesting and Storage

Days to Maturity: 50 to 60 days for snap beans; 85 to 110 days for pole limas; 65 to 75 days for bush limas; 60 to 110 days for pole beans.

Harvest: Snap beans - full size pods, small beans or larger beans as long as pods are still tender; pods break easily with a snap when ready; seed should not cause pods to bulge. Lima/Dry beans - Seeds will be full sized, and pods will be bright green. End of pod will be spongy. For dry beans (of all types) pods should remain on bush until dry and brown.

Approximate Yields: 3 to 5 pounds snap beans, 4 to 6 pounds lima beans per 10-foot row.

Amount to Raise: 8 pounds of snap beans, 5 to 10 pounds of lima beans per person.

Preservation: Freezing, canning, and drying.

Study Questions

52. A plant that tolerates partial shade needs at least _____ hours of sun per day.

53. A plant that will be seriously damaged by frost is: a) hardy; b) half-hardy; c) tender; d) weak

54. Approximate crop yields are influenced by: a) variety; b) local environmental conditions; c) planting designs; d) all of the above

55. Asparagus plants can be started from _____ or _____.

56. The maturation period for asparagus is: a) three weeks; b) two months; c) two to three years; d) ten years

57. _____ beans have a growth habit between bush and pole beans.

58. Beans that are often substituted for limas in cool climates are: a) fava beans; b) snap beans; c) soy beans; d) southern beans

Answers: 52 - 5; 53 - c; 54 - d; 55 - seed, crowns; 56 - c; 57 - half-runner; 58 - a

Broccoli

Environmental Preferences

Light: Sunny.

Soil: Well-drained, high organic matter.

Fertility: Rich.

pH: 6.0 to 6.7

Temperature: Cool (60 to 65ºF).

Moisture: Keep moist, not waterlogged.

Culture

Planting: Start seeds indoors for early spring transplants. Seed in beds or flats for fall transplants.

Row Spacing: 15 to 24 inches by 24 to 36 inches.

Hardiness: Hardy annual.

Fertilizer Needs: Heavy feeder. Use starter fertilizer when transplanting. Sidedress three weeks later and again as needed with 3 tablespoons of 33-0-0 per 10-foot row.

Cultural Practices

There are two types of broccoli, heading and sprouting. Most garden broccoli is of the heading type which is closely related to cauliflower and forms a large central head. When this is removed, side branches will form throughout the summer. Sprouting or Italian broccoli forms many florets or small heads but these do not produce a solid head.

Broccoli Raab or Turnip broccoli is not a true broccoli but, in fact, a type of turnip cultivated for its flower head. It can be sown in spring to raise as an annual or sown in fall to raise as a biennial. Harvest leaves in fall and flower shoots in spring before they open. Cook and eat like asparagus. Most turnips grown for their greens can also be treated this way.

To raise broccoli, buy transplants locally or produce your own and set out in spring or fall. Transplants for a fall setting can be produced along with cabbage and cauliflower transplants, taking about four weeks from seeding to setting into the garden. Sprouting broccolis are sown directly into the garden in spring. Follow packet directions. Broccoli has a relatively shallow, fibrous rooting system. Cultivate carefully or, even better, mulch.

The heads of broccoli are really flower buds. These must be harvested before the flowers open or show yellow. Mature heads measure 3 to 6 inches across. Lateral heads that develop later are smaller.

Common Problems

Diseases: Clubroot, yellows or fusarium wilt, blackleg, and black rot.

Insects: Cabbage root fly maggots, cutworms, cabbage worms, cabbage looper worms, flea beetles, aphids.

Cultural: Poor heading from buttoning; early flowers from interrupted growth due to chilling, extremely early planting, drying out, or high temperatures.

Harvesting and Storage

Days to Maturity: 60 to 100 days.

Harvest: Large terminal bud cluster before flowers open, then small side bud clusters as they develop over following weeks. Harvest with 6 to 8 inches of stalk. Harvest sprouting and other types according to packet instructions.

Approximate Yields: Six to ten bunches (about 4 to 6 pounds) per 10-foot row.

Amount to Raise: 8 pounds per person.

Storage: Very cold (32ºF), moist (95% relative humidity) conditions for 10 to 14 days.

Preservation: Freeze.

Brussels Sprouts

Environmental Preferences

Light: Sunny.

Soil: Well-drained loam, high organic matter.

Fertility: Rich.

pH: 5.5 to 6.5

Temperature: Cool (60 to 65ºF).

Moisture: Keep moist, not waterlogged.

Culture

Planting: Sow seeds early to mid-summer.

Spacing: 18 to 24 inches by 30 to 34 inches.

Hardiness: Hardy biennial.

Fertilizer Needs: Heavy feeder, sidedress 1 tablespoon ammonium nitrate per 20-foot row, two to four weeks after planting or when plants are 12 inches high.

Cultural Practices

Brussels sprouts are grown for harvest in the fall because cool weather during maturity is essential for good flavor and quality. Brussels sprouts are tall (sometimes 2 to 3 feet) erect biennials that are grown as annuals. The sprouts develop in the leaf axils and mature along the stalk. The lowest sprouts mature first and should be harvested when firm, 11/2 to 2 inches in diameter. Lowest leaves may be removed to permit sprouts to mature. New varieties are being developed for improved production. Plants started in spring and maturing sprouts in hot weather are more susceptible to aphid and other damage to the loose heads that form, giving very poor quality.

Common Problems

Diseases: Clubroot, yellows or fusarium wilt, black rot.

Insects: Cabbage root fly maggots, cutworms, cabbage worm, cabbage looper worms, flea beetles, aphids.

Cultural: Sprouts have loose tufts of leaves instead of firm heads because sprouts developed during hot weather; crop failures can also be due to water stress.

Harvesting and Storage

Days to Maturity: 80 to 100 days from seed.

Harvest: When sprouts are hard, compact, and deep green about 1 to 1-1/2 inches in diameter, after frosty weather for best flavor. Twist or snap off the stalk. The lowest sprouts mature first.

Approximate Yields: 4 to 6 pounds per 10-foot row.

Amount to Raise: Five plants per person.

Storage: Cold (32ºF), moist (95% relative humidity) conditions for three to five weeks.

Preservation: Freeze.

Cabbage

Environmental Preferences

Light: Sunny.

Soil: Well-drained.

Fertility: Rich.

pH: 5.5 to 6.5

Temperature: Cool (60 to 65ºF).

Moisture: Keep moist, not waterlogged.

Culture

Planting: Start seeds indoors for early spring transplants. Seed in beds or flats for fall transplants.

Spacing: 15 to 18 inches by 30 to 36 inches.

Hardiness: Hardy biennial.

Fertilizer Needs: Medium feeder, use starter fertilizer when transplanting, sidedress three weeks later using 3 tablespoons of 33-0-0 per 10-foot row.

Cultural Practices

Cabbage grows from March to December. It will withstand temperatures as low as 15 to 20ºF. Buy locally grown transplants or produce your own. Start them in growing structures four to six weeks before the first date when plants can be set out or sow a few seeds in the cold frame or garden every month in order to have cabbage plants thereafter. It takes about three weeks to get plants ready from seeding to set during the summer months. Plant only the earliest varieties after July 1. It is best not to plant cabbage family crops in the same spot year after year, since diseases and insect pests will build up. Rotate

crops within your garden.

Plant spacing affects head size. Close space (12 inches apart in the row) produces small heads. Average spacing is 15 to 18 inches apart in rows 30 inches apart. Varieties for sauerkraut are spaced wider. For a small family not interested in sauerkraut production, the dwarf varieties may be ideal. The heads are about the right size for a generous bowl of cole slaw, and the fast maturity makes these varieties excellent for succession planting. Cabbage is harvested when it reaches adequate size, depending on variety and growing conditions. Firm heads are preferred, especially for storage. Heads can be left on the plant in the garden for about two weeks in the summer, three to four weeks in the fall.

Common Problems

Diseases: Clubroot, yellows or fusarium wilt, blackleg or black rot.

Insects: Cabbage root fly maggots, cutworms, imported cabbage worms, cabbage looper worms, flea beetles, aphids.

Cultural: Head cracking or splitting from excessive water uptake and growth near maturity, root prune with spade or trowel or twist stalk to break some roots and reduce water uptake.

Harvesting and Storage

Days to Maturity: 70 to 100 days.

Harvest: When heads become firm, size will vary with variety, fertility, and spacing. If unable to harvest at maturity, bend over to break part of the roots to reduce head splitting.

Approximate Yields: 10 to 18 pounds per 10-foot row.

Amount to Raise: 15 pounds per person.

Storage: Very cold (32ºF), moist (95% relative humidity) conditions for four to five months.

Preservation: Can as sauerkraut, freeze for use in soups.

Cauliflower

Environmental Preferences

Light: Sunny.

Soil: Well-drained, high organic matter.

Fertility: Rich.

pH: 6.0 to 7.0

Temperature: Cool (60 to 65ºF).

Moisture: Keep moist, not waterlogged.

Culture

Planting: Plant after danger of frost is past. Start seeds indoors for early spring transplanting. Seed in beds or flats for fall transplanting.

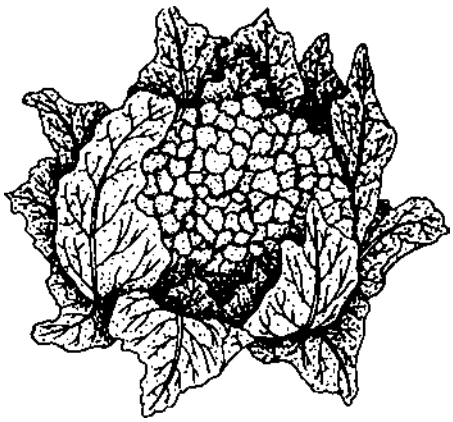
Spacing: 15 to 24 inches by 24 to 36 inches.

Hardiness: Hardy annual.

Fertilizer Needs: Heavy feeder, use starter fertilizer when transplanting, sidedress three weeks later and as needed using 3 tablespoons of 33-0-0 per 10-foot row.

Cultural Practices

Spring seedlings should be transplanted after danger of frost is past. Fall cauliflower should be sown in late June to July. Many gardeners experience buttoning of cauliflower heads in the spring. This is a failure of the cauliflower head to gain in size after it reaches about an inch or less in diameter. It is usually due to transplant stress or heat stress during the head formation period. Some cauliflower varieties require too long a growing season for fall production in colder areas of Virginia. Use short-season types or season extenders in these areas. Cauliflower should be blanched when the curd flower head is about 2 to 3 inches. Three to four large outer leaves are pulled up over the curd and fastened with a rubber band or are broken over the top of the cauliflower and tucked in on the other side of the curd. Normal blanching time is four to eight days and may take longer in the fall. Self-blanching types that have leaves that grow up over the head may eliminate the need for this practice. If weather is warm during the blanching period, tie the leaves loosely to allow air circulation. Harvest while the curd is still firm. If it gets too mature, it will become grainy or ricey.



Common Problems

Diseases: Club root, yellows or fusarium wilt, blackleg and black rot.

Insects: Cabbage root fly maggots, cut worms, cabbage worms, cabbage looper worms, flea beetles, aphids.

Cultural: Poor heading from interrupted growth due to chilling from extremely early planting, drying out, or high temperatures.

Harvesting and Storage

Days to Maturity: 55 to 120 days from transplanting.

Harvest: Cut before curd or head sections begin to separate. The curd should be compact, firm, white, and fairly smooth. Leave a ruff of leaves surrounding head when harvested to prolong keeping quality.

Approximate Yields: 8 to 12 pounds per 10-foot row.

Amount to Raise: 8 pounds per person.

Storage: Very cold (32ºF), moist (95% relative humidity) conditions for two to four weeks.

Preservation: Freeze, pickle.

Study Questions

59. The two types of broccoli are _____ and _____.

60. Early flowers of broccoli do NOT result from: a) late planting; b) interrupted growth from chilling; c) drying out; d) high temperatures

61. Brussels sprouts are: a) tender annuals; b) tender perennials; c) hardy biennials; d) hardy perennials

62. Brussels sprouts develop and mature along the stalk; the _____ sprouts mature first.

63. Cabbage can be grown from _____ to _____.

64. Water uptake in cabbage can be reduced if head cracking or splitting occurs by: a) root pruning; b) mulching; c) fertilizing; d) all of the above

65. _____ is failure of cauliflower heads to gain in size after reaching an inch or less in diameter.

66. Blanching should be done when the cauliflower curd flower head is:
a) 2-3"; b) 4-6"; c) 6-10"; d) 12"

Answers:
59 - heading, sprouting; 60 - a; 61 - c; 62 - lowest; 63 - March, December; 64 - a; 65 - buttoning; 66 - a

Corn, Sweet

Environmental Preferences

Light: Sunny.

Soil: Tender annual.

Fertility: Deep, well-drained loam.

pH: 6.0 to 7.0

Temperature: Warm (60 to 75ºF).

Moisture: Average.

Culture

Planting: Seed after danger of frost is past; extra sweet varieties should be planted when soil temperatures reach 65ºF.

Spacing: 9 to 12 inches by 4 to 36 inches minimum of three rows side by side (preferably four rows) to insure good pollination.

Hardiness:

Fertilizer Needs: Heavy feeder; preplant broadcast using 4 lbs of 5-10-10 per 100 sq. ft. row; sidedress when plants are 8 to 10 inches high and again when tassels begin to form using 1 lb. 5-10-10 per 100 sq. ft. row.

Cultural Practices

Sweet corn varieties differ significantly in time to maturity and in quality; yellow, white, bicolor, standard, and extra-sweet varieties are available. Most varieties planted are hybrids that have been bred for greater vigor and higher yields. A continuous harvest can be planned by planting early, mid-, and late-season varieties or by making successive plantings of the same variety every two weeks or when the last planting has three to four leaves (corn sown in early spring will take longer because of cool temperatures). Use only the earliest varieties for July plantings to assure a good fall crop. Fall-maturing sweet corn will almost always be the highest quality, since cool nights in September increase sugar content.

All sweet corn varieties are hybrids. Varieties are labeled as Super sweet (Sh), Sugary enhanced (Se), and Normal (Su). Super sweet must be isolated from all other sweet corn because cross-pollination between super sweet and normal or sugary enhanced hybrids will produce starchy, tough kernels. Isolation by a distance of 300 feet or 12 days difference in silking date is recommended. Sugary enhanced hybrids and normal sweet corn hybrids do not require isolation from each other.

Pollination is a very important consideration in planting sweet corn. Because corn is wind-pollinated, block plantings of at least three to four short rows will be pollinated more successfully than one or two long rows. Good pollination is essential for full kernel development.

Most of the various types of corn will cross pollinate readily. To maintain desirable characteristics and high quality, extra-sweet and standard sweet corn should be isolated from each other. A distance of 300 feet or planting so that maturity dates are 12 days apart is necessary to insure this isolation. Sweet corn plantings must be isolated from field corn and popcorn or ornamental corn as well. White and yellow types will also cross pollinate, but the results are not as drastic. Cross pollination of corn not only affects the quality of the next generation of plants if seed are saved, it can directly change the quality of the ears to be eaten as their characteristics are determined by both parent plants.

The extra- or super-sweet types convert sugar into starch more slowly than standard varieties. They are not necessarily sweeter than just-picked old favorites (though some cultivars are), but they will retain their sweetness after harvest longer than usual. Super-sweet varieties may be less creamy than standard varieties due to genetic differences. This characteristic decreases the quality of frozen or canned super-sweet corn, though newer cultivars of extra-sweets show improvement. Super-sweet varieties are intolerant of cold-damp soils so fungicide treated seed are important for good germination.

Early maturing varieties tend to be relatively small plants (called coon corn by old-timers because the ears are easy for raccoons to reach). These should be planted in rows 30 inches apart with plants 8 to 9 inches apart. For medium to large plant varieties, use 36-inch row spacing with plants 12 inches apart in the row. Be sure to plant a block of rows for good pollination and full ears.

It is not necessary to remove suckers or side shoots that form on sweet corn. With adequate fertility these suckers may increase yield, and removing them has been shown in some cases to actually decrease yield.

Mulching is a useful practice in corn growing because adequate moisture is required from pollination to harvest to guarantee that ears are well filled. Since main crops of corn usually ripen during Virginia's drier periods, it is especially critical to maintain soil water supplies; mulching reduces the need for supplemental watering and keeps the moisture content of the soil fairly constant. Most organic mulches are suitable; newspaper held down with a heavier material on top is an excellent moisture conserver in corn.

Normally, sweet corn is ready for harvest about 20 days after the first silks appear. Pick corn that is to be stored for a day or two in the cool temperatures of early morning to prevent the ears from building up an excess of field heat, which causes a more rapid conversion of sugars to starch.

Of course, the best time to pick is just before eating the corn; country cooks say to have the pot of water coming to a boil as you are picking the corn, husking it on the way from the garden to the house! This is an exaggeration, but with standard varieties, sugar conversion is rather rapid. Field heat can be removed from ears picked when temperatures are high by plunging the ears in cold water or putting them on ice for a short time. Then store in the refrigerator until ready to use. Extra-sweet varieties will also benefit from this treatment, but they retain sugars even at warmer temperatures.

Common Problems

Diseases: Stewart's wilt (bacterial disease spread by flea beetle); Smut (especially on white varieties); Stunt (transmitted by leafhoppers).

Insects: Corn earworm, European corn borer, flea beetles, Japanese beetles (eat silks), corn sap beetles (damage kernels after husk is loosened).

OTHER: Birds eating seed, raccoons eating mature ears of corn, gardener's impatience (picking too soon).

Cultural: Poor kernel development - failure to fill out to the tip; caused by dry weather during silking states, planting too close, poor fertility (especially potassium deficiency), too few rows in block resulting in poor pollination. Lodging (falling over) from too much nitrogen.

Harvesting and Storage

Days to Maturity: 63 to 100 days.

Harvest: When husk is still green, silks dry brown, kernels full size, and yellow or white color to the tip of the ear. Harvest at the milky stage. (Test by puncturing a kernel with thumbnail. If a clear liquid appears, the corn is immature. If the liquid is milky, the corn is ready. If no liquid appears, the corn is over-ripe.) Cover unharvested ears checked by this method with a paper bag to prevent insect or bird damage. Experienced gardeners can feel the outside of the husk and tell when the cob has filled out. Corn matures 17 to 24 days after first silk strands appear, more quickly in hot weather, slower in cool weather.

Approximate Yields: 5 to 10 pounds (roughly 10 to 20 ears) per 10-foot row.

Amount to Raise: 20 to 30 pounds or about 40 to 60 ears per person if canning or freezing.

Storage: Refrigerate immediately to prevent sugars from turning to starch; Cold (32ºF), moist (95% relative humidity) conditions, four to eight days, but standard varieties will become starchy after a few days.

Preservation: Frozen on or off the cob, canned.

Cucumbers

Environmental Preferences

Light: Sunny.

Soil: Well-drained; moderate-high organic matter.

Fertility: Rich.

pH: 5.5 to 7.0

Temperature: Hot (65 to 80ºF).

Moisture: Keep moist, not waterlogged; mulch helps maintain moisture.

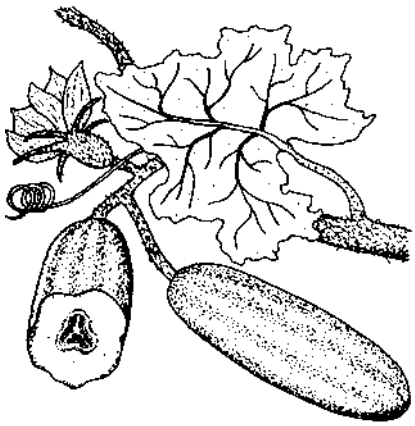
Culture

Planting: Seed after danger of frost has passed and soil has warmed, or use plants sown indoors in peat pots three to four weeks prior to planting time.

Spacing: 12 to 18 inches by 48 to 72 inches in rows, 24 to 36 inches by 48 to 72 inches in hills (two to three plants per hill); closer if trellised (see text).

Hardiness: Very tender annual.

Fertilizer Needs: Heavy feeder; sidedress one week after blossoming begins and again three weeks later using 3 tablespoons 33-0-0 per 10-foot row.



Cultural Practices

Varieties include both the slicer or fresh salad type and the pickle type (which can also be used fresh); vined, dwarf-vined, and bush varieties; all female or all-female seedless (no pollination required); burpless; and various

mixtures of these characteristics. Disease resistance is available in many varieties.

Varieties of cucumber are being released that are advertised as all-female, or gynoecious types. On a normal cucumber plant, the first 10 to 20 flowers are male, and for every female flower, which will produce the fruit, 10 to 20 male flowers are produced. This indicated to plant breeders that production could be increased greatly if many more female flowers were produced. Some of the new varieties produce plants that have only female flowers, while others have a greater proportion of female to male flowers. These plants tend to bear fruit earlier, with a more concentrated set and better yields overall. These require a pollen source, so seed from a different variety are included in the seed packet.

Parthenocarpic cucumbers are all female and are seedless because the fruit is produced without being pollinated. If this type of cuke is planted near others, pollination will occur and seeds will form. This type is often grown in greenhouses.

Burpless cucumbers are long and slender with a tender skin. Through plant breeding, the bitterness associated with the burp has been removed. Other causes of bitterness in cucumbers include temperature variation of more than 20ºF and storage of cucumbers near other ripening vegetables.

Most varieties of cucumber vines spread from row to row. Training on a trellis or fence along the edge of the garden will reduce space needed and also lift the fruit off the soil. If trellised, plant four to five seeds per foot in rows spaced 30 inches apart. Untrellised rows may need to be spaced 4 to 6 feet apart. When plants are 4 to 5 inches high, thin so they are 9 to 12 inches apart. It may be better to plant a second crop around July 1, which will have fewer disease problems, than to try to continue harvesting an early planting until frost.

There are many excellent bush varieties of cucumber now available. Most of these produce well for the limited amount of space and may be a desirable alternative in a small garden if trellising is not possible.

In order for the flower to develop into a fruit, pollen must be carried by bees from male flowers, on the same plant or on different plants, to the female flower, the one with the tiny swollen 'pickle' beneath the yellow petals. Poor cucumber set is common during rainy weather when bees are inactive. If pesticides are necessary, use them after sundown to avoid harming the bee population.

Plants respond to mulching with soil-warming, black plastic in the spring for earlier harvest. Organic materials are useful in the summer to retain moisture and keep the fruit clean in non-trellised plantings.

Working in the vines when leaves are wet may spread diseases. Wait until after morning dew or rain evaporates. Trellising gets leaves up off the ground so that they dry off faster. Also, if the vines are trellised, the gardener is less likely to step on the vines and there is no need to move the vines for weeding or other purposes, reducing the risk of damage. If vines are not trellised, avoid destroying blossoms or kinking vines by gently rolling the vines away rather than lifting them when searching for harvestable fruit.

There has been a significant increase in disease resistance in cucumber varieties in recent years. Try to select resistant varieties when possible.

Common Problems

Diseases: Bacterial wilt (spread by cucumber beetles), mosaic, leaf spot, anthracnose, scab, powdery and downy mildews.

Insects: Cucumber beetles, aphids, flea beetles, pickleworms.

Cultural: Misshapen cucumbers (low fertility or poor pollination), failure to set fruit (too few bees for adequate pollination, no pollinating plants for gynoecious hybrids, changes in temperature, too early and all flowers are still male).

Harvesting and Storage

Days to Maturity: 50 to 70 days.

Harvest: From when cucumbers are about 2 inches long up to any size before they begin to turn yellow, about 15 days. Remove by turning cucumbers parallel to the vine and giving a quick snap. This prevents vine damage and results in a clean break. Cutting may be easier in some cases.

Approximate Yields: 8 to 10 pounds per 10-foot row.

Amount to Raise: 10 to 15 pounds per person.

Storage: Medium cool (45 to 50ºF) and moist (95% relative humidity) conditions.

Preservation: Pickled.

Eggplant

Environmental Preferences

Light: Sunny.

Soil: Well-drained, high organic matter.

Fertility: Rich.

pH: 6.0 to 7.0

Temperature: Warm (70 to 85ºF).

Moisture: Average.

Culture

Planting: Transplant after danger of frost, when soil is thoroughly warm.

Spacing: 18 to 24 inches by 30 to 36 inches.

Hardiness: Very tender annual.

Fertilizer Needs: Heavy feeder; use 3 tablespoons of ammonium nitrate 33-0-0 per 10-foot row. Before planting broadcast 3 lbs. 10-10-10 per 100 square feet. Use a starter solution on transplants. Sidedress 1 lb. 10-10-10 per 100 square feet 3 to 4 weeks after planting and repeat in one month if needed. When fruits are swelling, apply a high potash tomato fertilizer.

Cultural Practices

The standard eggplant produces egg-shaped, glossy, purple-black fruit, 6 to 9 inches long. The long, slender, Japanese eggplant has a thinner skin and more delicate flavor. Both perform well in containers.

Warm to hot weather throughout the season is necessary for good production. Seeds germinate quickly at 70 to 90ºF; and plants should be grown for eight to ten weeks before setting them out. Cold temperatures will stop plant and root growth, reducing plant vigor and yields. Use hot caps, cloches, or Wall-O-Water™ to protect plants from cold conditions.

Though eggplants do well in hot weather; they must have well-drained soil and do not thrive in very humid areas. When plants are about 6 inches high, nip back the growing tip to encourage branching. Pick fruits when immature, about 2/3 maximum size. Mature fruit should not be left on the plant as this will reduce overall productivity.

Because of the eggplant's susceptibility to verticillium wilt, rotate plantings with other crops on the same garden soil.

Common Problems

Diseases: Verticillium wilt.

Insects: Flea beetles, aphids, lace bugs, Colorado potato beetle, red spider mites, whitefly.

Harvesting and Storage

Days to Maturity: 100 to 150 days from seed; 70 to 85 days from transplants.

Harvest: Fruit should be large, shiny, and uniformly deep purple in color. When the side of the fruit is pressed slightly with the thumbnail and an indentation remains, the fruit is ripe. Long, slender, Japanese eggplant may be ready to harvest from finger or hotdog size. When fruit is dull in color and has brown seeds, it is too ripe and should be discarded. Cut fruit from plant to avoid damage.

Approximate Yields: 20 pounds per 10-foot row.

Amount to Raise: 12 pounds per person.

Storage: Cool (45 to 50ºF), moist (90% relative humidity) conditions for one week.

Preservation: Freeze, pickle.

Globe Artichoke

Environmental Preferences

Light: Sunny to semi-shade.

Soil: Well-drained, deep, moisture-holding.

Fertility: Rich.

pH: 6.0 - 6.8

Temperature: Cool to warm (45 to 75ºF); frost free areas.

Moisture: Moist, but without standing water.

Culture

Planting: grown as annuals, in early spring.

Spacing: 3 feet apart in rows with 4 feet between rows.

Hardiness: Tender perennial.

Fertilizer Needs: Heavy feeder, generous amounts of organic matter, high N and Ca in spring, plus later sidedressings of N.

Cultural Practices

While ideal conditions for growing artichokes are mild winters and cool summers with high humidity, those with 100 days of good growing weather can attempt their culture. 'Imperial Star' can be grown from seed in the mountains of western Virginia, but they need to be planted in the spring and established in the field by early May for summer harvest. In warmer areas, fall establishment is recommended for spring harvest. One variety, 'Grand Buerre,' has consistently produced edible buds the first year in Pennsylvania trials and has also been proven in Virginia. Therefore, this variety may even be grown as a tender annual by planting seed indoors in peat pots about the same time early vegetables are sown, transplanting outdoors after danger of frost (or two weeks earlier with protection). 'Grand Buerre' and other varieties may also be grown from offshoots (suckers), purchased from a nursery, or from roots that have been overwintered. Roots are set 6 to 8 inches deep.

The globe artichoke plant is a large, spreading member of the thistle family, requiring a rich soil and lots of space. If roots are to be overwintered, the plants should be placed in an area which will not be disturbed by tilling. Large amounts of organic matter should be added to lighten heavy soils and increase moisture-holding capabilities of sandy soils. Generous fertilizing at planting time and monthly sidedressings will keep the plants growing rapidly, which is desirable for producing tender buds. In areas where temperatures may be high when the plant is ready to flower, supplemental feeding should be withheld until 90 to 100 days before daytime high temperatures will be back in the mid-70s. Buds produced in hot weather may be tough and fibrous or woody. Mulch during hot weather and remove mulch during cool, moist periods. Artichokes should be watered well in dry weather, but they will not tolerate standing water or soils with poor drainage, since the crown tends to rot under such conditions.

Suckers or offshoots may be taken from growing plants, preferably early in the season. Select shoots from plants which produce well. Carefully dig around the base of the shoot. If it has a piece of root at least 2-1/2 to 3 inches long and an inch thick, gently cut it from the parent plant, saving as many rootlets as possible. Trim off all but a few leaves and transplant as soon as possible; water frequently and shade if necessary.

Overwintering may be the most difficult part of globe artichoke culture. Artichoke leaves and buds will blacken at about 28ºF. These should be removed from the plant, but approximately 10 to 12 inches of the stem should be left above ground to prevent soils from getting into the crown. In mild climates with light soil, hill soil around the stems or mulch heavily. In areas where the ground freezes hard, leave the stem on the plant as above. Mulch with a dry material, such as straw, leaves, or sifted ashes, about a foot deep, and cover with a box or basket. Remove this covering as soon as danger of hard ground freeze has passed in the spring.

Globe artichoke roots may also be overwintered in a cold frame, or dug, brushed clean, and kept in a fairly dry place from 33 to 40ºF. They should be loosely packed in burlap bags or in dry straw when overwintered in this manner. Success has also been reported with planting each root in a large pot, withholding fertilizer, and watering only very

lightly until time to plant in the garden.

Common Problems

Diseases: Crown rot, black tip, curly dwarf, botrytis.

Insects: AND PESTS: Artichoke aphids, plume moth (rid area of thistles, which are the alternate hosts), slugs, snails, and caterpillars.

Cultural: Frost free areas having cool, foggy summers. Hot weather produces tough bud scales. Cold temperatures may cause blistering of the outer skin which is all right to eat, but buds blackened by frost should not be eaten. Plants lose vigor after four to five years. Divide crown.

Harvesting and Storage

Days to Maturity: 100 days; two seasons for many cultivars.

Harvest: When buds have attained maximum growth but before they begin to open. Cut 3 inches below the base of the bud. Cool rapidly to 40ºF.

Approximate Yields: 3 to 20 buds per plant, depending on climate and age of plant.

Amount to Raise: Two to six plants per person, depending on climate and personal taste.

Storage: Store fresh artichokes unwashed and dry in plastic bag; can freeze whole buds up to 2 weeks at 32ºF, or can hearts.

Study Questions

67. To ensure good pollination, corn should be planted: a) in one long row; b) from transplants; c) in four rows side by side; d) in February

68. _____ is a useful practice in corn production to maintain soil water during pollination.

69. Parthenocarpic cucumber fruit are seedless because: a) they come from the male flowers; b) they are not pollinated; c) they are cross pollinated; d) they are a different genus

70. Failure of cucumber plants to set fruit can occur because: a) there are too few bees; b) the temperature changed; c) it is too early and the flowers are all male; d) all of the above

71. Eggplants are highly susceptible to _____ disease.

72. Plant and root growth of eggplant stop during: a) hot weather; b) cold weather; c) dry weather; d) wet weather

73. The globe artichoke belongs to the _____ family.

74. _____ may be the most difficult part of globe artichoke culture.

Answers: 67 - c; 68 - mulching; 69 - b; 70 - d; 71 - verticillium wilt; 72 - b; 73 - thistle; 74 - overwintering

Gourds

Environmental Preferences

Light: Sunny.

Soil: Well drained, high in organic matter.

Fertility: Medium-rich.

pH: 5.5 - 7.0

Temperature: 70 - 85ºF in day time and a few degrees cooler at night (not to go below 60ºF).

Moisture: Water liberally during growing season.

Culture

Planting: Seed after all danger of frost, 1-2 inches deep.

Spacing: Minimum of 3-4 ft between vines in rows and 4 ft. between rows; or 1-2 seeds in hills spaced 12-24 inches apart to 6 ft. apart, depending on variety.

Hardiness: Tender; grow as warm season annuals.

Fertilizer Needs: Broadcast 4 lbs. 5-10-5 per 50 ft. row before planting; sidedress one month later with 2 lbs

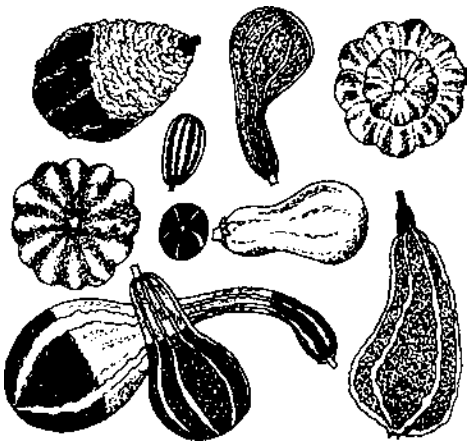
5-10-5 per 50 ft. row; sidedress again if leaves start to become light green.

Cultural Practices

Gourds are an easily grown annual vine. The plants may attain a length of 12 to 15 feet. Vines are capable of vigorous growth; the best fruits will be produced when the vines are supported on a trellis, fence, or arbor. Under such conditions, they may serve as an attractive landscape feature.

Sow seeds where the plants are to grow unless seedlings are grown in plant bands. The plants will not tolerate much root disturbance during the transplanting operation.

The plants need a growing season of about 140 days to produce a full crop of mature fruit.



Ample fertilizer should be applied to promote active green growth. Mix fertilizer with the soil before the seeds are planted. About a month after growth starts, apply a side dressing and scratch into the top inch of soil. A liberal watering will help dissolve the nutrients and move them down to the root zone. If the plants become light green in color repeat the side dressing application.

Gourds need a liberal supply of moisture to maintain vigorous growth during the summer. Weeds should be controlled to avoid competition for moisture and nutrients. Gourds have a shallow root system so care should be exercised in cultivation to avoid root damage.

An ideal system of culture is to use a 1-inch mulch of fresh sawdust, fresh shredded bark, or wood chips, to conserve soil moisture and help control weeds. During the late summer and early fall, a reduced supply of water is desirable to promote ripening of the fruit.

If smaller numbers of fruit are acceptable, gourds can be pruned and maintained in a limited area. The fruit to be harvested for craft and decorative uses should be left on the vine until fully mature but removed before frost.

The Luffa variety, also known as Vegetable Sponge, Sponge Gourd or Dishrag Gourd has a rampant growing vine that produces medium green fruit, 12 to 18 inches long. Immature fruits are edible and are sometimes known as CeeGwa or Chinese Okra. When the fruit matures, it forms a fibrous and springy inside which can be separated from the seeds and skin and used for bathing or dish washing. To conserve space in the garden and produce straight fruit, they should be grown on a trellis. Because of the thick, rapid-growing vine and bright yellow flowers, some people like to use the luffa as a screen.

The Snake Gourd is most often grown in the U.S. for its curious, long, mature, dry fruit that is advertised as "so like a real snake it serves as a scarecrow; fools some of your friends, too." However, in India and the Far East, it is considered a food crop, the immature fruit being sliced and boiled. The fruit is narrow and cylindrical and can reach up to 6 feet in length. They should be trellised, and some people attach a weight to the end to keep them growing straight.

Another plant that is considered by some to be a gourd is the Turks Turban squash. The bright orange-red, flattened fruits are often 8 to 10 inches across, they are striped and spotted with varied rich colors. Prepared like winter squash, it is an excellent winter vegetable.

Common Problems

Diseases: Similar to cucumber; depending on variety, powdery mildew, mosaic virus, fusarium wilt, fruit rot (use mulch to help prevent fruit rot); mold growth on outer skin during curing process (can be scraped off or left for decorative effect).

Insects: Cucumber beetle, Squash beetle, thrips.

Harvesting and Storage

Lagenaria varieties can be eaten like squash or eggplant when immature. Harvest fruits about one week after bloom. The Luffa variety can be eaten like cucumber or cooked like a vegetable when fruits are four inches long or less.

The small decorative gourds have a somewhat thick flesh and require special attention when harvested. They should be picked when fully mature, and before frost, to reduce the possibility of spoilage during or after curing. When ripe, the stem will turn brown and start to shrivel. The rind should be hardening, but the skin will be quite tender. Cut the fruits from the vines with pruning shears, leaving a short section of the stem attached. This stem may drop off when the gourd dries, but will be attractive if it remains on the fruit.

Gourds must be handled with care to avoid bruising and scratching. Such damage may cause rot and unsightly spots. Wipe each fruit with a cloth dampened with rubbing alcohol to remove dirt and decay organisms. If the gourds are quite dirty, they may be washed in warm, soapy water.

Rinse in clean water to which a household disinfectant has been added. Dry each fruit carefully with a soft cloth.

The gourds should be cured for about a week in a well-ventilated porch, garage, or shed. Place the fruit one layer deep on shallow slatted trays or on an open shelf. Turn the gourds each day, and discard any that shrivel or develop soft spots.

During the first week of curing, the skin will become quite hard and tough. An additional period of about three weeks will be needed for complete drying. For this process, the gourds may be stored in shallow wood or cardboard trays in a well-ventilated room, attic, or garage. If no other suitable location is available, they may be placed under a bed or chest. Continue to inspect the fruit every few days to remove any that shrivel or show evidence of decay. Gourds should not be stored in a damp basement; a closed, heated room; or in tight, unventilated containers. Such conditions will encourage the development of mold and rot.

The large gourds, such as the dipper or sponge types, have relatively thin rinds and are somewhat easier to cure than the small decorative sorts. The large gourds will tolerate exposure to a few light frost periods without damage. They may be cured in slatted crates in a well-ventilated garage or shed.

Approximate Yields: Prolific for most varieties.

Amount to Raise: One or two plants of several varieties, depending on use.

Storage: Well-cured, decorative gourds usually retain their attractive color for at least three or four months. A protective coating of white shellac, floor wax, or furniture wax will enhance their appearance and prolong their life. Gourds may become faded and unattractive after four to six months.

Preservation: Gourds have traditionally been thought of as an autumn decoration, but, in fact, have served a wide variety of useful purposes throughout the world. Grown like winter squash, many are edible in the immature stage, then lend themselves to other roles as they mature.

Lagenaria species, such as the Calabash, Dipper, Large Bottle, and Hercules Club, have been used as water vessels, as storage containers for grains and seeds, even for musical instruments. The large bottle gourds are excellent for bird houses. All lend themselves to a variety of craft projects.

The small, fancy gourds are of a different species and do not lend themselves to hollowing out for craft projects; however, they do make excellent additions to fall centerpieces and can be attached to autumn wreaths or other decorations. They come in a mixture of yellow, orange, green, and white fruit with shapes like apples, pears, or eggs; some are striped or bi-colored, some are smooth-skinned, others warty.

Gourds with a dull color may be brush or spray painted with enamel or gilded with gold or silver. For some arrangements and special uses, the artificial color may be quite appropriate. Uniform coverage may be secured by suspending the gourds by a string tied to the stem.

The fall and winter holiday seasons are ideal times for displaying decorative gourds. They are particularly attractive in a fruit bowl, cornucopia, or loose arrangement on a table, chest, or mantel. They may also be placed in ornamental baskets or hung in chains or loops at the mantel or front door.

Gourds may be displayed with other natural or artificial fruits. Fresh flowers or leaves with interesting color or texture may be used to add interest to the arrangement. Perishable materials should have the stems inserted in small water tubes which may be concealed among the gourds. Bitter sweet, dried flowers, or seed pods may also be employed to provide contrast in color or form.

To give stability to a display, the gourds may be attached to the container or to each other with small wads of floral clay.

Saving and Storing Seeds: Seeds may be saved from decorative gourds, but because of cross pollination, the next year's crop may be quite variable and different from the original types. You may secure some interesting and attractive forms and colors by planting seeds from your own gourds.

The fruits to be used as sources of seeds should be fully mature. Separate the seeds from the pulp and spread in a thin layer on cloth or absorbent paper until thoroughly dry. Store in a cool, dry place until needed for planting next year. Under good storage conditions, the seeds will remain viable for four or five years.

Lettuce

Environmental Preferences

Light: Sunny, tolerates shade; prefers shade in summer.

Soil: Well-drained, loose loam.

Fertility: Rich.

pH: 6.0 to 7.0

Temperature: Cool (60 to 70ºF).

Moisture: Moist, but not waterlogged; frequent, light waterings.

Culture

Planting: Seed leaf or butterhead types as soon as soil can be worked in the spring, or in late summer. Cripshead and cos types may be transplanted in early spring or fall.

Spacing: Romaine, leaf, or butterhead -- 4 to 10 inches x 12 to 24 inches; crisphead -- 12 to 15 inches x 18 to 30 inches.

Hardiness: Hardy annual.

Fertilizer Needs: Medium-heavy feeder; use starter solution on transplants, sidedress if nutrient deficiencies are noted.

Cultural Practices

Lettuce, a cool-season vegetable crop, is one of the easiest

to grow. Lettuce withstands light frost; however, sunlight and high summer temperatures usually cause seedstalk formation (bolting) and bitter flavor. Slow-bolting or heat-resistant varieties are available and are recommended for extending the lettuce-growing season. There are several types of lettuce commonly grown in gardens.

Crisphead, also known as iceberg, is the lettuce most widely available as a fresh market type. It has a tightly compacted head with crisp, light green leaves. Many gardeners find this type difficult to grow because it requires a long season and some of the most advertised varieties are not heat-resistant and tend to go to seed as soon as temperatures go up. Select a slow-bolting variety and start seed indoors in late winter or late summer for best results. Transplant in early spring or fall to take advantage of cool weather and mulch well to keep soil temperatures from fluctuating and to hold in moisture. An organic mulch is more suitable than black plastic after soil warms up. Mulching also keeps soil off the leaves, reducing chances of disease from soil-borne organisms.

Butterhead, or Bibb lettuce, is a loose-heading type with dark green leaves that are somewhat thicker than those of iceberg lettuce. Butterheads develop a light yellow, buttery appearance and are very attractive in salads. A miniature variety of butterhead, Tom Thumb, is very easy to grow, requiring a short growing time. One head of this lettuce is about right for one or two servings, so this is one lettuce to plant in succession, about two weeks apart. It may be started indoors for an even longer season. Bibb lettuce will develop bitterness readily if temperatures get too high.

Romaine, or Cos, is less commonly grown by gardeners, but is a very nutritious lettuce that deserves attention. It, too, is relatively easy to grow, forming upright heads with rather wavy, attractive leaves.

Leaf type lettuce, either with green or reddish leaves, is the one most gardeners raise. This type is fast-growing, long-lasting lettuce used for salads, sandwiches, and in wilted lettuce salads. Leaf lettuce basically needs only to be planted and harvested.

Cultivate carefully as lettuce is shallow-rooted. Use frequent, light waterings to encourage rapid growth, but do not overwater, as this may cause disease of roots or leaves. Overhead watering should always be done in the morning to give plants time to dry off. As mentioned above, mulches are helpful in maintaining soil moisture and keeping leaves off the ground.

Lettuce planted in very early spring should be given full sun so that the soil will warm enough for rapid growth. For long-season lettuces, plant so that crops such as sweet corn, staked tomatoes, pole beans, or deciduous trees will shade the lettuce during the hottest part of the day when temperatures are over 70ºF. Interplanting (i.e., planting

between rows or within the row of later-maturing crops like tomatoes, broccoli, and Brussels sprouts) is a space-saving practice. Some lettuces, like Tom Thumb and leaf lettuces, are attractive in flower borders.

Lettuce is best planted in succession, or using different varieties that mature at different times. Thirty heads of iceberg lettuce harvested at once can present a major storage problem! Leaf and Bibb lettuces do well in hotbeds or greenhouses during the winter and in cold frames in spring and late fall.

Common Problems

Diseases: Stem, leaf, and root rots.

Insects: Aphids, root aphids.

Cultural: Tip burn from irregular moisture or lack of calcium; bolting, bitterness due to high temperature or lack of moisture; leaf rots due to soil and/or water on leaves.

Harvesting and Storage

Days to Maturity: 40 to 80 days, depending on type.

Harvest: Leaf lettuce can be used as soon as plants are 5 to 6 inches tall. Use the older, outer leaves which contain high levels of calcium first. You may wish to harvest every other one of the largest plants to accomplish thinning.

Bibb lettuce is matured when the leaves begin to cup inward to form a loose head. The heads will never become compact. Cos or Romaine is ready to use when the leaves have elongated and overlapped to form a fairly tight head about 4 inches wide at the base and 6 to 8 inches tall. Crisphead is matured when leaves overlap to form a head similar to those available in groceries; heads will be compact and firm.

Crisphead lettuce will keep about two weeks in the refrigerator. Leaf, Bibb and Romaine will store as long as four weeks if the leaves are dry when bagged. If lettuce is to be stored, harvest when dry, remove outer leaves, but do not wash; place in a plastic bag, and store in the crisper drawer.

Approximate Yields: 5 to 10 pounds per 10-foot row.

Amount to Raise: 5 to 10 pounds per person planted over cool season.

Storage: Cool (32ºF), moist (95% relative humidity) conditions for two to three weeks.

Preservation: Cool, moist refrigeration; canning and freezing not recommended.

Melons

Environmental Preferences

Light: Sunny.

Soil: Well-drained with moderate organic matter; sandy.

Fertility: Medium.

pH: 6.0 to 7.5

Temperature: Hot (70 to 85ºF).

Moisture: Average.

Culture

Planting: Seed after all danger of frost is past and when soil warms. Begin transplants in peat pots three to four weeks before this time.

Spacing: 2 to 3 feet between bulbs in rows 5 to 7 feet for muskmelon; 6 to 8 feet between hills 7 feet apart for watermelon.

Hardiness: Very tender annual.

Fertilizer Needs: Heavy feeder. Use a starter solution for transplants. Sidedressing with nitrogen may lower yield and/or quality. Late-maturing varieties, however, may need some sidedressing at fruit set.

Cultural Practices

Muskmelons and watermelons are warm-season crops requiring a long growing season of 80 to 100 days from seed to fruit. Most present varieties are not well suited to small gardens because of the space requirement. Newer bush varieties are available for use in small gardens. Melons can be produced from transplants or planted directly. Those grown from transplants can be harvested as much as two weeks earlier than melons grown directly from seed, since the gardener must wait until danger of frost is past to plant. Plant or transplant muskmelon in rows 5 feet apart with hills spaced every 2 to 3 feet, two

or three plants per hill. Watermelon hills should be 6 to 8 feet apart, and rows 7 to 10 feet apart if a path is desired between rows. Seed should be sown 1/2 to 1 inch deep after danger of frost has passed and soil is warmed.

Muskmelons and watermelons are well suited for growing on black plastic mulch. The black plastic absorbs heat readily, allowing the soil to warm quickly. It tends to keep the soil moisture level from fluctuating greatly. In addition, the mulch is very effective in controlling weeds, decreasing the labor necessary to care for melons. Male and female flowers are separated on the same plant. Bees must carry pollen from flower to flower to insure good fruit. Use insecticides late in the evening to avoid killing bees. Melon plants can be trained in rows for easy harvesting. Growing on a trellis allows closer spacing (rows 3 feet apart), but each trellised melon must be supported by a sling made of a material which dries quickly to prevent rot. Old nylon stockings, cheesecloth, and other net-like materials make good fruit slings. Very large watermelons probably should not be trellised at all, since the weight of the fruit, even if supported, would likely damage the vine.

The two most common types of melons are *Cucumis melo* var. *reticulatus* (netted muskmelons) and *C. melo* var. *inodorus* (winter melons). Netted muskmelons include what we commonly call "cantaloupes," but true cantaloupes or rock melons are *C. melo* var. *cantaloupensis* (not cultivated in the U.S.). Netted muskmelons have netted surfaces with vein tracts and green to deep salmon-orange flesh. Winter melons include casaba, crenshaw, and honeydew and have smooth or corrugated, non-netted surfaces without vein tracts and greenish white to orange or pink-tinted flesh. All forms of *C. melo* readily hybridize with each other. Watermelons (*Citrullus lanatus*) have green surfaces often with stripes and pink, red, or yellow flesh.

Common Problems

Diseases: Bacterial wilt (spread by cucumber beetles), fusarium wilt, leaf spot, powdery and downy mildews, Alternaria blight.

Insects: Cucumber beetles, squash vine borer, pickleworms, squash bug.

Cultural: Poor flavor and lack of sweetness due to poor fertility; low potassium, magnesium, or boron; cool temperatures; wet weather; poorly adapted variety; loss of leaves from disease; picking unripe melons. Poor pollination caused by wet, cool weather, lack of bee pollinators, and planting too close, resulting in excessive vegetative growth. A heavy rain when melons are ripening may cause some of the fruit to split open. Fruit in contact with soil may develop rotten spots or be damaged by insects on the bottom. Place a board or a couple inches of light mulching material, such as sawdust or straw, beneath each fruit when it is nearly full-sized.

Harvesting and Storage

Days to Maturity: 70 to 130 days.

Harvest: Muskmelons are harvested at full-slip; i.e., when the stem separates easily at the point of attachment. Honeydew, Crenshaw, and casaba melons are cut off after they turn completely yellow. These melons will rot if left on the ground for too long. For watermelons, become familiar with the variety being grown to determine the best stage for harvesting. The best indicator is a yellowish color on the underside where the melon touches the ground. A dead tendril or curl near the point where the fruit is attached to the vine is used by some as an indicator that the fruit is ready for harvest. You may also thump the fruit, listening for the dull sound of ripe fruit, rather than a more metallic sound; however, this technique takes some practice, and if you have just a few fruit, it is probably wise to include all of the above when making your decision.

Approximate Yields: 8 to 40 pounds per 10-foot row; more if trellised.

Amount to Raise: 10 to 15 pounds per person.

Storage: Medium-cool (40 to 50ºF), moist (80 to 85% relative humidity) conditions.

Preservation: Cool, moist storage; may freeze muskmelon balls.

Okra

Environmental Preferences

Light: Sunny.

Soil: Well-drained.

Fertility: Rich.

pH: 6.0 to 8.0

Temperature: Warm (70 to 85ºF).

Moisture: Average.

Culture

Planting: Sow after danger of frost when soil is warm. Can be transplanted but is difficult.

Spacing: 12 by 12 inches - dwarf types; 12 to 18 inches by 24 to 36 inches -standard types.

Hardiness: Very tender annual.

Fertilizer Needs: Heavy feeder, 2 to 3 pounds of 10-10-10 per 100 square feet before planting, side dress every 14 days from the time the first flower opens with 1 pound of 10-10-10 per 100 feet of row.

Cultural Practices

Okra is a tall, upright plant with a hibiscus-like flower. The immature, young seed pods are the edible part of this plant. Okra seeds are not long lived, and if seeds are over a year old, germination will be reduced. Germination time is shorter and germination rate increases if seeds are scarified and soaked overnight. The okra family does well under dry conditions, but an adequate moisture level is required for good yields. Okra is subject to root rot and is sensitive to water logged soils. Weeds should be cultivated to prevent them from competing with the plants. Pods should be harvested every three to four days so plants will continue to produce. If pods are left to ripen, the plants will decline in production. Because okra is susceptible to wilts, crops should be rotated.

Common Problems

Diseases: Verticillium and fusarium wilts.

Insects: Nematodes, corn earworm, stinkbugs, ants, Japanese beetles.

Harvesting and Storage

Days to Maturity: 50 to 65 days from seed.

Harvest: Pods should be about 2 to 3 inches long and picked within a few days after flower petals have fallen.

Approximate Yields: 5 pounds per 10 feet of row.

Storage: Cool (40 to 50ºF), moist (95% RH) conditions; three to five days.

Preservation: Freeze, can, or pickle.

Study Questions

75. In late summer and early fall, ripening gourds can be promoted by reducing: a) fertilizer; b) water; c) sun; d) temperature
76. Gourds should be cured for about _____.
77. Bolting of lettuce is caused by: a) cold weather; b) cloudy weather; c) high temperatures; d) lack of fertilizer
78. Irregular moisture or lack of _____ can lead to tip burn of lettuce.
79. Sidedressing melons with _____ may lower yield and/or quality.
80. When trellising melons, it is important to: a) sling the ripening fruit; b) fertilize weekly; c) root prune; d) provide supplemental lights
81. The edible part of the okra plant is the _____.
82. Because okra is susceptible to wilts, crops should be _____.

Answers:
75 - b; 76 - one week; 77 - c; 78 - calcium; 79 - nitrogen; 80 - a; 81 - immature seed pods; 82 - rotated

Onions

Environmental Preferences

Light: Sunny. (Green onions tolerate partial shade.)

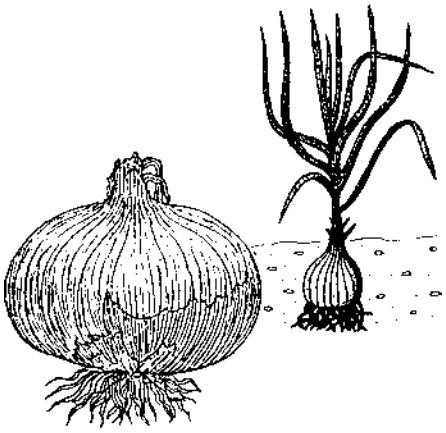
Soil: Well-drained loam.

Fertility: Medium-rich.

pH: 5.5 to 7.0

Temperature: Cool (45 to 60ºF) during development; Medium-hot (60 to 75ºF) during bulbing and curing.

Moisture: Moist, but not waterlogged.



Culture

Planting: Use sets, seeds, or transplants in the spring for bulbs and for green or bunching onions. Seeds may be started indoors eight weeks before setting out; use sets in the fall for perennial or multiplier types of onions.

Spacing: 1 to 6 inches by 12 to 24 inches for standard spacing; 4 inches by 4 inches for wide row in rows up to 2 feet apart. Plant close, then thin and use thinnings as green onions.

Hardiness: Hardy biennial - bulb onions, green or bunching onions; Hardy perennials - Egyptian onions or perennial tree and multiplier.

Fertilizer Needs: Heavy feeder. Apply 4 to 5 pounds 10-10-10 per 100 square feet before planting. Use starter solution for transplants. Sidedress one to two weeks after bulb enlargement begins, using 3 tablespoons 33-0-0 per 10-foot row.

Cultural Practices

Onions are often grouped according to taste. The two main types of onions are strong flavored (American) and mild (often called European). Each has three distinct colors, yellow, white, and red. In general, the American onion produces bulbs of smaller size, denser texture, stronger flavor, and better keeping quality than European types. Globe varieties tend to keep longer in storage.

Onion varieties also have different requirements as to the number of hours of daylight required to make a bulb. If the seed catalog lists the onion as long day, it sets bulbs when it receives 15 to 16 hours of daylight and is used to produce onions in Northern summers. Short day varieties set bulbs with about 12 hours of daylight and are used in the deep South for winter production. This explains why Virginia is not a major onion production area and yields are lower than in the more northern and southern regions of the U.S. Consider selecting quick maturing varieties marked day neutral for earlier bulb production while weather is still cool for sweeter bulbs.

For green or bunching onions, use sets, seeds, or transplants in spring; or use Egyptian (Perennial Tree) and the Yellow Multiplier (Potato Onion) sets in the fall.

For bulb production, plant sets in early spring. Set 1 to 2 inches apart and 1 to 2 inches deep in the row. Thin to 4 inches apart, and eat the thinned plants as green onions. Avoid sets more than an inch in diameter because they are likely to produce seed stalks. Too early planting and exposure to cold temperatures also causes seed stalk development. Some people have best bulb production using seedlings or transplants rather than sets. Egyptian Tree or Multiplier onions should be set in late October or early November. Plant 4 inches apart in rows 1 to 2 feet apart. Distance between rows is determined by available space and cultivating equipment.

Bulbs compete poorly with weeds due to shallow root systems. Shallow cultivation is necessary; do not hill up soil on onions as this can encourage stem rot. Insure ample moisture especially after bulbs begin enlarging. Onions should be harvested when about two-thirds of the tops have fallen over. Careful handling to avoid bruising helps control storage rots. Onions may be pulled and left in the field for several days to dry then cured in a well-ventilated attic or porch for one to two weeks out of direct sun. Tops may be left on or cut off; but leave at least 1 inch of the top when storing. Thorough curing will increase storage life.

Common Problems

Diseases: Neck or stem rot, bulb rot.

Insects: Thrips, onion root maggots.

Cultural: Bulb rot from bruising, insufficient drying; split or double bulb from dry soil during bulb formation; very small bulb from too late planting, too dry soil, or wrong varieties.

Harvesting and Storage

Days to Maturity: 85 to 185 days for mature bulbs.

Harvest: Harvest green onions when tops are 6 inches tall. Harvest bulbs after 2/3 or more of the tops have fallen over. Do not wait more than one to two weeks after this occurs. Allow for thorough drying before storage.

Approximate Yields: 10 to 15 pounds per 10-foot row.

Amount to Raise: 10 to 15 pounds per person.

Storage: Cool (32ºF), dry (65 to 70% relative humidity) conditions for six to seven months.

Preservation: Onions may be stored dry or pickled and canned. They freeze well if chopped and covered with water. For fresh storage, maintain good air circulation. One effective storage method is to place onion in discarded hosiery, tie a knot, and add another onion. When hosiery is filled, suspend from rafters in storage area.

Peas

Environmental Preferences

Light: Sun, tolerates shade in summer.

Soil: Well-drained, light.

Fertility: Medium-rich.

pH: 6.0 to 7.5

Temperature: Cool (55 to 70ºF).

Moisture: Moist, but not water-logged.

Culture

Planting: Seed in early spring as soon as the soil is workable. Inoculating seeds with powdered nitrogen-fixing bacteria may increase yields on new land. Snap peas should be planted after soil begins to warm (45 - 50ºF).

Spacing: 1 to 3 inches by 12 to 30 inches (6 to 10 inches between double rows).

Hardiness: Hardy annual.

Fertilizer Needs: Light to medium feeder, excess nitrogen delays flowering, sidedress after heavy bloom and set of pods 3 tablespoons 33-0-0 per 10 feet of row.

Cultural Practices

The two main types of spring peas used in the home garden are English peas or garden peas, edible podded peas, which include snow peas and snap peas. Southern pea (including cowpea or black-eyed pea) is a warm-season crop grown in the same manner as beans (see p. 282-284) and is in a different genus.

Garden or English peas are the more widely used peas and have either smooth or wrinkle seeded varieties. Wrinkle seeded varieties tend to be sweeter than smooth varieties. Edible podded peas (Chinese pod peas, snow peas, and snap peas) can be eaten without shelling in salads or appetizers. The whole edible podded pea may be prepared in a similar manner as green beans, but will not need as much cooking (stir-frys or steamed).

Peas are frost-hardy and prefer cool, moist weather. Early spring or fall sowings do best. Some varieties show resistance to heat, but partial shading may be necessary during summer heat. Mulching with organic matter can also help to keep soil cool.

Avoid direct contact of germinating seeds or seedlings with chemical fertilizers. Peas have a low salt tolerance and are easily injured. Careful, shallow cultivation is also important.

Dwarf and most intermediate varieties are self-supporting; however, twigs and branches may be stuck into the ground adjacent to the rows for some support. Taller varieties will need poles, trellises, or fencing to grow on. By encouraging the pea vine to climb up the supports, peas and foliage are lifted off the ground, resulting in less disease problems and easier picking.

Common Problems

Diseases: Fusarium wilt, root-rot.

Insects: Seed maggot, pea weevil, aphids.

Cultural: Poor germination (cold, wet soils), poor flowering (excessive vegetative growth from too much nitrogen), poor bloom set (too hot temperatures).

Harvesting and Storage

Days to Maturity: 55 to 75 days.

Harvest: Garden peas when pods are filled in; shell and eat while peas are still tender and sweet. High temperature causes rapid loss of sugar content.

Smaller ones are tastier than larger ones. Edible podded snow peas should be picked as soon as peas are perceptible bumps inside the pods. Harvest snap peas when pods have reached full size before surface becomes pebbly and faded in color, or they will be too mature and will need to shelled for peas.

Approximate Yields: 2 to 5 pounds per 10 feet of row.

Amount to Raise: 5 to 8 pounds per person.

Storage: Cool (32ºF), moist (95% RH) conditions, one to three weeks.

Preservation: Can or freeze garden peas; freeze edible podded peas.

Peppers

Environmental Preferences

Light: Sunny.

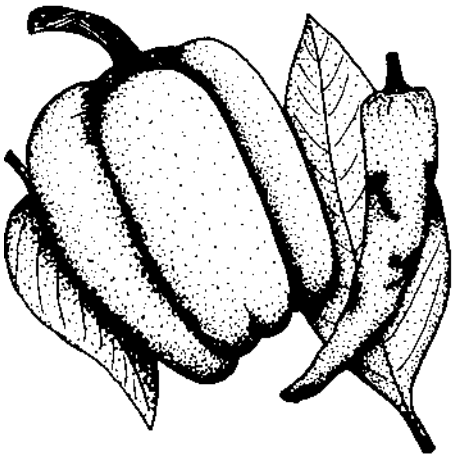
Soil: Well-drained, loose soil with moderate organic matter.

Fertility: Medium-rich.

pH: 5.5 to 6.5

Temperature: Warm (70 to 75ºF).

Moisture: Average.



Culture

Planting: Set out transplants after soil has thoroughly warmed in the spring. Start seed indoors six to eight weeks prior to this date.

Spacing: 18 to 24 inches by 30 to 36 inches.

Hardiness: Tender annual

Fertilizer Needs: Light to medium feeder. Use starter solution for transplants. Sidedress cautiously after first fruit sets with 3 tablespoons 33-0-0 per 10-foot row; too much fertilizer may cause excessive vegetative growth.

Cultural Practices

Most peppers are classified according to their degree of hot or mild flavor. The mild peppers include Bell, Banana, Pimiento, and Sweet Cherry, while the hot peppers include the Cayenne, Celestial, Large Cherry, and Tabasco.

Bell peppers, commonly measuring 3 inches wide by 4 inches long, usually have three to four lobes and a blocky appearance. Green bell peppers can be left to turn red or yellow when fully ripe. Some varieties now produce orange, purple, yellow or even chocolate colored fruit. About 200 varieties are available. Banana peppers are long and tapering and harvested when yellow, orange, or red. Another sweet pepper, Pimiento, has conical, 2 to 3 inches wide by 4 inches long, thick-walled fruit. Most Pimientos are used when red and fully ripe. Cherry peppers vary in size and flavor. Usually they are harvested orange to deep red.

Slim, pointed, slightly twisted fruits characterize the hot Cayenne pepper group. These can be harvested either when green or red and include varieties such as Anaheim, Cayenne, Serrano, and Jalapeno. Large cherry peppers are very hot - more mild than Serrano, but hotter than Jalapeno. Celestial peppers are cone shaped, 3/4 to 2 inches long, and very hot. They vary in color from yellow to red to purple, making them an attractive plant to grow. Slender, 1- to 3-inch, pointed Tabasco peppers taste extremely hot and include such varieties as Chili Piquin and Small Red Chili.

Peppers generally have a long growing season and suffer slow growth during cool periods. Therefore, after the soil has thoroughly warmed in the spring, set out 6- to 8-week-old transplants to get a head start toward harvest. Practice good cultivation and provide adequate moisture. Mulching can help to conserve water and reduce weeds.

Hot peppers are usually allowed to fully ripen and change colors (except for Jalapenos) and have smaller, longer, thinner, and more-tapering fruits than sweet peppers. Yields are smaller for hot peppers.

Common Problems

Diseases: Tobacco mosaic virus, bacterial spot, anthracnose.

Insects: Aphids, flea beetles, cutworms, European corn

borer.

Cultural: Blossom end rot from moisture irregularities or calcium deficiency; blossom drop from night temperatures rising above 75ºF or excessive fruit set on entire crop.

Harvesting and Storage

Days to Maturity: 100 to 120 days from seed; 70 to 85 days from transplants.

Harvest: Harvest sweet peppers when they reach full size. When allowed to mature on the plant, most varieties turn red, sweeten, and increase in vitamins A and C content. Cut instead of pulling to avoid breaking branches. Most hot peppers are allowed to ripen and change color on the plant. Entire plants may be pulled and hung just before full frosts.

Approximate Yields: 2 to 8 pounds per 10-foot row.

Amount to Raise: 3 to 10 pounds per person.

Storage: Medium-cool (45 to 50ºF), moist (95% relative humidity) conditions for two to three weeks.

Preservation: Freeze; use in pickles and relishes or dried as spices.

Potatoes

Environmental Preferences

Light: Sunny.

Soil: Well-drained with moderate organic matter.

Fertility: Medium-rich.

pH: 4.8 to 6.5

Temperature: Cool (55 to 65ºF).

Moisture: Uniform moisture, especially while tubers are developing.

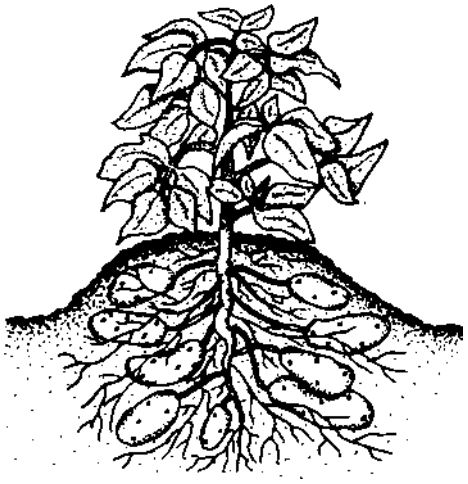
Culture

Planting: Plant 1-1/2- to 2-ounce seed pieces with at least one good eye in early spring; will resist light frost.

Spacing: 10 to 12 inches by 24 to 36 inches.

Hardiness: Tender annual

Fertilizer Needs: Medium-heavy feeder. Add high phosphorus fertilizer before planting, using 2-1/2 lbs 5-10-10 per 50-foot row. Sidedress 1 or 2 times after tubers begin forming using 1 lb. 10-10-10 per 50-foot row.



Cultural Practices

Both white-skinned and red-skinned potatoes can be grown as an early crop for new potatoes and as a late crop for storage. Choose an early maturing variety and a medium- to late-maturing variety. Plant potatoes early from March 15 to April 20, depending on your location. Hard frosts and freezes may set back growth. Potatoes prefer cool springs and moisture throughout the growing season. Crops can be successfully planted as late as June for fall harvest and storage, but yield may be reduced.

Avoid a garden site in a turned-under lawn as grub worms may damage developing tubers unless soil insecticides are used.

A soil pH of 6.0 to 6.5 is most desirable; however, scab disease will be less when the pH is between 5.0 to 5.2. Work this into the furrow and mix with the soil before planting. Purchase certified seed stock that has been inspected for diseases that lower yields. Saving your own seed potatoes is generally not worthwhile because viruses and diseases often show up the next year. Seed potatoes should be firm and unsprouted. Wilted and sprouted potatoes usually have lost vigor from being too warm in storage. Seed pieces for planting should be cut to about 1-1/2 to 2 ounces or into 1-1/2-inch cubes. Potatoes about 6 ounces in size will cut into four pieces nicely. Each seed piece should have at least one good bud or eye. Allow to dry or cure before planting. Plant potatoes in furrows cut-side down, 3 to 5 inches deep. Later crops should be planted 5 to 6 inches deep.

Chitting, a controlled sprouting of the seed potato, is an old English technique for forcing potatoes. Early varieties respond best. Place potatoes in a cool room (55ºF) with

indirect light. Short, sturdy green sprouts about 1/2 inch long will develop in about one month, providing sprouted seed potatoes for planting.

Pull a ridge of soil over each row when planting. Drag a board or hoe across the ridges just before the sprouts break through to eliminate weeds. Later cultivation should be shallow and far enough from the rows to make certain that no roots are damaged.

When the tops have grown too large to allow cultivation, a finishing cultivation, sometimes called laying-by or hillingup, is given. Laying-by throws soil over the potatoes to prevent exposure of the potatoes to sun which can cause greening or scalding. Green portions on potatoes taste bitter and contain an alkaloid. Cut off and discard green areas before using.

An alternative of planting in areas with heavy clay soil is to grow plants in straw or leaf beds above ground. This requires 2-3 feet of organic matter and more frequent watering than in ground production but produces clean, easily dug tubers.

Common Problems

Diseases: Early blight; scab; late blight; tuber rots; virus complex, fusarium, verticillium, and bacterial wilts.

Insects: Colorado potato beetles, flea beetles, leafhoppers.

Cultural: Green skin from sun exposure; hollow heart from alternating wet and dry conditions; Black Walnut wilt from being too close to a Black Walnut tree.

Harvesting and Storage

Days to Maturity: 100 to 120 days.

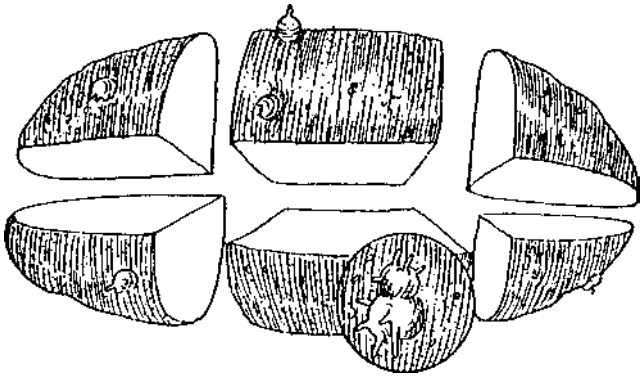
Harvest: Dig early potatoes when tubers are large enough to eat. Harvest potatoes for storage two weeks after the vines die down or just after the first light frost nips the vines, before heavy freezing. Avoid skinning tubers when digging and avoid long exposure to light.

Approximate Yields: 6 to 15 pounds per 10-foot row.

Amount to Raise: 75 to 100 pounds per person (about 15 pounds of seed potatoes).

Storage: Medium-cool (40 to 50ºF), moist (90% relative humidity) conditions for six to eight months. Sprouting is a problem at higher temperatures.

Preservation: Medium-cool, moist conditions.



Study Questions

83. The two types of onion are _____, which are strong flavored, and _____, which are milder.

84. In the spring, bulbs and green or bunching onions are started by: a) sets; b) seeds; c) transplants; d) all of the above

85. Excess _____ can delay flowering of peas.

86. Peas have a low _____ tolerance and are easily burned by chemical fertilizers.

87. A hot pepper that is not allowed to ripen and change color on the vine is the _____.

88. Compared to sweet peppers, hot pepper yields are _____.

89. Avoid planting potatoes in areas that were previously planted with _____, as grub worms can be a problem.

90. _____ refers to controlled sprouting of the seed potato.

Answers: 83 - American, European; 84 - d; 85 - nitrogen; 86 - salt; 87 - Jalapeno; 88 - smaller; 89 - lawn; 90 - chitting

Rhubarb

Environmental Preferences

Light: Sunny.

Soil: Well-drained loam.

Fertility: Rich.

pH: 5.5 to 7.0

Temperature: Requires a winter minimum 30ºF (ground temperature) for two months.

Moisture: Moist, but not waterlogged.

Culture

Planting: Plant roots in early spring; the crown bud should be 2 inches below the surface.

Spacing: 36 to 48 inches by 36 to 48 inches.

Hardiness: Hardy perennial.

Fertilizer Needs: Heavy feeder (1 pound 5-10-20 per 10 feet of row before plants are set).

Cultural Practices

Old roots should be dug and divided to make new plantings. Cut roots into four to eight pieces, each piece should have at least one strong bud. Plant pieces 3 feet apart in rows 4 feet apart, covered with 3 inches of soil. Roots should be divided after five or more years. Seed shafts should be removed as they appear.

Seeds are not recommended to start plantings because they take too long to become established.

The leaf blades should not be eaten because they contain a large amount of oxalic acid; only the petioles or leaf stalks should be eaten. Petioles are of highest quality in the spring. Leaf stalks that are damaged by frost should not be eaten because oxalic acid may migrate to the stalks from the leaves.

Rhubarb can be forced indoors during the winter. A vigorous crown can be dug up in the fall for indoor forcing and planted outside again in the spring.

Common Problems

Diseases: Phytophthora (crown rot).

Insects: Rhubarb curculio, slugs.

Cultural: Small leaves and stalks (excessive crowding, old plants, and/or low soil fertility).

Harvesting and Storage

Days to Maturity: One year after planting.

Harvest: Rhubarb should not be harvested during the first year, and there should be only a limited harvest the second year. Harvest rhubarb from early spring to June. Some leaves should be left to store food reserves. Stalks should be pulled and not cut to prevent damage to crown. Leaf blades should be removed and only the fleshy stem of the petiole should be used. Petioles are usually 8 to 15 inches when harvested.

Approximate Yields: 8 to 12 pounds per 10 feet of row.

Amount to Raise: 10 pounds per person.

Storage: Cool (32ºF), moist (95% RH) conditions; two to four weeks.

Preservation: Freezing, canning.

Squash

Environmental Preferences

Light: Sunny.

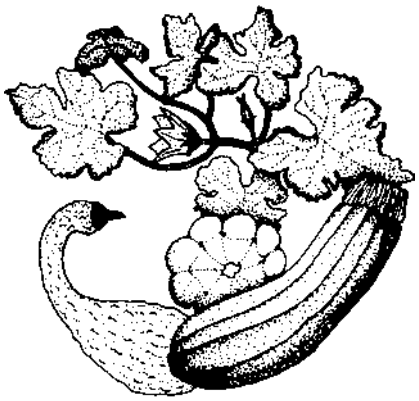
Soil: Well-drained.

Fertility: Medium-rich.

pH: 6.0 to 7.5

Temperature: Warm (65 to 75ºF).

Moisture: Average.



Culture

Planting: Seed or transplant after danger of frost is past and soil has warmed.

Spacing: 3 to 4 feet by 4 to 6 feet for hills with two to three plants per hill; 2 to 3 feet by 3 to 5 feet for single plants.

Hardiness: Very tender annual.

Fertilizer Needs: Heavy feeder. Sidedress one week after blossoming begins with 3 tablespoons 33-0-0 per 10-foot row; repeat three weeks later.

Cultural Practices

Summer squash grows on non-vining bushes. There are many varieties having different fruit shapes and colors. The three main types include the yellow straight neck or crooked neck; the white, saucer shaped, scallop, or patty pan; and the oblong, green, gray, or gold zucchini.

Winter squash is allowed to mature on the vine and develop a hard rind to permit winter storage, although with many varieties it can be picked early and used like summer squash. Cultural techniques are the same as for other squashes. Winter squashes are generally categorized according their fruit size. Small fruits (1 to 4 pounds, 80 to 100 days to harvest) include acorn types, butternut types, and some true winter squash types. Intermediate fruits (6 to 12 pounds, 110 days to harvest) include banana squash, Cushaw, Hubbard, and Sweet Meat varieties. Large fruits (15 to 40 pounds, 120 days to harvest) include Blue Hubbard, Boston Marrow, and Jumbo Pink Banana varieties. Jumbo fruits (50 to 100+ pounds, 120 days to harvest) are often called Jumbo Pumpkins and include Big Max and various Mammoth varieties. Some of the small-fruited types have been bred for bush or semi-vining growth habits. Another winter squash, Spaghetti Squash or Vegetable Spaghetti, has gained in popularity in recent years. Its flesh, when steamed or baked, separates into spaghetti-like strands. The delicate flavor is unique combined with its firm yet tender texture making it useful as a low calorie, low starch pasta substitute. The plant vines vigorously and benefits from trellising. The large, oblong fruits turn yellow when fully ripe. Spaghetti Squash may be stored as a winter squash or cooked and frozen successfully.

Culture

Soil containing plenty of well-rotted compost or manure is ideal, although good crops may be grown in average soils which have been adequately fertilized. For extra early fruit, plant seeds in peat pots in greenhouses or hotbeds and transplant about three weeks later after danger of frost. Older plants that have hardened off and stopped growth will not transplant well and should be discarded. Squashes are warm-season plants and do not do well until soil and air temperatures are above 60ºF. Seed or transplants can be planted through clear, black, or infrared transmissible (IRT) plastic mulches. Cover seed with 1 inch of soil.

Squash plants have separate male and female flowers on the same plant. Pollen must be transferred from the male flowers to the female by bees. Use insecticides late in the evening to prevent killing bees which use the pollen as food and will carry them back to the hive.

Common Problems

Diseases: Powdery and downy mildews, blossom blight, bacterial wilt.

Insects: Cucumber beetles, squash vine borers, pickle worm.

Cultural: Blossom end rot from irregular moisture or calcium deficiency; failure to set fruit (see cucumber).

Harvesting and Storage

Days to Maturity: Summer squash: 50 to 65 days; winter squash: 80 to 140 days.

Harvest: Harvest summer squash when immature, only about 6 to 8 inches long and 1-1/2 to 2 inches in diameter for elongated types, 3 to 4 inches in diameter for patty-pan types, and 4 to 7 inches long for yellow crooknecks. If the rind is too hard to be marked by the thumbnail, the fruit is too old. Remove old fruit to allow new fruit to develop.

Harvest winter squash when fruits turn a deep, solid color and the rind hard. Allow to ripen on the vine. Harvest after vine dries up before heavy frost. Cut the stem 2 to 3 inches from the vine as fruit without a stem tend not to store well.

Approximate Yields: 20 to 80 pounds per 10-foot row.

Amount to Raise: 10 to 25 pounds per person.

Storage: Summer squash: cool (32 to 50ºF), moist (90% relative humidity) conditions for 5 to 14 days. Winter squash: warm (45 to 55ºF), very dry (50 to 60% RH) conditions for two to six months.

Preservation: Summer squash: cool, moist storage; may can as pickles or relishes; may freeze (quality may

be poor on frozen squash). Winter squash: usually kept in warm, dry storage, canned, or frozen.

Sunflowers and Jerusalem Artichokes

Environmental Preferences

Light: Sunny.

Soil: Deeply cultivated, light loam.

Fertility: Will grow in just about any soil.

pH: 6.0 to 7.5

Temperature: Warm.

Moisture: Above average.

Culture

Planting: Sunflower - may be planted up to two weeks before the average last spring frost. Jerusalem artichoke -plant seed tubers early in spring when soil can be worked.

Spacing: Sunflower - 12 x 16 inches for small plants, 36 x 36 inches for large plants. Jerusalem artichoke - 6-inches deep in hills 1 foot apart with rows 3 to 4 feet apart or 2 inches deep spaced 1 x 3 feet.

Fertilizer Needs: Neither plant requires additional fertilizer if planted in a moderately fertile soil.

Cultural Practices

Sunflowers and Jerusalem artichokes are very closely related plants that are grown for different products. Sunflowers are grown for their seed and ornamental purposes. Jerusalem artichokes are grown for the edible tuber. A row of sunflowers makes a beautiful "living fence," and multiple rows make a good windbreak. Be sure to keep the rows on the north end of the garden to prevent them from shading smaller plants. Sunflowers are hardy to light spring and early fall frosts. They like heat and plenty of moisture during the growing season. Irrigate during excessively dry periods. Mulching will conserve moisture and supply needed nutrients.

Overcrowding causes the plants to fall in heavy winds. However, it is best to group two to three stalks together to help them withstand winds. Tying the stalks to a support will keep them from falling over when the seed heads get heavy. Sunflowers can be used as "living poles" when planted with climbing plants, such as morning glories or scarlet runner beans which are very attractive to hummingbirds. Be sure to group the sunflowers when using this practice. If the birds are eating the seeds, harvest the heads or cover them with netting, cheesecloth, paper bags, or perforated plastic bags.

Jerusalem artichokes or "sunchokes" are native North American plants that are grown for the white-skinned, white-fleshed, knobby tuber. In the home garden they can be as invasive as bamboo and must be controlled. Never plant in clay soil as it is impossible to wash the small particles of soil from around the knobs. Plant a bed of Jerusalem artichokes out of the way of the rest of the garden. They spread rapidly and can even take over an area if the tubers are not carefully and thoroughly dug since even a small part will regrow. Sunchokes will grow in containers and can be better controlled this way. Keep weeds under control by mulching, and water if weather is excessively hot or dry. Sunchokes are bothered very little by insects or disease. The knobby tuber flavor is best after a light frost in the fall, giving them a rich, nutty, sweet flavor with a texture similar to potatoes. Chokes can be left in the ground to be dug all winter or may be kept in a box of moist sand. The tubers should be washed and brushed off before cooking, not peeled. Jerusalem artichoke may be a good carbohydrate source for diabetics as it is completely starchless, storing carbohydrates as insulin which can be assimilated by diabetics. Like fruits, sunchokes store sugars as levulose, and they contain only one tenth the calories of white potatoes.

Common Problems

Diseases: Sunflower - rust, downy mildew, verticillium wilt. Jerusalem artichokes - few disease problems.

Insects: Sunflower - aphids. Jerusalem artichokes - no major pests.

Other: Sunflower - birds may beat you to the harvest of sunflower seeds.

Harvesting and Storage

Days to Maturity: 80 to 120 days (sunflower and Jerusalem artichoke).

Harvest: Sunflower: harvest when seeds in the center of each head are mature. The back of the head will turn greenish-yellow to yellow, and the bracts will turn brown. Cut with about a foot of stalk attached, and hang the head in a warm, dry place. Cheesecloth or other netting tied around the head will prevent seeds from falling to the floor.

Jerusalem artichoke: for best flavor, harvest tubers after first frost in the fall or about one month after yellow flowers have faded and plants begin to die. Tubers are irregular in shape and size. May be eaten raw or used in stir frys and casseroles.

Approximate Yields: Sunflower - 1 head per plant. Jerusalem artichoke - several tubers per plant.

Amount to Raise: Sunflower - 2 plants per person. Jerusalem artichoke - based on individual preference and space.

Storage: Sunflower - if picked before completely dry, hang the head by the stalk in an airy, dry place, such as a well-ventilated attic. When thoroughly dry, gently rub the seeds from the head, and store them in airtight containers.

Jerusalem artichoke - store in ground for digging as needed, or dig in fall and store in moist sand in cool temperatures.

Sweet Potatoes

Environmental Preferences

Light: Sunny.

Soil: Well-drained, medium-light, sandy loam, low organic matter.

Fertility: Low-medium.

pH: 5.2 to 6.5

Temperature: Warm to hot (70 to 85ºF).

Moisture: Drought resistant once established, excess moisture is not desirable during root enlargement.

Culture

Planting: Transplants or "slips" are set out after danger of frost is past and soil has warmed. "Slips" may be started from sweet potatoes five to six weeks before this date.

Spacing: 12 to 18 inches by 36 to 48 inches.

Hardiness: Tender annual.

Fertilizer Needs: Light feeder, excessive amounts of nitrogen will reduce yields, lower quality, or both.

Cultural Practices

Sweet potatoes need a long growing time and grow best in medium to light sandy soils which are well-drained and relatively low in nitrogen. Excess nitrogen and heavy applications of fresh animal manures cause long, spindly roots of low quality. Heavy tight soils cause misshaped roots.

There are two types of sweet potatoes, moist and dry. The moist-flesh or "yam" type is the most popular. Moist sweet potatoes may be bronze, red, pink, and orange. The dry, or firm-flesh type skin color vary from yellow to white.

Most home gardeners buy transplants or "slips" from a local plant grower. To produce transplants, bed potatoes in a greenhouse or hot bed five to six weeks before the setting date. Use only disease-free potatoes. Dip for five minutes in a borax solution (1 pound of borax to 6 gallons of water) before bedding. Bed roots side by side in 2 or 3 inches of sand. Ordinarily, 1/2 bushel will cover 8 to 10 square feet of bed surface and produce about 1000 transplants. Cover roots with 3 to 4 inches of sand. Keep bed warm (70 to 80ºF) and watered. Pull plants in about five to six weeks when rooted and about 6 to 8 inches tall.

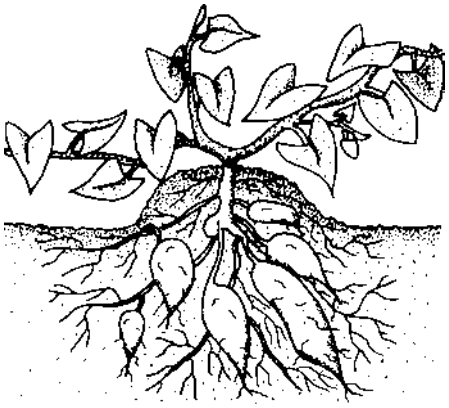
Shape rows into ridges about 10 inches high. Space them about 3 feet apart. Place transplants or "slips" 15 inches apart. A starter solution of 1/4 pound of 20% nitrogen fertilizer to 5 gallons of water, using one-half pint per plant, is recommended. Sweet potatoes grow until vines are killed by frost. Harvest the crop when the greatest number of 6- to 8-ounce potatoes are found in the hill by simple digging. Clip the vines before frost so the crop can be harvested easily with less damage to the potatoes. Immediately remove vines blackened by early frosts. Plow or spade out one row at a time and pick up the potatoes. Be sure potatoes are clean, dry, and free of injury before storing to reduce rotting. Handle gently to prevent bruising - do not throw or drop into crates.

Common Problems

Diseases: Several diseases affect sweet potatoes (use "certified" plants and rotate sites from year to year). Most prevalent are stem rot or wilt, black rot, scurf.

INSECTS: Flea beetles, sweet potato weevil.

CULTURAL: Long, stringy, rough, and irregular roots (heavy clay soils, poor drainage, excessive moisture), cracking and splitting (excessive moisture during three to four weeks before harvest).



HARVESTING AND STORAGE

DAYS TO MATURITY: 120 to 140 days from transplanting.

HARVEST: Roots should be dug so as to keep cutting and bruising to a minimum. Frost will kill the vines, but the potatoes should be dug prior to the first frost, since the dead vines can cause decay to spread to the roots. Maturity of the potatoes can be judged this way: a broken or cut surface dries on exposure to air if the potato is mature but remains moist and turns dark if it is immature. Dig anytime after they are mature but before a frost.

APPROXIMATE YIELDS: 8 to 12 pounds per 10 feet of row.

AMOUNT TO RAISE: 75 to 100 pounds per person.

STORAGE: "Cure" by keeping roots in a very warm place for two to three weeks at 80 to 90ºF, then store in warm (55 to 60ºF) dry (80 to 85% RH) conditions for four to six months.

Study Questions

91. Rhubarb roots should be divided after _____ years.

92. The parts of rhubarb that can be eaten are the _____and _____.

93. Summer squash grows on non-vining _____ while winter squash grows on _____.

94. Winter squash store better if: a) they are kept moist; b) they have some stem attached; c) they are refrigerated; d) they are immature

95. Sunflowers are grown for their _____ and ornamental purposes, while Jerusalem artichokes are grown for their edible _____.

96. Sunchokes should NOT be planted in:
a) full sun; b) clay soil; c) spring; d) containers

97. During root enlargement, sweet potatoes do not like excess:
a) moisture; b) mulch; c) sunlight; d) warmth

98. _____-type sweet potatoes have flesh color variation from bronze to orange while _____-type sweet potatoes have skin color variation from yellow to white.

Answers:
91 - five or more; 92 - petioles, leaf stalk; 93 - bushes, vines; 94 - b; 95 - seed, tuber; 96 - b; 97 - a; 98 - moist, dry

Tomatoes

ENVIRONMENTAL PREFERENCES

LIGHT: Sunny.

SOIL: Well-drained, loam.

FERTILITY: Medium-rich.

TEMPERATURE: Warm (70 to 80ºF).

MOISTURE: Moist, but not waterlogged.

CULTURE

PLANTING: Transplant after all danger of frost is past and when the soil has warmed.

SPACING: 18 to 36 inches by 36 inches if staked or caged.

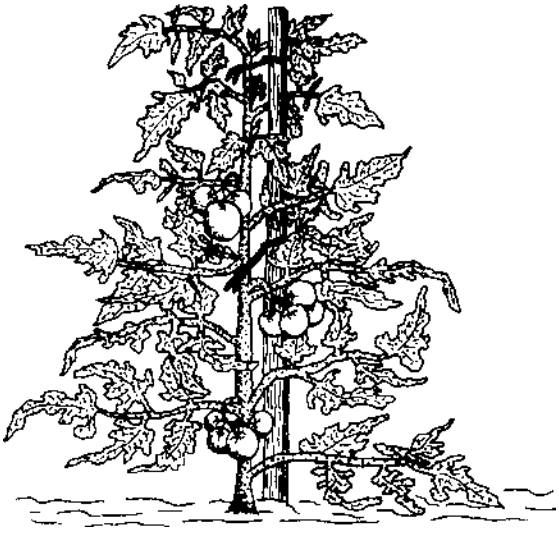
HARDINESS: Tender annual.

FERTILIZER NEEDS: Heavy feeder. Use starter solution for transplants. Sidedress one to two weeks after the first hand or cluster of tomatoes begin to develop with 3 tablespoons 33-0-0 per 10-foot row. Sidedress again two weeks after the first ripe tomato with a balanced fertilizer such as 5-10-5; repeat one month later.

CULTURAL PRACTICES

Tomatoes are valuable garden plants in that they require relatively little space for large production. Each standard tomato plant, properly cared for, yields 10 to 15 pounds

or more of fruit.



Choose varieties with disease resistance bred in for best results. Letters after the variety name indicate tolerance or resistance to the following:

- Fusarium Wilts Race 1(F)
- Early Blight (As)
- Fusarium Wilt Race 1 and Race 2 (FF)
- Bacterial speck [Pseudomonas] (B)
- Root-knot Nematodes (N)
- Septoria leaf spot (L)
- Tobacco Mosaic Virus (T)
- Stemphylium Gray leaf spot (St)
- Alternaria Stem Canker/Crown Wilt (A)

The varieties of tomato plants available may seem overwhelming to a new gardener; ask gardening friends for the names of their favorites. This will give you a good idea of what does well in Virginia. Several major types of tomatoes exist that can be chosen according to need:

Based on plant characteristics -

(a) Midget, patio, or dwarf tomato varieties have very compact vines best grown in hanging baskets or other containers. The tomatoes produced may be, but are not necessarily, the cherry type (1 inch diameter or less). Some produce larger fruit. These plants are usually short-lived, producing their crop quickly and for a short period.

(b) Compact or determinate tomato plants refers to the plant habit of growing to a certain size, setting fruit, and then declining. Most of the early ripening tomato varieties are determinate and will not produce tomatoes throughout a Virginia summer.

(c) Indeterminate tomato plants are the opposite of the determinate types. The vines continue to grow until frost or disease kills them. These are the standard, all-summer tomatoes that most people like to grow. They require support of some kind for best results, since otherwise the fruit would be in contact with the soil, thus susceptible to rot.

Based on fruit characteristics -

(a) Cherry tomatoes have small, cherry-sized (or a little larger) fruits often used in salads. Plants of cherry tomatoes range from dwarf (Tiny Tim) to seven-footers (Sweet 100). One standard cherry tomato plant is usually sufficient for a family, since they generally produce abundantly.

(b) Beefsteak type tomatoes are large-fruited types, producing a tomato slice that easily covers a sandwich, the whole fruit weighing as much as two pounds or more. These are usually late to ripen, so plant some standard-sized or early tomatoes for longest harvest.

(c) Paste tomatoes have pear-shaped fruits with very meaty interiors and few seeds. They are less juicy than standard tomatoes and are without a sizeable central core. Paste tomatoes are a favorite for canning since they don't have to be cut up and since they are so meaty.

(d) Color of tomatoes include orange, yellow, pink, or striped, and often the only way to get a specific one is by growing your own. Most are heritage varieties obtained through seed-saver groups. Tests have shown that there is no relationship between color and acidity of tomatoes.

(e) Winter storage tomatoes are a relatively new item for gardeners. The plants are set out later in the season than most tomatoes and fruit are harvested partially ripe. If properly stored, they will stay fresh for twelve

weeks or more. While the flavor does not equal that of summer vine-ripened tomatoes, many people prefer them to grocery store tomatoes in winter.

Tomato plants may be started indoors from seed or transplants may be purchased. If starting your own plants, use a light soil mix and give the plants plenty of light. Tall, spindly transplants are usually caused by low light levels in the home. Unless you have a sunny, south-facing window, supplemental light will probably be necessary. The seed are sown six to eight weeks before the last frost date in your area. A few weeks before transplanting time, harden-off indoor grown plants by exposing them to an increasing number of hours outdoors each day. Bring plants in if there is danger of frost. A few varieties of tomato (the sub-arctics) are bred to grow well in low spring temperatures; however, these are rarely available in the usual markets and ordinarily must be grown from seed.

When you are ready to put home-grown or purchased plants into the ground, select stocky transplants about 6 to 10 inches tall. Set tomato transplants in the ground covering the stems so that only two or three sets of true leaves are exposed. Horizontal planting of tomato plants is an effective way to make plants stronger, especially leggy ones. Roots will form along the buried portion of the stem, giving better growth and less chance of plant injury from a too-weak stem. Do not remove the containers if they are peat or paper pots, but open or tear off one side to allow roots to get a good start. If non-biodegradable containers are used, knock the plants out of the pots before transplanting, and loosen the roots somewhat. Press the soil firmly around the transplant so that a slight depression is formed for holding water. Pour approximately one pint of starter solution or dilute fish emulsion around each plant to wash the soil around the roots.

Plants should be staked or caged. Though it requires more initial work, this makes caring for tomatoes easier than letting them sprawl. Since they are off the ground, fruit rots are reduced, spraying is easier and may be required less, and harvesting is much less work. For staking, space them 24 inches apart in rows 3 feet apart. Use wooden stakes 6 feet long and 1-1/2 or 2 inches wide. Drive them 1 foot into the soil about 4 to 6 inches from the plant soon after transplanting. Attach heavy twine or strips of cloth to the stakes every 10 inches. As the plants grow, pull the stems toward the stakes and tie loosely. Prune staked tomatoes to either one or two main stems. At the junction of each leaf and the first main stem a new shoot will develop. If plants are trained to two stems, choose one of these shoots, normally at the first or second leaf-stem junction, for the second main stem. Remove all other shoots, called suckers, weekly to keep the plant to these two main stems. Pinch shoots off with your fingers. Tomato plants may also be set along a fence or trellis and tied and pruned in a manner similar to that used with stakes.

Growing tomatoes in wire cages is a method gaining in popularity among gardeners because of its simplicity. Cage growing allows the tomato plant to grow in its natural manner, but keeps the fruit and leaves off the ground, offering the advantages of staking as well. Using wire cages requires a large initial expenditure and a large storage area, but many gardeners feel that the freedom from pruning and staking is worth it. The cages, if heavy duty, will last many years. Be sure to get fencing with at least 6 inch spacing between wires so that you can get your hand inside to harvest the tomatoes. If tomato plants in wire cages are pruned at all, once is enough; prune to three or four main stems. Wire-cage tomatoes develop a heavy foliage cover, reducing sunscald on fruits and giving more leeway when bottom leaves become blighted and have to be removed. Many staked plants are nearly naked by late summer. Caged plants are less prone to the spread of disease from plant handling, since they do not have open wounds and must be handled less frequently than staked plants. However, it helps to space the plants somewhat further apart (3 feet is good) to allow good air circulation between plants; humidity is higher because of the foliage density, and diseases, such as late blight, spread rapidly in humid situations. If well-nourished and cared for, caged tomatoes can produce exceptional harvests and make up for the extra space with high production. This type of culture is especially suited to indeterminate varieties.

Common Problems

Diseases: Early blight, septoria leaf spot, verticillium and fusarium wilts, late blight, tobacco mosaic virus, bacterial spot.

Insects: Flea beetle, hornworm, stink bugs, Colorado potato beetle, fruitworm, aphids, mites, whiteflies, cutworms, Japanese beetles.

Other Pests: Nematodes.

Cultural: Blossom-end rot, irregular soil moisture or calcium deficiency; poor color, yellow spots or

large whitish-gray spots, sunscald from lack of foliage cover; leaf roll, physiological condition often found in pruned tomatoes; fruit cracking, irregular soil moisture; black walnut wilt, caused by roots of tomato plants coming in contact with toxin from black walnut tree.

Harvesting and Storage

Days to Maturity: 55 to 105 days.

Harvest: Harvest fully vine-ripened but still firm. Picked tomatoes should be placed in shade. Light is not necessary for ripening immature tomatoes but it is necessary for color development. Some green tomatoes may be picked before the first killing frost and stored in a cool (55ºF), moist (90% relative humidity) place. When desired, ripen fruits at 70ºF.

Approximate Yields: 15 to 45 pounds per 10-foot row.

Amount to Raise: 20 to 25 pounds per person if used fresh; 25 to 40 pounds for canning.

Storage: Medium-cool (50 to 70ºF), moist (90% relative humidity) conditions for one to three weeks for green tomatoes.

Cool (45 to 50ºF), moist (90% relative humidity) conditions for four to seven days for ripe tomatoes.

Preservation: Can or freeze as sauces or in chunks (whole or quartered), peeled.

Culinary Herbs

Herbs have been used for seasoning, medicine, fragrance, and sorcery for thousands of years. Among the legendary varieties are henbane and mandrake for witches' spells, St. Johnswort for casting out evil, comfrey for healing, and alchemilla (lady's mantle) for gold. Each leaf of the Alchemilla gathers a drop of dew during the night; it was believed that if the drops were gathered and used properly, they would facilitate the process of alchemy - the making of gold from base metals. Tarragon, rosemary, and thyme are among the most ancient of seasonings, yet there are few culinary achievements that can top good poultry roasted with these three herbs.

Most herbs can be grown successfully with a minimum of effort. Several are drought-tolerant, some are perennials, and many are resistant to insects and diseases. They are versatile plants, providing flavors for seasoning food and fragrances for room-freshening potpourri. And with their enticing scents, diverse textures, attractive shapes, and countless shades of green and gray, herbs are often used to make a landscape that appeals to the senses of touch and smell as well as sight.

The classic use for herbs in the landscape is the formal garden. Many intricate designs have been drawn and planted using the beauty of herb plants to enhance the pattern of the garden; diamonds, compasses, and knots are among the most popular designs. The knot garden is especially intriguing; herbs with various textures and colors are planted carefully and trimmed neatly to create the appearance of ropes looping over and under each other. The effect is striking, especially when viewed from an upper-story window. Theme gardens are also popular. There are Biblical gardens, scent gardens, tea gardens, witch's gardens, kitchen gardens, and apothecary gardens, to name a few.

Site

When selecting a site to plant your herbs, keep in mind that most culinary herbs are native to the Mediterranean region and therefore prefer full sun, good air circulation, and well-drained soil.

Start with a small herb garden that can be easily constructed and maintained, but leave space around it so that you can plan its expansion during the long, cold months of winter. Choose a soil that is fertile and loamy for best results; although many of the herbs will live in poor ground, for the healthiest plants and best harvest, they need good soil to thrive. Most herbs require a soil pH of 6.3 to 6.8 for optimum growth, but lavender prefers a pH of 6.5 to 7.0.

Prepare the soil to a depth of 8 inches. If it is heavy or has poor drainage, amend it with composted organic matter. Raised beds are an excellent solution to this problem. Fill them with a mixture of the heavy soil and the suggested amendments, or use a pre-mixed, soilless potting medium.

Plant perennial herbs in an area that will not be disturbed by tilling. Those that spread by runners, such as the mints, should be given a large, isolated area or must be contained in some fashion (to a depth of 10 to 12 inches) to prevent them from taking over the garden.

Some tender perennials need protection from winter winds. Plant on an eastern exposure, if possible. Evergreen trees and shrubs can be used to break the wind and create a "microclimate" for the herbs. Rocks are often

incorporated into the design of herb gardens to provide focal points and windbreaks and to help keep roots cool and moist during the heat of summer.

Propagation

Annual herbs are best started from seed. When starting small seeds indoors, the easiest method is to sow them directly into peat pots filled with seed-starting mix, about six weeks before the last frost date. Cover seed with a thin layer of moist seed-starting mix or milled sphagnum moss. Later, thin the seedlings to four or five per pot. Larger seeds may also be started by this method, then thinned to one plant per pot. Keep the soil surface moist by misting with a spray bottle until the plants are established.

Although many perennial varieties may be started from seed, it is much easier to get plants from your local nursery or a reputable mail-order company. In addition, many culinary herbs, such as tarragon, can only be propagated asexually; seed-grown plants lack the oils that give them flavor. Propagate them from root divisions or cuttings taken in the summer, after new growth has hardened. Root cuttings in a window box or some other suitable container, preferably covered with plastic to maintain high humidity. About 5 inches of clean, coarse sand is a good rooting medium. Keep the sand moist and out of direct sunlight when the plants are young. In four to six weeks, move the plants to pots or cold frames for the winter. Transplant all herb plants after danger of severe frost. Control weeds during the growing season to prevent competition for water and nutrients which are needed by your herbs. A light mulch (about one inch) will conserve soil moisture and help control weeds.

Most of the herbs that have a mature height under 12 inches may be grown in 6-inch pots as indoor plants. There are many dwarf varieties of the larger herbs that would be appropriate indoors, as well. Basil 'Spicy Globe,' dwarf sage, winter savory, parsley, chives, and varieties of oregano and thyme are some of the best for windowsill culture. When given proper care in a sunny window, they will supply sprigs for culinary use through all seasons. When cooking, use greater quantities of fresh herbs; although they often have better flavor than dried herbs, they are usually not as strong.

Culture

Although many herbs are considered drought-tolerant, some moisture is needed to maintain active growth. For a continual supply of fresh-cut herbs, periodic irrigation during dry periods is needed. As with all plants, a thorough watering with a period of drying is preferred over frequent sprinkling. Annual herbs require a higher level of available soil moisture than most perennial herbs.

Proper nutrient balance is very important. Weak, succulent growth can be caused by over-fertilization, making the plant susceptible to disease and insect pests. Rapid growth also dilutes the concentration of essential oils that impart the distinctive flavor to the culinary herb. Inadequate fertilizer can severely limit new growth, predisposes the plant to insect and disease problems, and increases the susceptibility of tender perennials to winter injury. A light application of fertilizer to perennials in early spring should promote new root and shoot growth and ensure vigor in the new growing season. Generally, adequate herb growth can be achieved with 1/4 to 1/2 the nitrogen recommended for vegetables in your area. Sequential harvests of annual herbs will be facilitated by light applications of fertilizer after each heavy harvest.

The high concentration of essential oils in healthy, actively growing herbs repels most insects. However, aphids and spider mites can be a problem. Aphids seem to be more prevalent in crowded conditions with rapidly growing, succulent plants. Spider mites thrive in dry conditions and can be controlled by spraying the plants with plain water at regular intervals, especially during periods of drought. Since there are very few labeled pesticides for use on herbs, the best defense against pests is preventative cultural management, such as good sanitation, removal of weak or infested growth, and regular pruning.

Periodic, judicious pruning promotes vigorous, sturdy plants that are less susceptible to disease and winter injury. If they are allowed to grow unchecked, some herbs will take on a gangly, unkempt appearance. If you are lavish in your use of herbs, regular harvesting for use in cooking, potpourri, and flower arrangements should keep your herbs sufficiently pruned.

Harvesting

It is best to harvest your herbs in the morning, just after the dew has dried, but before the sun gets hot. The concentration of essential oils is highest at this point. Harvest your herbs for fresh use all season, but for drying, cut just before the plants bloom. This will ensure the maximum concentration of essential oils. When harvesting, cut just above the first joint of tender growth

- it takes the plant longer to send out new shoots from woody growth.

Stop making large harvests of the perennial herbs in late summer or fall. This will allow time for new growth to harden and gather carbohydrates in preparation for winter. However, small harvests can be made during most of the fall. Sage flavor may actually be improved by two or three frosts prior to harvest.

If you are interested in saving seed for the next season, choose one or two plants of each variety and allow them to bloom and go to seed. Harvest the seed heads when they change from green to brown or gray, and dry them thoroughly to ensure a good germination rate.

Drying

The best dried herbs are those that have been dried rapidly, but without excessive heat or exposure to sunlight.
When harvesting to dry, it is often necessary to spray the plants with a garden hose the day before cutting to clean dirt and dust off the leaves. The next morning, after the leaves have dried, make your harvest. Remove dead or damaged leaves and make small bunches of the herbs. Tie the stems together and hang them in a temperate, well-ventilated, darkened room that has little dust. Label each bunch, since several of the herbs look similar when dried.

Herbs may also be dried by removing the leaves and spreading them in a single layer on cookie sheets or foil, though it is preferable to use trays made of window screening for maximum air circulation. Again, remember to label the different varieties for accurate identification after drying.

Herb leaves are dry if they crumble into powder when rubbed between your hands. When the drying process seems to be complete, fill a small, glass container with the herb and seal. Put it into a hot oven for about 15 minutes or microwave it (don't use a metal cover!) for about 5 minutes, then check for condensation on the inside of the jar. If there is moisture present, let the rest of the herbs dry some more; if your harvest is not completely dry when stored, it may succumb to molds. If necessary, herbs may be dried on cookie sheets in an oven set for 110ºF or less, though there is some loss of essential oils using this method.

When completely dry, store whole leaves in air-tight containers, preferably of dark glass or some material that will not let in light, in a cool to temperate place out of direct sunlight. This will ensure good flavor and color in your seasonings. To conserve essential oils, do not crush the herb until you add it to your cooking.

Study Questions

99. Standard tomato plants, properly cared for, yield _____ pounds or more of fruit.

100. _____ tomatoes continue to grow after fruiting until frost or disease kills them.

101. The preferred site requirement for most culinary herbs includes: a) full sun; b) good air circulation; c) well-drained soil; d) all of the above

102. Annual herbs are best started from _____.

103. The best time to harvest herbs to take full advantage of the presence of essential oils is in the: a) spring; b) morning; c) fall; d) evening

Answers:
99 - 10 to 15; 100 - indeterminate; 101 - d; 102 - seed; 103 - b

Organic Gardening/Landscaping

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Herb Culture and Use Chart

Common Name	*Scientific Name*	*Height (inches)*	*Plant Spacing (inches)*	*Cultural Hints*	*Uses*
Annuals					
Basil	*Ocimum spp.*	20-24	12	Grow from seed. Sun.	Use in anything with tomatoes.
Borage	*Borage officinalis*	24	12	Grow from seed, self-sowing. Best in dry, sunny areas.	Young leaves in salads for cucumber flavor.
Chervil	*Anthriscus cerefolium*	10	3-6	Sow in early spring. Partial shade.	Aromatic leaves used in soups and salads.
Coriander	*Coriandrum sativum*	24	18	Grow from seed. Sow in sun or partial shade.	Seed used in confections, leaves in salads, oriental and eastern food.
Dill	*Anethum graveolens*	24-36	12	Grow from seed, sow in early spring. Sun or partial shade.	Feathery foliage and seeds used in flavoring and pickling.
Parsley	*Petroselinum spp.*	6	6	Grow from seed, start in early spring. Slow to germinate. Sun. Biennial.	Brings out flavors of other herbs. High in vitamin C.
Perennials					
Catnip	*Nepeta cataria*	3-4	18	Hardy; sun or shade. Grow from seed or by division.	Leaves for soothing tea.
Chives, Garlic Chives	*Allium spp.*	12	12	Little care. Divide when overcrowded. Grow from seed or by division.	Good indoor pot plant. Cut long strands at base; mild onion or garlic flavor
French Tarragon	*Artemesia dracunulus*	24	24	Sun or semi-shade. Grow from cuttings or division.	Aromatic seasoning; principle flavor in bearnaise sauce; great with fish or chicken
Lavender	*Lavendula spp.*	24	18	Propagate from cuttings. Grows in dry, rocky, sunny locations with plenty of lime in the soil. Requires pH 6.5 to 7.2.	Use for sachets, potpourri.
Lemon Verbena	*Aloysia triphylla*	36	36	Tender perennial; propagate from cuttings. Sun or partial shade.	Strongest lemon scent. Used in teas or potpourri.
Lovage	*Levisticum officinale*	3-4 feet	30	Rich, moist soil. Grow from seed planted in late summer. Sun or partial shade.	Of the carrot family; strong celery flavor.
Mints	*Mentha spp.*	1-3 feet	18	Grow from cuttings or division. Sun or partial shade.	Aromatic; used as flavoring. Unusual varieties include orange, blue balsam, ginger, chocolate.
Oregano	*Origanum spp.*	24	9	Grow from seed, cuttings, or division. Sun.	Flavoring for tomato dishes, pasta.
Rosemary	*Rosmarinus spp.*	3-6 feet	12	Grows in well-drained nonacid soil from cuttings. Sun. Marginally hardy; plant in protected site.	Leaves flavor sauces, poultry, meats, rice, and soups. Good for topiary, bonsai.
Sage	*Salvia spp.*	18	12	From seed or cuttings. Sun. Renew every 3-4 years.	Seasoning for meats, especially pork; herb teas.
Thyme	*Thymus spp.*	8-12	12	Light soil, well-drained. Renew every 2-3 years. Grow from cutting or division. Sun.	Aromatic foliage for seasoning. Varieties include lemon, orange, nutmeg, and wooly.

Traditional Gardening Perspective

"There are no green thumbs or black thumbs. There are only gardeners and non-gardeners. Gardeners are the ones who ruin after ruin get on with the high defiance of nature herself, creating, in the very face of chaos and tornado, the bower of roses and the pride of irises." - The Essential Earthman, *Henry Mitchell, 2003*

Organic Gardening Perspective

"Organic is an overriding philosophy of living which assumes that we are part of an integrated ecosystem, with a set of principles that are Nature's not man's." - The New Organic Grower, *Eliot Coleman, Chelsea Green, 1989*

The term "organic" is used frequently to describe various gardening and landscaping practices as well as numerous products available for sale. There are some misconceptions about just what the term means as well as much misinformation about what constitutes organic gardening. Most often the word "organic" is used to describe a no-pesticide gardening system or a no-chemical system. This is not always the case. The purpose of this section is to define what "organic" means and to describe the practices and principles used in effective organic gardening systems.

Organic Defined

Finding a reliable, consistent definition of organic gardening is a challenge in itself. There are so many perceptions of what is involved in an organic system that finding a general consensus is difficult.

The Merriam-Webster Dictionary defines organic as "Food grown or made without the use of artificial chemicals."

The US Department of Agriculture defines organic products as food or other agricultural products that have been produced through approved methods that integrate cultural, biological, and mechanical practices that foster cycling of resources, promote ecological balance, and conserve biodiversity. Synthetic fertilizers, sewage sludge, irradiation, and genetic engineering are not to be used. (U.S. Department of Agriculture, National Organic Program). More specifics about the program can be found here: http://www.ams.usda.gov/about-ams/programs-offices/national-organic-program

According to the USDA National Organic Standard Board, organic agriculture:

* Is an ecological production management system that promotes and enhances biodiversity, biological cycles, and soil biological activity;
* Is based on minimal use of off-farm inputs and on management practices that restore, maintain or enhance ecological harmony;
* Has a primary goal of optimizing the health and productivity of interdependent communities of soil life, plants, animals and people.

Reading through these and many other definitions the impression begins to evolve that organic gardening and landscaping is a very complex approach to sustaining plants by developing and maintaining an ecosystem that promotes plant health and vigor. Next, we will cover two of the most common certification programs, just to understand how wide the difference in programs can be.

Certified Organic, USDA

The National Organic Program (NOP) is the federal regulatory framework governing organic crops and other Agricultural products. This program was enacted into law by Congress in October 2002. It is administered on the national level by the U. S. Department of Agriculture (USDA) and in Virginia it is administered by the Virginia Department of Agriculture and Consumer Services (VDACS). This program is closely related to the Organic Food Production Act of 1990 (7 U.S.C.A. § 6501-22) that required that the USDA develop national standards for organic products. The regulations (7 C.F.R. Part 205) are enforced by the USDA through the National Organic Program under this act.

Under these regulations any producer who markets any products as "Organic" must first obtain certification to make this claim. This is a long and difficult process that investigates every aspect of the production process to ensure that all organic guidelines are followed. The elements that are examined include soil management, soil amendments, plant management, seed and plant sources, chemicals including pesticides and fertilizers, and anything else that comes in contact with the plants or otherwise influences plant growth. Since past treatments of the soil determine if the land is suitable for organic production the producer must provide documentation that no synthetic products of any kind were applied to the soil for 3 years prior to any harvests. Both approved and non-approved substances are listed in Title 7, part 205 of the

NOP regulations.

The certification process in Virginia involves reviews of producer records and on-site investigations to verify the organic claim. These certifications are performed by an independent certifying agency. The USDA does inspections and investigates complaints. Certified Organic can apply to almost any agricultural product including fruit and vegetables, meats, eggs, dairy products, lumber, tobacco, and Christmas trees. To be certified as organic, at least 95% of the inputs and production methods must be organic.

Organic producers who have gross sales of less than $5,000.00 per year are not required to obtain the organic certification. However, they cannot sell their products as "Certified Organic" but can only label their goods as "Organic." They must adhere to approved organic agricultural production methods.

Certified Organic vs. Certified Naturally Grown

As stated above, Certified Organic refers to agricultural products that are produced within the strict guidelines of the National Organic Program (NOP) administered by the U. S. Department of Agriculture. There is no such law nor are there strict guidelines that govern the production of Certified Naturally Grown agricultural products. The term Natural is not regulated by the government and there can be a lot of interpretation of just what the term signifies.

Certified Naturally Grown

There is at least one privately run organization that caters to producers who do not wish to participate in the NOP program. This organization offers a certification program that employs a number of the NOP guidelines. Certified Naturally Grown (CNG) is a non-profit organization offering certification tailored for small-scale, direct-market farmers and beekeepers using natural methods (http://www.cngfarming.org/). Certified Naturally Grown minimizes the necessary paperwork and relies on annual peer inspections versus inspections run by the state. The CNG program favors smaller producers who do not want the burden of obtaining and maintaining a NOP certification. The CNG program has adopted the lists of permitted and non-permitted substances used by the Organic Certification program in Title 7 part 205 of the NOP as a part of their guidelines for certification.

There are significant differences between the two certifications. The CNG program relies entirely on peer review of growing practices and does not include certified inspectors nor does it include paperwork evidence to support the growers' claims. The inspectors can include other CNG farmers, non-CNG farmers, extension agents, and customers. The NOP Organic Certification uses a USDA-accredited certifying agency (VDACS) and third-party inspectors who are trained for the certification process to review all aspects of the agricultural production process and review all of the paperwork required to prove the growers' claims that their products are in accordance with NOP standards.

It is difficult to say that one program should be preferred over the other and in most cases the Certified Naturally Grown label identifies agricultural products that are grown without many of the commonly used synthetic fertilizers and pesticides. However, the Certified Organic label on products clearly identifies that these products were produced under closely regulated and clearly defined farm or garden operations.

Products may be marketed as Naturally Grown without any certification whatsoever. These producers and their products are not subject to regulation by any government agency nor are they governed by voluntary membership

in a private certification organization. In this case the definition of Naturally Grown is left to the producers' own interpretation of the term. Thus, it is important to understand the difference between the varying certification programs.

Study Questions

104. Which government agency oversees Certified Organic products? a) U.S. Department of Forestry, b) U.S. Department of Agriculture, c) U.S. Department of Commerce, d) all of the above play a role, e) none of the above.

105. Which government agency oversees Certified Naturally Grown products? a) U.S. Department of Forestry, b) U.S. Department of Agriculture, c) U.S. Department of Commerce, d) all of the above play a role, e) none of the above.

106. Organic means: a) an ecological production management system, b) no synthetic chemicals used for pest mast management, c) maintains an ecosystem that promotes plant health and vigor, d) all of the above.

Answers: 104 - b; 105 - e; 106 - d.

Building the Organic Garden Soil

Starting from scratch to build an organic soil is a simple task but it can take time to complete. Depending on the present condition of the soil this task can take months or even years until a satisfactory soil has been developed.

The first step is to know what is there to start with. This means a soil test must be performed to measure fertility and pH levels to determine what adjustments, if any, will need to be made to the soil chemistry. In addition to the traditional soils test a second level of testing will be needed. At the bottom of the Soil Sample Information Sheet (VCE Publication 452-126) just under the box marked Routine there is another box marked Organic Matter. Both the Routine and the Organic Matter boxes should be checked. This will provide a sample result that also measures the amount of organic material already in the soil, expressed as a percentage. Remember that the soils are tested based on what types of plants will be produced in that soil so this will need to be determined prior to taking the sample.

The next step is to learn what the plants will need for the soil in an organic gardening system. In most cases the basic needs for nutrients and pH levels will be the same. It is important to remember that the purpose of this sample is to build the soil to support the health and vigor of the plants, not to simply determine how much lime and fertilizer to use.

Next, start building the soil by incorporating organic materials such as compost, manure, crushed limestone, and other materials to bring the soil up to the level needed to support the plants. In many cases the materials can be spread on top of the soil and then worked in, down to a depth that will be slightly below the anticipated root depth for the desired plants. This practice of incorporating organic material into the soil never ends. Organic material improves the soil as it breaks down and therefore becomes depleted. It must be replaced often to continue to achieve the benefits for plant growth. The frequency of adding organic material depends on the soil type and the climate. A simple guideline to use at the beginning is to add it annually then adjust the schedule as needed.

Periodic re-testing will be needed to track the progress toward the desired soil composition. Once that level has been achieved the soil will still need to be tested every 3 years to maintain everything at the correct level.

As an aside, it is important to note that under the rules of the USDA Certified Organic program, land must not have man-made fertilizers or synthetic pesticides applied to that property for at least three years before the crops and produce can be certified as organic. Organic farms maintain buffers between certified organic fields and conventional production fields. Local conditions and the individual doing the organic certification determine the width of buffers.

Soil Amendments

Compost

Compost is one of the primary soil amendments that organic gardeners rely upon. Most organic gardeners prefer to make their own compost to insure that only organic materials go into the mix. This helps to avoid accidental introduction of pesticides and other synthetic materials that may come from unknown sources. Composting is covered in detail in another chapter in this handbook but there are some considerations that are specific to organic gardening that should be remembered

when making compost at home.

Organic compost is characterized by the addition of organic waste products only. Compost that is from plant parts that have been treated with synthetic fertilizers, pesticides, and other man-made chemicals cannot be used in an organic system (however, these products can be composted in Certified Organic Production). These materials can be composted, but this should be done in a different location and should not be mixed with the compost that is intended for use in an organic garden. Many household waste products that are bought from the grocery store should not be used in organic compost unless they were labeled as certified organic at the store. This includes banana peels, egg shells, fruit peelings, and other produce. (Again, as an aside, these products can be composted in Certified Organic Production)

Manure

Manure is another soil amendment used by organic gardeners but this too needs to be scrutinized. The NOP standard does not permit human sludge from waste treatment plants to be used in organic production. Sludge is composed of whatever people flush down their toilets and pour down their kitchen sinks. Since there is no certainty as to what is in the sludge it should not be used. Animal waste is most often used in organic systems but it should come from animals fed with organic feed and raised under organic guidelines to prevent accidental introduction of unwanted chemicals into the system. The animal waste should be well composted before it is used or it should be applied no sooner than 120 days prior to any harvest according to NOP standards. Poultry litter, for example, is a source of nitrogen, and can be used if the poultry itself was produced by accepted organic methods.

As is often the case, a soil test will point to a need for additional fertilizer or other products to provide the correct soil chemistry for the type of plants being grown. One common misconception in organic gardening is that these soil additives cannot be bought and must be made by the gardener. It is very important to learn to read labels where gardening products are sold. There are many products that are organically derived and these will be labeled as organic. For example, there are natural sources of important nutrients such as nitrogen, phosphorous and potassium. Most of these products, if labeled as organic, are produced from naturally occurring minerals in nature such as rock with high concentrations of these elements, animal waste, or wood ash.

Organic Materials Review Institute

The Organic Materials Review Institute (OMRI) is an independent nonprofit that reviews materials and certifies them as meeting organic standards. In many stores products with an OMRI label are sold (http://www.omri.org/). OMRI products may be used in Certified Organic production and processing of foods, feeds, pesticides, etc. In the example given earlier, the crushed limestone may have an OMRI label and the pelleted limestone may not. If the manufacturer of the pelleted limestone wanted to have an OMRI label on their product, they then could apply to OMRI to certify that their product is produced in a sustainable way that complies with OMRI and Certified Organic standards. OMRI may ask them to change a product or a process in order to be able to put the OMRI label on their product. The company producing the pelleted limestone would pay a fee to OMRI. Once the changes had been made, the pelleted limestone could then have an OMRI label and a consumer would know it was produced in a sustainable way and a farmer or grower could use that product and keep their farm's Organic Certification.

Study Questions

107. One of the best ways to add organic matter to soil is with _____.

108. Fresh manure can be harmful because: a) It has a high concentration of salts and nitrogen, b) can cause bacterial contamination of food crops, c) it cannot be harmful, it is beneficial, d) both a and b.

109. OMRI stands for _____ _____.

110. Heavy clay soils are best amended with: a) sand, b) compost, c) perlite, d) vermiculite, e) none of the above.

Answers :
107 - compost; 108 - d; 109 - Organic Materials Review Institute; 110 - b.

Plant Health Management

Organic Gardening Perspective (From www.ibiblio.org; UNC Chapel Hill)

"Chronic problems with pests or diseases are symptoms of crop failure and not the cause." Crop or garden failures

are usually caused by :

* Poor soil
* Poor plant selection
* Poor plant placement
* Faulty watering or feeding practices
* A fouled ecosystem

All of these are the result of the gardener's cultural practices. We have defined organic gardening as the "kind of gardening that employs environmentally friendly materials and environmentally friendly cultural practices."

In an organic gardening system, there are no quick fixes to plant health problems. Traditional gardening methods can utilize synthetic fertilizers and pesticides to correct problems quickly but these options may not be available to the organic gardener.

Many garden and landscape pests can be prevented by maintaining plant health, and the organic gardener takes a pro-active approach to managing plant health. Healthy plants can utilize their own internal defenses to repel insects and to prevent disease pathogens from becoming established in the various plant tissues. Plants that are weak and/or unhealthy will attract pest problems. Therefore it is important to follow an effective strategy in establishing healthy plants and monitoring plant health to keep the impact from plant pests to a minimum.

Many plant health issues are dealt with through cultural practices, often done well in advance of the occurrence of pest and nutrient problems. The gardens are managed in such a way as to prevent these problems from occurring in the first place. These cultural best management practices are often found in both conventional gardening techniques as well as organic gardening, and should not be viewed as exclusive to one of the other. These strategies will utilize plant selection, proper planting methods, pest monitoring, sanitation, and when necessary various control methods.

Employing proven cultural practices in the garden has been proven through research to reduce or avoid plant health woes has been covered in detail throughout this handbook. The organic gardener uses this information to enhance the garden production while avoiding the use of synthetic agricultural chemicals. There are numerous plant problems that will still arise and will need to be dealt with depending on weather conditions and what is happening on surrounding lands but being pro-active toward plant health in general will make the task easier.

The following are a few practices the organic gardener may employ as cultural practices in the garden.

Plant selection

Select and use only those plants that will grow in the prevailing climate conditions for the location of the site. Plants should be listed in the local USDA Hardiness zone. Plants should be known to thrive in the soil moisture and sunlight conditions for the planting site. Use a soil test to determine if the present soils are adequate for the plants desired or if soil amendments will be needed. If soil amendments are needed then it will be necessary to maintain amendments throughout the life of the plant.

When selecting plants, inspect each one carefully. Look for any evidence of unwanted insects such as egg masses, cocoons, or the insects themselves. Also look for signs or symptoms of diseases such as dark spots on foliage, odd growths on the stems, open wounds, or evidence of rot. Reject any plants that seem to be "off-color", wilted, or simply do not appear to be healthy. Learn which insects and disease pathogens are like to be encountered in the area and select plant varieties that have been bred with resistance to these pests if any are available.

Resistant species/cultivars

The horticulture and agricultural community is continually working to create new varieties and cultivars of favorite plants that are resistant to pests that are common to that species of plant. These resistant specials and new cultivars are developed through traditional breeding programs where many plants with diverse genetics are grown and offspring that are resistant to disease or pests, or have larger or better fruit are selected. Sometimes two cultivars are crossed each year and seed is produced. These seeds produce a hybrid variety. The seeds will not come true if collected and planted the following year.

When selecting new plants for the garden or landscape try to select from these new verities as much as possible to avoid the use of pesticides.

It is important to note that Certified Organic production does not allow growers to use genetically modified organisms (GMO). GMO crops have had the genes of

another variety or another species spliced into their DNA. This is usually done to help convey some pest resistance or herbicide tolerance for a crop. As with any breeding program, genes and traits remain with the variety from that point forward.

Soil management

To grow healthy plants there must be a healthy root system. One key to a healthy root system is a healthy soil. Manage the soil to optimize its benefits for the specific plants that will be grown. This is normally done with amendments such as compost and lime to improve structure, drainage, moisture holding ability, and pH. Cover crops such as grains and legumes are used to protect the soil when there is no crop present and these can be incorporated into the soil to add nutrients and organic matter or can be mowed and left in place to serve as an organic mulch.

Water Management

Many plant health issues arise from improper use of water. Too little or too much water can both lead to planting failures, plant diseases, and plant stress that will attract insect pests. It is important to learn what the moisture requirements are for the plants being grown and then manage the water that is being made available to those plants. It is important to remember that the soil structure influences the water available to the plants' roots and incorporate this knowledge into the irrigation schedule.

Irrigation

Irrigating in the early morning will not only reduce evaporative moisture lost, it will also reduce the chances of foliar diseases in the garden. Watering in the morning will allow the leaves to dry more quickly as the weather warms up. Watering in the evening will allow the foliage to stay wet for a longer period of time and that may help in the development of a disease pathogen.

Also, it is important to try to avoid wetting the foliage when irrigating. The water must go into the soil to be taken up by the plants' roots. Keeping the foliage dry will help to prevent many diseases such as Septoria leaf spot and Early Blight on tomatoes for example.

Proper Planting practices

Whether planting seeds, seedlings, container grown plants, or balled & burlap specimens be sure to plant at the right time of year and under the right conditions. Follow closely all of the guidelines for correct planting such as depth and spacing. Pay close attention to the roots as this is the only time this most important part of the plant will receive very much attention. Planting properly will help to get the plants off to a good start and will increase the chances of better plant health throughout the life of the plant.

Plant spacing

Proper spacing of new plants is critical to their health. Planting too close will reduce air circulation between plants and can lead to intense below ground competition for growing space among the roots. Both of these can place the plants under stress. Be certain to learn the proper spacing between plants and follow that guideline. For perennial plants the spacing should be based on the mature size of the plants.

Plant location

The garden needs to be planned to take full advantage of the growing conditions available. Rows and individual plants should be arranged to take advantage of prevailing winds, direction of sunlight, and movement of water both above and below ground. Tall plants should be sited so they do not interfere with the sunlight requirements of smaller plants.

Air circulation

Good air circulation in around plants has been proven to reduce the incidence of disease. It is important to use proper spacing between plants, as recommended by the seed or seedling producer, to accomplish this. It is okay to plant on a wider spacing than recommended but it is not okay to plant closer together unless an intensive gardening method, such as raised beds, is being used.

Companion Planting

Over the centuries of gardening, there has been a lot learned about how plants interact with each other and their environments. One thing that has been learned is that some plants will grow and produce better if they are in close proximity with certain other plants. The plants can attract pollinators better if they work together, some plants will attract insect predators to aid in pest prevention, and some plants repel some types of insect pests. These plants are known as companion plants. One of the first demonstrations in this country occurred when the Native Americans introduced the Pilgrims to a planting method that grouped beans, squash, and corn in hills together so that the plants could provide mutual benefits to each other which resulted in an overall increase in fruit production. A second example of this is the practice of planting

marigolds near garden vegetables. The marigolds can help to attract pollinators and will also repel insect pests and soil nematodes.

Another aspect to this practice is that certain plants may be antagonistic to one another. Instead of helping each other to grow better and will actually prevent each other from reaching optimal growth.

Here are a few examples of companion planting:

Examples of Companion Planting

Crop:	Helped by:	Hindered by:
Tomato	Onion Nasturtium Marigold Asparagus Carrot Parsley	Potato Fennel Cabbage
Bush Beans	Potato Cucumber Corn Strawberry Celery	Onion
Carrots	Tomato Onion Lettuce Rosemary Sage	Dill

From ATTRA; Companion Planting; Basic Concept and Resources, George Kuepper & Mardi Dodson, July 2001, 16 pages

Organic Pest Management

Introduction/protection of insect predators

Nature provides a large number of insect predators that will help keep insect pest populations below damaging levels. Insects, birds, and spiders will prey on insects. It is important to plant some species to attract these predators and to manage the garden environment to provide a suitable habitat for these predators.

It is important to remember that for these creature to be present there must be something for them to eat. Regular use of insecticides, organic or not, may lead to the departure of these important predators and that can subsequently lead to an increase in the insect pests. In addition, pesticides use can destroy populations of beneficial insects such as predators and pollinators. Prior to using any pesticide consider these factors, alternatives, and consider accepting a low level of the insect pest population.

Plowing/tilling/cultivating

Turning the soil when the garden is not being used to grow plants will expose potential pathogens to dry air and sunlight. This exposes the soil to an environment where many soil-borne pathogens cannot survive. Cultivation can be a part of a conventional or organic gardening plan, and should be considered as you plan your garden.

Weed Control

Weed growth in and near a garden can hinder plant health in two ways. Weeds will compete with desirable plants for growing space and for nutrients and moisture in the soil. The other problem is that weeds often serve as hosts for insects and diseases that will become pests in the garden. Therefore it is important to prevent weeds from becoming established.

The most common method of controlling weeds in an organic garden, as with any garden, is regular weeding. If the weeds are young and tender they will pull out of the soil easily. Pulling or digging weeds regularly will prevent them from becoming established.

Some gardeners will use mulch to reduce weed growth in the garden but organic mulches will soon begin to break down and become more of a favorable environment for weed growth.

Weed barriers have become a popular method to prevent

weed growth in a garden. There are commercial products that are designed to be placed around plants that will deter weeds from growing but will allow air and moisture to pass through. The commercial barriers must be removed and replaced whenever the soil is worked, these products are not biodegradable. Many gardeners have started recycling newspapers by spreading them, about three pages thick, around the plants. If newspapers are used, avoid pages with colored ink as the colors may have harmful chemicals. When it is time to work the soil, whatever is left of the newspapers can be tilled into the soil. When weed barriers are used they should be covered with a thin layer of mulch to hold them in place and to make the garden more attractive.

Sanitation

The importance of sanitation in the organic garden and landscape cannot be understated. The spread of many plant diseases can be stopped by the prompt removal of diseases plants or plant parts. Debris that has been left in a garden may become an alternate home for insects and diseases that will attack the garden at a later time.

Removal of plant debris is an effective way to prevent many pests from invading the landscape. Leaves and twigs left near plants, unused fruits and vegetables left to rot in the gardens, dead plants left in the annual flower beds will all serve as hiding places for insects and disease to spend the dormant season so they will be in place and ready to invade the gardens again next year. It is important to clean this material up on a regular schedule. In almost all cases this organic debris can be added to the compost pile where it can cure out and “cook” the potential pests to render then ineffective.

Removal of diseased plants is always a good practice. Often there will only be one or two plant parts that need to be removed or pruned out to prevent the spread of the disease to the rest of the plant and to other plants. Bacterial diseases such as Fire Blight on ornamental pear trees is a good example of this. In some cases it will be necessary to remove the whole plant to protect other plants in close proximity as is the case with Boxwood blight and rose rosette disease. These diseases plant parts should be disposed of in an alternate location from the compost area.

Cleaning garden tools is a good sanitation practice. Both cutting and digging tools are exposed to whatever they come in contact with. Some plant diseases can be vectored (spread) by pruning tools and soil borne diseases can adhere to the soil that is stuck to a shovel. Garden tools should be cleaned after each use to prevent this avenue for the spread of diseases.

Quarantine new plants

New plants for the garden or landscape may already be infected with a disease or infested with an insect pest. The pest may not express itself in the near future. Therefore new plants, especially ones from an unknown source, should be kept separate from the rest of the garden and landscape until the gardener is reasonably certain the new plants are pest free.

Mulch in the Organic Garden

Research has proven the benefits to be gained from the use of mulch in a garden. For the organic gardener this just means that organic mulches should be used. Organic mulch can be pine needles, shredded bark, ground leaves, or other organically derived products that can be placed around the plants without harming them. Follow the guidelines elsewhere in this handbook to determine how much to use: shallow around small annual plants and up to 3 or 4 inches deep around large woody perennials.

The benefits from mulch are simple. Mulch will trap moisture by blocking direct sunlight from the soil thereby keeping more moisture in the soil for plant roots. Mulch will also keep the soil it covers cooler on hot summer days reducing stress on the plants. During the winter, mulch can be used to insulate perennial plants that may not be quite as cold hardy as they should be for where they are planted.

In annual planting beds organic mulch has one more advantage. It can be tilled into the soil at the end of the growing season to add to the organic composition of the soil.

Study Questions

111. Plant diseases can be managed with: a) site selection, b) soil fertility, c) irrigation management, d) all of the above, e) none of the above

112. GMO is: a) Resistant to disease, b) has been altered in a way that does not occur naturally, c) resistant to herbicides, d) are permissible for USDA Certified Organic, e) all of the above

113. A synergistic planting relationship between plant species _____.

114. List four things that eat insect pests.

115. _____- removal of plant debris that may be infested with insects or contaminated by disease.

Answers:
111 - d; 112 - b; 113 - companion planting; 114 - insects, spiders, nematodes, birds, snakes; 115 - sanitation.

Organic Chemical Controls

Contrary to the belief of many, Certified Organic crop production does not mean that no pesticides are applied. It means that any pesticides applied must be natural, not synthetic, products. These must be approved by OMRI (Organic Materials Review Institute). This designation will be included on the label. Many insecticides based on natural products have a shorter residual life and so may need to be applied more frequently. Please note, all pesticide recommendations must come from the Virginia Cooperative Extension Pest Management Guide – Home Grounds and Animals, Publication 456-018, which can be found here: https://pubs.ext.vt.edu/456/456-018/456-018.html.

However, the following is some basic information about the organic pesticides, and is taken directly from the Pest Management Guide, beginning on page 2-1. This information will help gardeners to decide when and where to use these chemical controls. Research on the efficacy of these products is limited. Most of these products do not have residual activity and will require repeated applications. It is important to read the label and follow all precautions regarding protective clothing, mixing, and labeled plants. Just because they are OMRI approved doesn't mean that safety can be disregarded.

Bacillus thuringiensis (Bt) - This bacteria forms a protein called cry toxin that has specific activity against insects. When the insects ingest these bacteria their digestive track is paralyzed, forms pores and the animal eventually starves to death. Different strains of BT are effective against Lepidoptera (butterflies and moths), Diptera (flies), Coleoptera (beetles) Hymenoptera (bees, wasps, ants and sawflies) and nematodes. Bt is generally quite selective about the pests it is able to manage. This leaves beneficial insects and pollinators unharmed. Each strain of the bacteria may have different characteristics and control different insects. Each strain is registered with the EPA as a pesticide

Bt/Sandiego – A strain of BT that will control Colorado potato beetles. As well as Elm Leaf Beetle and willow leaf beetle. This strain of bt is genetically engineered (GMO) and as such is not OMRI approved for organic production.

M-One, M-Track, Foil, Novodor - These are trade names for the Bt/Sandiego strain listed above.

Insecticidal soap – these are potassium fatty acid compounds that are toxic to cell membranes and cause insects to quickly die. It is generally most effective on soft buddied insects such as aphids, thrips, whiteflies, spider mites and immature leafhoppers. If the concentration is too high, there may be a phytotoxic response by the plant. Read and follow label directions.

Pyrethrin – this is a neurotoxin that is extracted from the chrysanthemum plant. It is a broad spectrum insecticide that is broken down by sunlight. At lower concentrations it is also an insect repellent. This chemical is also easily broken down by the acids in a mammalian stomach. Pyrethrin can also be toxic to humans, follow directions for use of this product.

Diatomaceous Earth (DE) – also called diatomite. This is a light colored soft rock that can easily be made into a powder. This stone is the fossilized remains of diatoms, or hard shelled algae. DE is a common ingredient in toothpaste and cat litter. The abrasive powder absorbs the waxy covering on the outside of insets and causes them irritation and dehydration which may result in death. It also has some efficacy against slugs and snails. Although a mild toxin, products containing DE must be registered with the EPA.

Neem - Neem oil is a contact pesticide extracted from the neem tree native to India and the Middle East. It is an insect repellent and larvicide. Insects that are in the larval stage are not able to mature into adults. Neem also has fungicidal properties and may be sold as a fungicide as well.

Capsaicin - this is an extract from hot chili peppers. It is used as a repellent for mammals and insects. It does not

have any repellent properties for birds.

Hot Pepper Wax – the active ingredient in this product is capsaicin. See Capsaicin.

Spinosad - an insecticide that was discovered in 1985 after noticing the insecticidal properties of a bacterium, Saccharopolyspora spinosa, in sugar cane from the Virgin Islands. As an insecticide it is a unique neurotransmitter toxin and has a wide range of larval and mature insects that it controls. This hydrophobic insecticide was first registered for use in crops by the EPA in 1997. It is toxic to insects by contact and ingestion, though ingestion is much more effective.

Potassium laurate - is a potassium salt of fatty acids effective against soft-bodied insects and mites. OMRI approved. This may sometimes be called a soap salt or an insecticidal soap. It is also used a an herbicides and an algaecides. Additionally, it is used as a deer and rabbit repellent. See also M-Pede, see also insecticidal soap.

M-Pede - potassium salt of fatty acids effective against soft-bodied insects and mites. Higher volumes can cause fruit injury. May cause marking of table grapes and pears. Do not apply after delayed dormant stage of pears. OMRI approved.

Kaolin clay – This is a fine particle silica clay that is used as an insect repellent.

Horticultural oil – horticultural oils can be petroleum or vegetable based oils. They are used as a contact insecticide or miticide to smoother the pest.

Beauveria bassiana – this is a soil borne fungus that causes a white muscardine disease in insects within a few days of coming into contact with the pest. This disease is deadly to the insects. The fungus has a broad host range, though some strains are more toxic to some species and other strains more toxic to other insect species.

Copper - There are numerous copper products available to home gardeners. In general, on apples and pears, copper can be used as a green-tip bud spray for fire blight suppression or a scab fungicide. On peaches and nectarines, coppers can be used in the fall at leaf drop or at bud swell in the spring for leaf curl control or bacterial spot suppression. Some copper products are approved for organic production. However, if coppers are used in successive sprays at full rates during the growing season, they can cause fruit russetting and purple spots on apple leaves and shothole of peach and nectarine leaves. Copper has also been shown to have efficacy in managing Downey mildew on cucumbers and early blight on tomato. http://www.nysipm.cornell.edu/grantspgm/projects/proj12/veg/seaman2.asp However, again, please refer to the Pet Management Guide for specific application timing and rates for copper and copper based pesticides.

Sulfur - Sulfur has two roles in organic gardening. It can be used as an amendment to lower soil pH and it can be used as a fungicide. Sulfur has been used for centuries in the grape growing regions of France to control fungi.

Wettable Sulfur - a fungicide that is used for the control of apple scab, peach brown rot, powdery mildew, and other diseases. It is a finely-ground powder to which a small amount of wetting agent has been added. Do not use in high temperatures. Do not use with oil sprays or within two weeks of an oil spray.

Dormant spray oil – This product can be diluted with water and is effective in suppressing scale insects and red mite egg hatch. It should be used only on dormant trees or with up to 1/2-1 inch of green showing. OMRI approved (be sure to check label). This name is given because of the time of the year that the application is made. It is not an indication of it being a vegetable or petroleum base product. Dormant oils work by suffocating insects, mites and their eggs. They may also destroy the cuticle layer of some insects and cause internal damage or desiccation to the insect.

Entomopathogenic nematodes - Products with Steinernema riobrave or Heterorhabditis as active ingredient. These are parasitic round worms that feed on insects. They feed on the insects and cause them to die. They feed on soil dwelling insects as well as some insects that live above ground. They are not considered toxic to humans. They are not regulated by the EPA as a pesticide.

Bacillus popilliae **(Milky Spore disease)** - This is a bacteria that infects the grubs of Japanese Beetles only. This is best applied in the late summer when the grubs are small and feeding near the surface. This bacterium will survive in the environment through cold and drought. It may take up to a month for grubs that have consumed the bacterium to parish from milky spore disease.

Weed Control

Most of the limited organic herbicide options are for post emergent control of weeds. They are often acids and oils that are designed to burn and smother weeds. They generally don't have any efficacy on the roots of plants so perennial weeds will require repeat applications. Also repeated use of corrosive acids may have detrimental effects on sidewalks and the pH of soils. It is also important to note that care must be taken when handling any of these products. Be sure to read and follow the label, and wear appropriate personal protective equipment and utilize proper application equipment. The following information comes from pages 5-11 and 5-12 of the 2015 Pest Management Guide: Home Grounds and Animals (https://pubs.ext.vt.edu/456/456-018/456-018.html).

Acetic acid (Weed Pharm 20% acetic acid or other labeled formulations (Vinegar)) - Contact nonselective herbicide. Do not use unlabeled forms of acetic acid. This product has a danger signal word. Wear eye protection, a long-sleeved shirt, long pants, shoes, socks, and waterproof gloves since this product is corrosive. Cover the weed foliage thoroughly. Treat weeds when small, as large annual weeds may require retreatment. Perennial weeds need retreatment, as this is a contact herbicide and does not affect underground plant parts such as roots, bulbs, and rhizomes. Keep the spray off the foliage and stems of desired plants.

Clove oil - contact weed control: See information about acetic acid and follow the instructions listed above for acetic acid.

Cinnamon oil - contact, non-selective weed control

Rosemary oil - contact, non-selective weed control

Thyme oil - contact, non-selective weed control

Citric acid - contact, non-selective weed control

Ammoniated soap of fatty acid – originally registered as a mammal repellent, it now has a label as a weed killer. It is similar to the products above, and is a contact, non-selective weed control.

Ethanoic acid – contact, non-selective weed control. Please see acetic acid notes.

Corn gluten (Alaninyl-alanine) – Different from the list above, this is a pre-emergent. The proteins in the corn have an inhibiting reaction as new seed roots emerge. It is effective on small seeded plants, but larger seeds remain unaffected. It has a fairly high nitrogen content of 9% and as such is a large dose of fertilizer when applied to a lawn or garden. Its effectiveness has not always been consistent in research trials. This product should not be applied where it can easily run into water.

Study Questions

116. True or False – certified organic farmers never use pesticides.

117. This active ingredient is an animal repellent and comes from an extract of hot peppers. a) capsaicin, b) spinosad, c) rosemary oil, d) kalicinite.

118. This bacterial toxin has good efficacy against many insects and is used by conventional and organic growers alike. a) clove oil, b) copper, c) Bt, d) potassium bicarbonate.

119. This herbicide carries a danger warning on its label. a) neem, b) cinnamon oil, c) *Bacillus popilae*, d) acetic acid.

Answers:
116 - false ; 117 - a; 118 - c ; 119 - d.

Chapter 14
Fruits in the Home Garden

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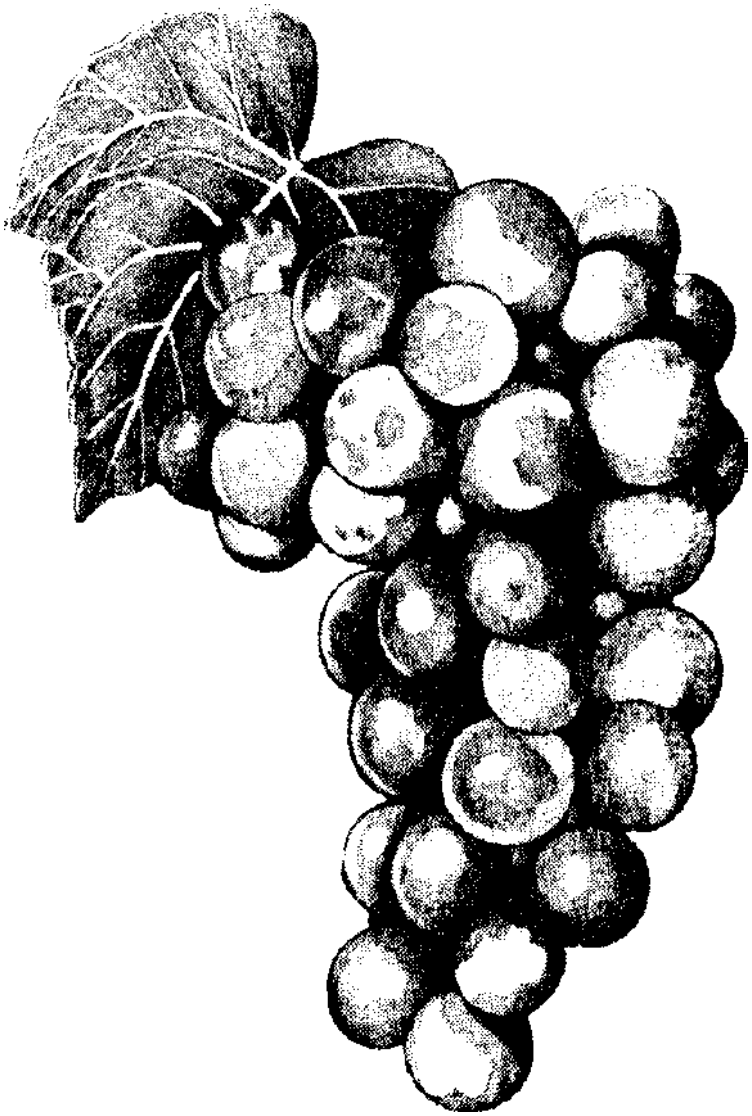
Chapter 14



Fruits in the Home Garden

Chapter 14

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The small fruits section is an updated version of the VCE publication 426-840 written by Diane Relf and Jerry Williams.

Success with a fruit planting depends upon how well it is planned and how well carried out the plans are. Relatively less care is required in the culture of sour cherries and pears than other tree fruits, but even these cannot be expected to produce good quality fruit year after year if left unattended. Proper attention must be given to insect and disease control, pruning, fertilization, soil management, and other necessary practices. Small fruits offer advantages over fruit trees for home culture in that they require a minimum of space for the amount of fruit produced and bear one or two years after planting. Also, pest control typically is easier. Success with a small fruit planting will depend on the attention given to all phases of production: variety selection, soil management, fertilization, pruning, and pest control. Plant only what you can care for properly. It is better to have a small, well-attended planting than a large, neglected one.

Contents

Tree Fruits

Planning a Tree Fruit Planting

It is desirable to locate the fruit planting as close to your home as possible. Where space is limited, fruit trees may be set in almost any location suitable for ornamental plants. Consider the mature size of the tree when designing the planting. Dwarf fruit trees fit nicely in ornamental plantings as well as orchards. They come into bearing earlier than standard-sized trees, occupy less space, and can be more easily pruned and sprayed with equipment normally available to the average gardener. Most nurseries carry dwarf and semidwarf apple trees of all varieties. Dwarf pear, peach, and cherry trees of a few varieties are offered by some nurseries, but are not recommended because trees may not survive more than five years due to disease and incompatibility problems.

Size of Planting

Space, site, family size, available time, and pollination requirements determine the size of the planting. Choose fruits based on family preference, adaptability, and available space. Never attempt to plant more than you can care for properly. The information in the table below

Space Requirement, Yield, Bearing Age, and Life Expectancy of Tree Fruits

Fruit	*Minimum Distance Between Plants (feet)*	*Approximate Yield per Plant (bushels)*	*Bearing Age (years)*	*Life Expectancy (years)*
Apple - seedling root	30	8	6 to 10	35 to 45
Apple - semidwarf	18	4	4 to 6	30 to 35
Apple - dwarf	8	2	2 to 3	30 to 35
Pear - standard	25	3	5 to 8	35 to 45
Pear - dwarf	12	1/2	3 to 4	15 to 20
Peach	20	4	3 to 4	15 to 20
Plum	20	2	4 to 5	15 to 20
Quince	15	1	5 to 6	30 to 40
Cherry - sour	18	60 qt.	4 to 5	15 to 20
Cherry - sweet	25	75 qt.	5 to 7	20 to 30

should help you determine the size of your planting.

Tree Spacing

How far apart must the trees be set? This is an important factor and, to a large extent, it influences selection of site and varieties. The table below shows the minimum desirable distances between fruit trees in home orchards. They can be set farther apart if space allows but, for best results, should not be set closer than the minimums indicated. To maintain a bearing surface low enough for necessary pest control, and to maintain uniform bloom throughout the tree, trees should not be crowded.

Site Selection

The importance of selecting the best site possible for fruit planting cannot be overemphasized. Good air drainage is essential. Cold air, like water, flows downhill. For this reason, fruit buds on plants set in a low spot are more likely to be killed by frost than those on a slope. Frost pockets; low, wet spots; and locations exposed to strong, prevailing winds must be avoided. South-facing slopes encourage early bud development and can sometimes result in frost damage. Select late-blooming varieties for this location.

Deep, well-drained soil of moderate fertility should be

Some Suggested Varieties for the Home Fruit Garden

Varieties are listed in order of ripening

APPLES	CHERRIES (sweet) - 2	PLUMS (Japanese)
Lodi - 1c, 2	Napoleon (Royal Anne) - 1c, d	Early Golden - 1c, d
Jerseymac - 1c, d, 2	Vernon - 1c, d	Methley - 1c, d
Ginger Gold - 1c, d	Ulster - 1c, d	Shiro - 1c, d
Paulared - 1c, d, 2	Hedelfingen - 1c, d	**NECTARINES**
Gala - 1d, 2	Windsor - 1c, d	Redgold - 1d
Grimes Golden - 1c, d, 2	Hudson - 1c, d	Flavortop - 1d
Jonathan (red strain) - 1c, d, 2	**CHERRIES (sour)**	Fantasia - 1d
Golden Delicious - 1c, d	Montmorency - 1c, f	**PEACHES**
Delicious (red strain) - 1c, d, 2	**PEARS**	Jerseydawn - 1d
Idared - 1c, d, 2	Harrow Delight - 1c, d	Redhaven - 1c, d, f
Winesap - 1c, d, 2	Moonglow - 1c, d	Loring - 1c, d, f
Stayman (red strain) - 1c, d, 2	Harvest Queen - 1c, d	Redkist - 1c, d, f
Rome Beauty (red strain) - 1c, d, 2	Maxine - 1c, d	Earnies Choice - 1c, d, f
Fuji - 1c, d, 2	Seckel - 1c, d	Cresthaven - 1c, d, f
Granny Smith - 1c, d, 2	Orient - 1c	Raritan Rose - 1d
Cripps Pink (Pink Lady) - 1c, d, 2	Kieffer - 1c	Biscoe - 1c, d, f
SCAB-IMMUNE APPLES	**PLUMS (European)**	Encore - 1c, d, f
Pristine - 1c, d, 2	Earliblue - 1c, d	White Hale - 1d
Williams Pride - 1d, 2	Blue Bell - 1c, d	Carolina Belle - 1d
Redfree - 1d, 2	Stanley - 1c, d	Summer Pearl - 1d
Dayton - 1c, d, 2	Shropshire (Damson) - 1c	
Crimson Crisp - 1d, 2		
Scarlet O'Hara - 1d, 2		
Jonafree - 1d, 2		
Liberty - 1d, 2		
Sundance - 1c, d, 2		
Enterprise - 1c, 2		
Goldrush - 1c, 2		

1 - Principal uses: c - cooking; d - dessert; f - freezing.
2 - In Eastern Virginia mildew, blight, brown rot, bacteriosis, fruit cracking, and poor color can be serious problems due to climatic conditions, and these varieties are difficult to grow.

selected. A fertile, sandy loam or sandy clay loam is suitable for most tree fruits. Adequate water drainage is the most important soil characteristic. Poor fertility may easily be improved by proper fertilization and cultural practices, but improving soil with poor internal drainage is difficult and expensive. Moderately fertile soil is desirable; deep, well-drained soil is vital.

Variety Selection

Give special attention to the selection of varieties. They must be adapted to your soil and climatic conditions. If possible, without sacrificing too much yield or quality, select varieties with the fewest insect and disease problems.

Several varieties of the same kind of fruit maturing at different times may be planted to prolong the harvest season. Consider the value of certain varieties for special uses, such as freezing, canning, and preserving. Some varieties may be purchased in season from commercial growers more economically than you can grow them yourself.

Cross-pollination is necessary for satisfactory fruit set in many tree fruits. Select varieties that are cross-fruitful and that have overlapping bloom dates. To be certain of adequate cross-pollination, plant at least three varieties of apples. Don't confine your selections to Winesap and Stayman; These varieties will not cross-pollinate. Golden Delicious is used by many commercial growers as a pollinizer for other varieties of apples in their orchards. Ornamental crabapples can also be used as a pollinizer for all apple varieties.

The preceding table lists some varieties of tree fruits suitable for planting in Virginia. The varieties are listed in the order of ripening, and the list includes only those varieties of proven merit under Virginia conditions.

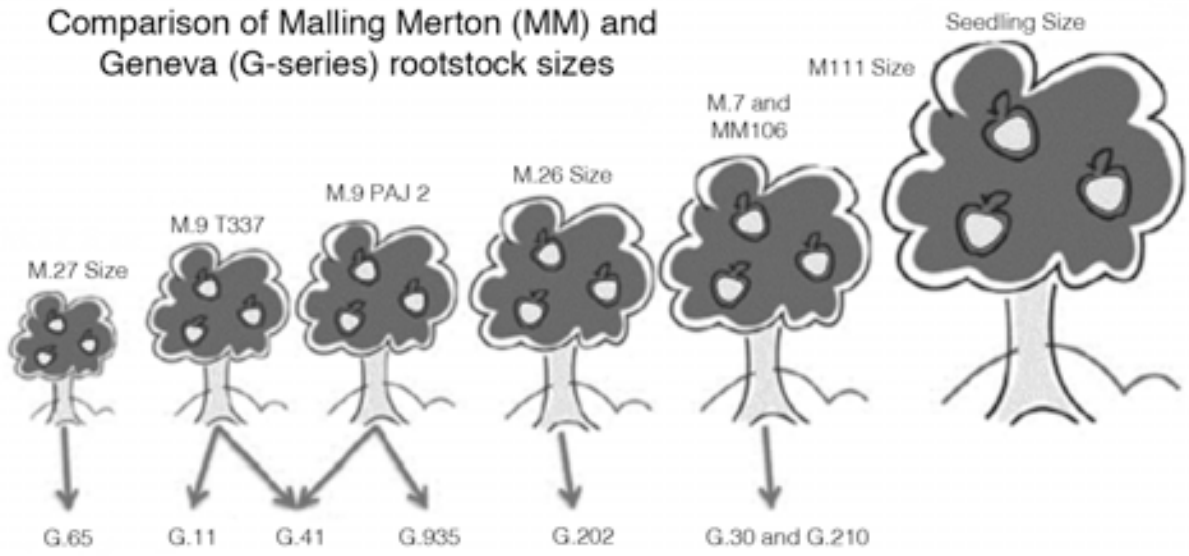
At least two of the recommended pear, plum, and sweet cherry varieties should be planted. In general Japanese and European plums are not effective as pollinizers for each other; two varieties of the same type should be planted. Windsor is a good pollinating sweet cherry variety. Sour cherries cannot be used to pollinate sweet cherries because they are different species.

All of the sour cherry, peach, and nectarine varieties listed are sufficiently self-fruitful to set satisfactory crops with their own pollen.

Apricots present a unique challenge to Virginia growers. The buds of currently available varieties respond to the first warm days of early spring and are usually killed by frost or low temperature after bloom. Unless protection can be provided, a crop can be expected no more frequently than once every three to five years. For those who can provide protection, planting considerations are provided.

Apple Rootstocks

Apples, like other tree fruits, will not produce trees with the same characteristics from seed. If you plant a seed



Adapted, with permission, from: http://www.ctl.cornell.edu/plants/GENEVA-Apple-Rootstocks-Comparison-Chart.pdf

from a Red Delicious apple, the fruit would likely be small, unattractive, and of poor quality. Therefore, fruit trees are propagated vegetatively by either budding or grafting scion wood of the desired cultivar on a rootstock. The rootstock and scion variety maintain their respective genetic identities, but are joined at the graft union and function as a unit.

Traditionally, apple trees have been propagated on rootstocks from apple seeds. More recently, increasing use is being made of vegetatively propagated or clonal rootstocks which have inherent advantages over seedlings. Three major considerations in rootstock selection are:

Size Control

Most apple trees available to are grafted onto clonal rootstocks for tree size control. By proper selection of rootstock, one can determine mature tree size. For example, the same variety of apple will produce a 16- to 18-foot tree on the rootstock Malling Merton (MM)111, down to a dwarf tree of 7 to 8 feet or less on Malling (M)9 or M.27rootstock. Intermediate sizes can be attained by other rootstocks, such as M.26 and M.7. Some apple trees may be offered to consumers may be labelled as dwarf trees, but the buyer does not know the rootstock or how dwarfing it may be. However, there are nurseries willing to offer selected scion/rootstock combinations to home fruit growers. Some of the earlier rootstocks such as M.9 and M.26 were susceptible to diseases, such as fireblight. The newer "Geneva-series" rootstocks are more resistant to fireblight and collar rot and these are suggested for planting if available. The relative sizes of trees on the various rootstocks are shown in below. Another rootstock Budagovsky.9, "Bud.9" produces trees similar in size to M.9, G.11 and G.41 is also resistant to fireblight.

Precocity

The earliness at which a tree produces fruit is also directly affected by the rootstock. Trees on seedling rootstocks usually do not begin fruiting until they are 7 to 8 years old. Trees onM.9, G.11, G.41 or Bud.9 rootstock will often produce crops in two to three years. Other rootstocks are intermediate in this regard. Usually, the more dwarfing the rootstock, the earlier the tree will bear fruit.

Stability

A major consideration in selecting apple rootstocks is the degree of anchorage provided. For example, trees on M.9, M.27, G.11, G.41, G.65 and Bud.9 rootstock are very small, but because of brittle roots, must be provided some type of support. This can consist of a post, a trellis, or other means of holding the tree upright. The semi-dwarfing M.7 rootstock may require support for the first few years, but some varieties can grow without support. The more vigorous MM.111 rootstock does not require support and is thus like seedlings.

More detailed information on selecting apple rootstock can be found online at http://www.extension.org/pages/66189/apple-rootstocks:-understanding-and-choosing-the-right-rootstock#.Vduzjc5YXdm.

Buying Trees

Obtain the best nursery stock available. Buy only from reputable nurseries that guarantee their plants to be true to name, of high quality, and packed and shipped correctly. Beware of bargains. High prices do not necessarily mean high quality, but good nursery stock is not cheap.

Usually, 1-year-old trees are preferred. A common mistake made by many gardeners is to select oversized or ready-to-bear nursery trees. Experience has shown that younger trees bear almost as soon, are easier to keep alive, and develop into more-healthy, vigorous trees than do the oversized stock. The older trees cost nurseries more to grow and are sold for higher prices, but are usually worth less than younger trees.

For peaches, nectarines, and apricots, a 4-foot tree, ½-inch in diameter, is considered the ideal size for planting. Vigorous, 4- to 7-foot, 1-year-old whips about 3/4-inch in diameter are preferred for apples. Pears, quince, plums, cherries, and apples may be planted as 1- or 2-year-old trees. Either will be satisfactory as long as the trees have attained sufficient size and have good root systems.

When purchasing apple trees on dwarfing rootstock, be sure to specify the rootstock desired. There are several possibilities for planting: M.9, G.935 and Bud.9 trees and smaller are very dwarfing, have rather weak root systems, and must have mechanical support; M.7 and G.30 trees, which produce trees 70 to 80% as large as a mature tree from seedling may require early support for most varieties; and MM.111EMLA (virus free) which produces a tree 80 to 90% of the size of a mature tree from seedling, does not require support, and is nearly problem-free except for its large size.

Setting the Orchard

Time of Planting

Virginia climatic conditions are such that good results can be obtained regardless of whether the trees are planted in fall or early spring. Planting about a month after the first killing frost in the fall or about a month before bloom in the spring is generally recommended. The important things to remember are that trees should be dormant and the soil should have proper moisture content.

Handling Nursery Stock

Fruit trees are usually purchased as containerized plants from local nurseries and garden centers or as bare root trees from mail order companies. Both types of trees can give good results. Mail order companies usually offer a larger selection of varieties.

Mail order trees should be inspected upon arrival to make sure the roots and packing material are moist. If trees cannot be planted immediately, they can be stored in the original packing for a week or two in an unheated basement or garage. Do not expose to freezing temperatures which may damage roots, or high temperatures which may induce bud break. Check the roots frequently and moisten if necessary. In the absence of a cool storage place, trees can be heeled in carefully in a trench of moist soil in a shaded location. It is a good idea to soak the roots in a bucket of water for a few hours before planting.

Planting the Trees

Preparation of the soil where fruit trees are to be planted should be as thorough as preparation of the soil for a vegetable garden or ornamental planting. If the places selected for trees are in a lawn, it is best to remove the turf and spade the soil deeply over an area of several square feet where each tree is to stand.

Dig the hole a little deeper and wider than necessary to accommodate the roots, leaving the soil loose in the bottom of the hole.

Prune the roots of young trees only where necessary to remove broken and damaged ones or to head back some that are excessively long. Should a tree be so badly scarred or damaged that there is doubt of its survival, it is wise to discard it.

Set the tree at approximately the same depth it grew in the nursery. Never set it so deep that the union of the scion and rootstock is below ground level when the hole is filled.

Then begin filling the hole with pulverized topsoil, shaking the tree gently to filter the soil among the roots. Tamp the soil firmly and thoroughly with your foot or a well-padded stick. The addition of water when the hole is about 3/4 full will aid in settling the soil around the roots and increase chances for the tree's survival. After the water has completely soaked in, finish filling the hole, leaving the soil loose on top.

Study Questions

1. Fruit trees require a soil that is: a) clay; b) well-drained; c) unsloped; d) very high in fertility
2. Planting several varieties of apples is beneficial for the following reasons EXCEPT:
   a) it allows for cross-pollination; b) it can prolong the harvest season; c) one can have fruits with a variety of special uses (canning, freezing, preserving, etc.); d) bees get tired of pollinating the same old varieties
3. Factors influenced by rootstock do NOT include:
   a) tree size; b) fruiting age; c) fruiting stability; d) fruit color
4. Preferred fruit tree transplants would be about _____ year(s) of age.
5. When planting fruit trees, it is important that:
   a) the trees are dormant; b) the soil is dried out; c) the graft is below soil level; d) it is done in the summer

Answers:
1 - b; 2 - d; 3 - d; 4 - one; 5 - a

Orchard Management

Cultural Practices

Young fruit trees should be mulched or cultivated until they begin to bear. Weeds must be eliminated so they will not compete for available moisture and fertilizer. Cultivation must be shallow to avoid injury to roots near the surface. The cultivated or mulched area should extend a little beyond the spread of the branches.

There are several concerns with use of mulch around fruit trees. Both organic and inorganic mulch (i.e., black

plastic) provide habitats for voles. Organic forms of mulch also release nitrogen throughout the season, which affects the grower's ability to control when and how much nitrogen is available. Fertility of established trees can be managed with mulch, and fertilizer is often not needed and can cause a reduction in fruit load.

Fertilize young trees three times. Apply fertilizer about two weeks after planting, and again six and 10 weeks after planting. Apply 0.03 pounds of actual nitrogen each time (i.e., 1/3 pound 10-10-10, 0.2 pound nitrate of soda, or 0.1 pound ammonium nitrate).

Temporary nitrogen deficiency may occur when mulch material low in nitrogen begins to decay. This can be overcome by the addition of nitrogen fertilizer. Usually about ¼ pound of ammonium nitrate, ½ lb. of nitrate of soda or 2 pounds of 10-10-10 to each 100 square feet of mulched area will be enough.

The use of black polyethylene plastic as a mulch has given good results. Holes may be punched in the plastic to allow moisture penetration. Although it does not decay and add humus to the soil, neither does it cause a temporary nitrogen shortage.

When trees are planted in rows, the area between the rows may be allowed to grow in sod or used for interplanting with low-growing vegetables or strawberries. Another option for inter-row planting is clover, which is easily managed and provides an organic source of nitrogen. There is no objection to this practice in the home orchard, provided ample plant nutrients and moisture are available for proper development of the fruit trees. Under sod culture, frequent, close mowing during the growing season is desirable. This reduces competition for necessary moisture and plant nutrients and also aids in disease and insect control.

Fruit trees, especially those on dwarfing rootstock, are becoming prominent in landscape designs. Under lawn culture, fruit trees can be given more attention than is usually convenient under other systems of culture. Equipment and materials for watering, pruning, spraying, and other cultural practices are essentially the same as those required for ornamental plantings. It is a good practice to cultivate lightly for the first year or two or until the tree has become firmly established. Lawn grass, if kept closely clipped, may be allowed to grow around the base of the tree in the third year, but fertilizer should be applied at twice the usual rate.

Chemicals for weed control should be used with extreme caution in the home garden. Careless use can result in severe injury to fruit trees and nearby ornamental plantings. See your Extension agent for latest weed control recommendations.

Fertilization

Before planting, test your soil pH. If your soil is acid, it should be limed to adjust the pH to a level between 6.0 and 6.5. As a rule, no fertilizer is recommended or needed at planting time. After the young tree becomes established and growth begins, apply nitrate fertilizer in a circle around the tree, about 8 to 10 inches from the trunk. Usually fruit trees show no increased growth or fruitfulness from the use of any nutrient element except nitrogen. Other elements are used by the tree; however, only in special cases are they deficient in the soil. Deficiencies are more likely to occur on light, sandy soils.

Because there are many soil types and varying levels of natural fertility, it is difficult to make one fertilizer recommendation that will apply equally well in all areas.

Vase

Central Leader

A rule of thumb practiced in many commercial apple orchards is to apply about ¼ pound of a 16% nitrogen fertilizer, or its equivalent, for each year of the tree's age from planting. For peach orchards, the amount of fertilizer should be doubled.

Over-fertilization with either organic or inorganic materials should be avoided. Excessive vegetative growth will result, usually accompanied by delayed fruiting and possible winter injury. Where poor growth results after the use of nitrogen only, other elements may be needed. Contact your local Extension agent for fertilizer recommendations specific to your locality.

Fertilizer may be applied either after the leaves have fallen or in early spring about three or four weeks before active growth begins. On light, sandy soils, it is best to delay application until early spring. When trees are grown in a lawn area, delay fertilizing the lawn until after trees are dormant to avoid late-summer growth on the trees.

The usual method of application is to scatter fertilizer evenly under the tree, starting about 2 feet from the trunk and extending to just beyond the tips of the branches.

Terminal growth and general vigor of the individual tree should be observed closely. Where growth the past year was short, increase the amount of fertilizer slightly. If growth was excessive, reduce the amount or withhold it entirely. Remember that both pear and quince are highly susceptible to fire blight, and excessive growth will make this disease more prevalent.

Mature, bearing trees of peach, nectarine, and sweet cherry should produce an average of 10 to 15 inches of new growth annually. From vigorous, young, nonbearing trees, about twice that amount can be expected. In general, 8 to 10 inches of terminal growth is considered adequate for mature, bearing apple, pear, quince, plum, and sour cherry trees. About twice that amount is sufficient for young, nonbearing trees.

Pruning

The general purpose of pruning fruit trees is to regulate growth, improve fruit size and quality, control tree size, and reduce production costs. Pruning is necessary to shape the trees for convenience of culture and for repair of damage.

Most pruning is done during the dormant season, preferably just before active growth begins in the spring. At this time, pruning wounds heal faster, flower buds can be easily recognized, and injury from low winter temperature is avoided. Summer pruning may be done to help train young trees to the desired shape, remove water sprouts and other undesirable growth, and maintain smaller tree size. It should be remembered, however, that all pruning has a dwarfing effect. For maximum yield of high-quality fruit, prune only as necessary to establish a tree with a strong framework capable of supporting heavy crops annually without damage and to maintain a tree sufficiently open to allow penetration of sunlight, air, and spray material for good fruit development and pest control.

Although pruning procedures vary according to the type, age, and variety, all newly planted fruit trees should be pruned in the spring before growth starts. This is necessary to stimulate lateral bud development from which to select good scaffold limbs. For a discussion of the proper pruning techniques to use on different fruit trees, see the pruning chapter.

Thinning

Quite frequently, peach and apple trees set many more fruit than they can mature to a desirable size. By thinning or removing excess fruit this difficulty can be overcome. Thinning not only allows for an increase in size of the remaining fruit on the tree, but also improves fruit color and quality, reduces limb breakage, and promotes general tree vigor. Thinning helps maintain regular, annual bearing in certain apple varieties, such as Golden Delicious, Yellow Transparent, and York Imperial, that otherwise have a tendency to bear heavy crops every other year. Another benefit from thinning fruits is that it permits more thorough spraying or dusting for effective disease and insect control.

Experimental results indicate that the sooner peach trees are thinned after bloom, the earlier the ripening and the larger the fruits at harvest. It is doubtful that final size of the fruits of any variety will be greatly increased by thinning if it is delayed much after the pits begin to harden (60 days after bloom).

It is generally recommended that peaches be spaced 6 to 8 inches apart on a branch. When thinning by hand, grasp the stem or branch firmly between your thumb and forefinger and pull the fruit off with a quick motion of the second and third fingers. Small fruited varieties on trees that are pruned lightly should be thinned to a spacing of 8 to 10 inches between fruit.

Many growers use the pole method of thinning peaches. A 4- or 5-foot section of bamboo or other light wood is used. A piece of 3/4-inch garden or spray hose about 15 inches long is forced tightly onto the end of the pole, leaving 8 to 10 inches of the hose extending beyond the end of the pole. A snug fit is necessary so the hose will remain in place while being used. Many modifications of this tool are used. One of the most common is a 30-inch section of plastic pipe, 1 inch in diameter. Remove peaches by striking the limbs about 18 inches from their tips with the flexible part of the hose, using sharp, firm blows. This dislodges any loosely attached fruits. With a little practice, you should be able to remove individual fruits by this method. Remove small and insect-injured fruit and retain the largest fruit.

Apples should be thinned as soon as possible after the fruit has set. If full benefits are to be obtained, thinning should be completed within 20 to 25 days after full bloom. In hand-thinning apples, use the same general technique used in hand-thinning peaches. A distance of 6 to 10 inches between fruits is recommended. With varieties of Delicious apples, where greater size of individual fruits is important, the greater spacing is preferred. The center apple of a cluster is usually the largest and the best apple to leave.

Thinning plums usually is limited to the large, Japanese varieties. The primary concern here is to facilitate insect and disease control. Plums are usually thinned by hand to about 4 inches apart.

Rodent Control

Voles may cause serious damage to the fruit planting. They chew off the bark at ground level or below and often completely girdle a tree, causing it to die. Most of this damage takes place during winter. Keep mulch pulled away from the base of the tree, and examine it frequently for the presence of voles. In many home and commercial plantings, voles are controlled by placing poison bait in their runways. These poisons and complete directions on how to use them may be obtained from many spray material dealers. Voles may also be controlled by trapping. This can be successful where only a few trees are involved.

Rabbits are responsible for the loss of thousands of young fruit trees each year. Perhaps the most satisfactory method of preventing rabbit damage is the use of a mechanical guard. Galvanized screen or “hardware cloth” with a ¼-inch mesh is frequently used. A roll 36 inches wide may be cut lengthwise, forming two 18-inch strips. By cutting these strips into pieces, 14 inches long, guards 14 by 18 inches are obtained. Roll or bend the strip around the trunk of the tree so the long side is up and down the trunk and the edges overlap. Twist a small wire loosely about the center to prevent the strip from unrolling. Push the lower edges well into the ground. This metal guard will last indefinitely and can be left in place all year, but do not allow weeds to grow inside the guard.

Tar paper, building paper, sheets of magazines, and aluminum foil can also be used in a similar manner, but must be removed in the early spring to prevent damage to the tree. Perforated plastic guards are available, but are not recommended because they do not allow enough air movement around the tree. However, there are plastic meshes, like the metal ones, that are acceptable.

Other methods of rabbit control have been successful. Ordinary whitewash has given good results in some instances. A repellent wash recommended by the USDA, containing equal parts of fish oil, concentrated lime sulfur, and water, is used by some commercial growers. Also, rabbit repellents under various trade names are available. All these materials may be applied with a paint brush, from the ground up into the scaffold limbs.

Tree Fruit Spraying

To successfully manage significant insect or disease problems, it is necessary to follow a spray program. Information on the use of chemicals for such a program is available from the Extension office.

To be successful with your spray program, spray at the proper time and do it thoroughly. Leave no portion of the tree unsprayed. To make the job easier and to ensure adequate coverage, thin out excessive growth and remove all dead and weak wood. Cut old trees back to 20 feet or less, if possible. Train younger trees so they reach a height of no more than 18 feet.

Semidwarf and dwarf trees should be considered when making your planting. Their small size makes the task of spraying easier. Early maturing varieties are less likely to be seriously affected by insects and diseases than late-maturing varieties because of the shorter growing season. This factor should not be overlooked in the selection of varieties.

Sanitation

Adopt good orchard sanitation practices. The destruction of places that harbor insects and diseases plays a large part in the control program. Conditions that encourage voles should also be eliminated.

These are some practices to include in an orchard sanitation program:

* Collect and burn debris.
* Remove and destroy all dropped fruit.
* Rake and burn apple and cherry leaves.
* Scrape loose bark from trunks, crotches, and main limbs of apple trees.
* Prune out and destroy all dead or diseased limbs, branches, and twigs.

Apple Varieties of Yesteryear

Arkansas Black Twig, Baldwin, Fall Cheese, Miliam, and Roxbury Russet are apple varieties not found in the modern supermarket, yet in the opinion of some apple connoisseurs, the dessert quality of these and other old-time apple varieties is superior to that of most of those in popular demand today.

Most of the old varieties are no longer grown because they had serious cultural problems such as poor storage, disease, bitterpit, alternate bearing, and nonuniform ripening. Many of the old varieties lost favor with the commercial grower because of low productivity, lack of attractiveness, susceptibility to the ravages of insects and diseases, and poor storage and shipping quality. Before growing an old variety, you should taste the fruit and talk to experts to determine the problems you are likely to have.

There is increasing interest in growing old fruit varieties. Individuals, historical organizations, and government-supported institutions are getting involved. Some commercial nurseries now propagate one or more of the better-known varieties, and there are several that specialize in antique fruit varieties of all types. North American Fruit Explorers (http://www.nafex.org/ Route 1, Box 94, Chapin, IL 62628), a nonprofit association of fruit gardening enthusiasts, actively promotes the culture of old fruit varieties. It is a valuable source for anyone interested in locating information on sources of bud wood, characteristics of varieties, and successful cultural practices.

Among the old-time apple favorites available from private and commercial sources are some that have occupied a prominent place in Virginia history. Perhaps the most widely known is the Albemarle Pippin. Although seldom found in the orchards of Virginia, it is of some importance in western states under the name Yellow Newtown. Still found in some of the old orchards on both the eastern and western slopes of the Blue Ridge are such varieties as Arkansas Black Twig, Baldwin, Ben Davis, Esopus Spitzenburg, Fallawater, Gano, Golden Russet, Gravenstein, Grimes Golden, Horse Apple, King David, Lady Apple, Limber Twig, Lowery, Maiden Blush, Milam, Mother Apple, Northern Spy, Roxbury Russet, Smokehouse, Virginia Beauty, Winter Banana, and Wolf River. Many of the less well-known but equally good varieties, such as Bellflower, Father Abraham, Fall Cheese, and Winter Cheese, may be found in private collections and at renovated historical sites.

Whether from a sense of nostalgia, a desire to preserve some of our history, or pride in having an antique to display, many of the old apple varieties have been saved from extinction. Some have already been around for centuries; hopefully, they can survive a few more. They are too good to lose.

Study Questions

6. A mulch that could provide habitat for harmful voles would be: a) sawdust; b) hardwood bark; c) black polyethylene plastic; d) all of the above

7. Excessive vegetative growth, delayed fruiting, and possible winter injury can be results of _____.

8. Thinning is done to: a) reduce fruit size,

Table 1. Space Requirement, Yield, Bearing Age, and Life Expectancy of Small Fruits

Fruit	*Minimum Distance Between Rows (feet)*	*Minimum Distance Between Plants (feet)*	*Approximate Yield per Plant (lbs.)*	*Average Bearing Age (years)*	*Life Expectancy (years)*
Blackberry (erect)	10	5	5-10	1	5-12
Blackberry (trailing)	8	6	5-10	1	5-12
Blueberry	6	5	4-6	3	20-30
Grape (American)	8	6	10	3	20-30
Grape (hybrids)	8	5	10	3	20-30
Grape (muscadine)	8	10	15	3	20-30
Raspberry (red)	8	3	3-5	1	5-12
Raspberry (black)	8	4	3-5	1	5-12
Raspberry (purple)	8	4	3-5	1	5-12
Strawberry (June bearing and day neutral)	3	1	1-2*	1	1-2
Strawberry (ever bearer)	3	1	3/4-1	1/3	2

* per parent plant grown in the matted row system

b) increase the number of fruits; c) increase fruit color and quality; d) all of the above

9. Vole damage can be reduced by: a) piling mulch around the tree trunk; b) whitewashing the lower trunk; c) trapping the voles; d) wrapping the tree trunk with paper

10. Collecting and burning debris, and removing all dropped fruits are examples of _____ practices.

11. Many old fashioned varieties of apples fell out of favor because: a) they were more susceptible to pests and disease; b) the fruits did not taste as good as new varieties; c) they became extinct; d) they didn't respond well to modern cultural practices

Answers:
6 - d; 7 - over fertilization; 8 - c; 9 - c; 10 - sanitation; 11 - a

Small Fruits

As a general rule, plant selection and production area in a home garden should be limited to what you can properly care for. It is better to have a well-tended, small planting area rather than a neglected, large one. Small fruits offer certain advantages over fruit trees for home culture in that small fruits require less space for the amount of fruit produced, and bear one or two years after planting. Success with small fruit planting will depend on the attention given to all phases of production including crop and variety selection, site selection, soil management, fertilization, pruning, and pest management.

Table 2. Some Suggested Varieties for the Home Small Fruit Planting

Crop	*Variety*	*Type*	*Fruit size*	*Yield/plant (lbs)*	*Flavor*
Blueberry	Brightwell	R[a]	M[b]	5	G[c]
	Duke	NH	M	2-3	VG
	Legacy	NH	M	5	VG
	O'Neal	SH	M	2-3	VG
	Powderblue	R	M	5	G
	Premier	R	M	5	G
	Suziblue	SH	VL	2-3	E

Table 2. Some Suggested Varieties for the Home Small Fruit Planting

Crop	*Variety*	*Type*	*Fruit size*	*Yield/plant (lbs)*	*Flavor*
Blackberry	Chester	F[d]	M	10-15	G
	Kiowa	F	VL	10-15	E
	Natchez	F	VL	5-10	G
	Navaho	F	M	5-10	E
	Ouachita	F	M	5-10	VG
	Prim-Ark® 45	P	L	10-15	VG
	Prim-Ark® Freedom	P	VL	10-15	VG
Crop	*Variety*	*Type*	*Fruit size*	*Yield/plant (lbs)*	*Flavor*
Raspberry (red)	Caroline	P	M	3-5	E
	Heritage	P	M	5	G
	Himbo Top	P	L	3-5	VG
	Joan J	P	M	3-5	E
	Josephine	P	L	3-5	E
	Killarney[e]	F	M	3	G
	Nova[e]	F	M	3	E
Crop	*Variety*	*Type*	*Fruit Color*	*Flower Type*	
Grapes (for table use)	Concord	Seeded	Blue/black[f]		
	Delaware	Seeded	Red		
	Himrod	Seedless	Golden yellow		
	Mars	Seedless	Black		
	Niagara	Seeded	White/green		
	Seneca	Seeded	White/yellow		
	Steuben	Seeded	Blue/black		
	Sunbelt	Seeded	Blue/black		
Grapes (for wine)	Chambourcin*		Red		
	Chardonel*		White		
	Norton		Red		
	Traminette		White		
	Vidal Blanc*		White		
Grapes (Muscadine)	Carlos		Bronze	Perfect	
	Magnolia		Bronze	Perfect	
	Nesbitt		Black	Perfect	
	Scuppernong		Greenish bronze	Female	
Crop	*Variety*	*Type*	*Fruit size*	*Yield/plant (lbs)*	*Flavor*
Strawberry	Earliglow	ES[g]	M	0.5-0.8	E
	Camarosa	MS	M	0.8-2	G
	Camino Real	ES to MS	L	1-2	VG
	Chandler	MS	M	1-1.5	G
	Flavorfest	MS to LS	M	0.8-1.5	VG
	Sweet Charlie[h]	ES	S	0.5-0.8	E

[a]R=Rabbiteye, SH=Southern Highbush, NH=Northern Highbush. Rabbiteye and Southern Highbush varieties are suitable for southern and central VA. Northern Highbush varieties are suitable for Northern Virginia and the mountains.
[b]Fruit size: VL=Very large, L=Large, M=Medium, S=Small.
[c]Flavor: E=Excellent, VG=Very good, G=Good.
[d]Type: F=Floricane (one crop per year), P=Primocane (two crops per year). All blackberry varieties listed are thornless except for Kiowa and Prime-Ark® 45.
[e]Killarney and Nova are floricane-bearing raspberries not suitable for southern or central Virginia.
[f]For grapes: seeded or seedless type, and wine color (red or white) or fruit color (table or muscadine grapes).
**These grape varieties must be grafted to a rootstock to ensure adequate vigor and tolerance to root-feeding phylloxera.*
[g]Bearing: ES=Early Season; MS = Mid-season; LS = Late Season.
[h]Sweet Charlie is suitable only for coastal plains and piedmont regions of the state.

Planning the Small Fruit Garden

Site selection

Locate your small fruit planting in full sun, as part of, or near the vegetable garden. Select a site that is free from frost pockets, low/wet spots, and exposure to strong prevailing winds. Blueberries should be planted far enough from the roots of trees, to avoid competition for moisture and nutrients. Blueberries may be planted to form a dense hedge, or used in a foundation planting around the home. Where space is a limited, small fruits could also be integrated with ornamental plants. Caneberries grow best on levelled lands. Grapes and raspberries may be planted on a trellis, or a fence along a property line.

Strawberries may be used as a border for a flowerbed, or as a ground cover Avoid planting early varieties on south-facing slopes and be sure to select a site where tomatoes, potatoes, or eggplants have not been grown. These crops often carry verticillium wilt which lives in the soil for many years, and some strawberry varieties are very susceptible to this disease. Strawberries bloom very early in the spring, and the blossoms are easily killed by frost. In areas where late frosts are a hazard, try to select a site for your planting that is slightly higher than surrounding areas. Do not set strawberries in soil that has recently been under sod. A land that was under crop cultivation for a prior year or two, may have soil better prepared for strawberries, and will assist in controlling weeds and white grubs, both of which are troublesome in strawberry plantings. Where grubs and ants are a problem, chemical control may be necessary.

Soils

Small fruits thrive in a fertile, sandy loam soil, rich in organic matter, but they will give good returns on the average garden soil under adequate fertilization and good cultural practices. Incorporation of additional organic matter before planting is desirable. Small fruits are best planted on raised beds eight to 12 inches high and two to four feet across. Drip irrigation is highly recommended.

For best results, small fruit plants should be set no closer than the minimums indicated in Table 1. Overcrowding frequently results in weak plants and low yields. It also makes insect and disease control more difficult.

Special attention should be given to variety selection. Varieties must be adapted to your soil and climatic conditions. If possible, without sacrificing too much yield or quality, select varieties with the least insect and disease problems. Table 2 lists some varieties of small fruits suggested for planting in the home garden under Virginia environmental conditions. For variety recommendations for currants and gooseberries, refer to Chapter 9 http://extension.psu.edu/publications/agrs-097 of The Mid-Atlantic Berry Guide for Commercial Growers 2013-2014.

Ordering Plants

Placing your order. Obtain the best nursery stock available. Buy certified plants from a reputable nursery. Place your order early, as soon as you decide what you want. Specify variety, size, grade of plants desired, and the preferred time of shipment. It is best to have the plants arrive at the time you are ready to set them out. Unless you specify otherwise, some nurseries will only send plant material at the proper time to be planted in your area.

When your order arrives, unpack the bundles and inspect the plants. The roots should be moist and have a bright, fresh appearance. Shriveled roots indicate that the plants have been allowed to freeze or dry-out in storage or transit. Such plants seldom survive. Water root system lightly only if they are very dry.

Minimizing plant stress. If the plants cannot be set immediately, they should be kept either in cold storage or heeled-in to soil. Wrap them in a garbage bag or other material that will prevent them from drying out, and store them at a temperature just above freezing. Strawberry plants in small quantities may be held in the refrigerator for a few days. If refrigerated storage is not available, remove the plants from the bundle and heel them in carefully in a trench of moist soil in a shaded location (Illustration 1). Pack the soil firmly around the roots to eliminate all air pockets and to prevent the roots from drying out.

Illustration 1

Establishing the Planting

There is probably nothing that causes more disappointment

and failure in small fruit plantings than the lack of careful preparation and attention to detail, at the time the plantings are established. Prepare the soil properly, set the plants carefully, and generally create conditions favorable for new growth. Detailed suggestions for the establishment of each of the small fruits follows. These suggestions should be closely followed for best results.

Maintaining the Planting

Once the planting has been established, future success will depend on the care it is given. If the planting is to be productive and long-lived, it must be properly fertilized. Competition from weeds or other plants must be avoided. Insects and diseases must be controlled, and the plants must be properly pruned. Study the maintenance suggestions for each of the small fruit crops, and plan to care for the planting properly. To do otherwise, will probably result in disappointment and wasted effort.

Blueberries

There are three types of blueberries that can be grown in home gardens in Virginia; rabbiteye, southern highbush and northern highbush. Although they may be grown in any area where native blueberries, azaleas, mountain laurel, or rhododendrons do well, they have a better flavor when grown where nights are cool during the ripening season. They are very exacting in soil and moisture requirements. Berries should be picked as soon as they ripen, to minimize infestation of fruits with spotted wing drosophila.

Rabbiteye and southern highbush type blueberries are best suited for climates where summers are generally hotter. These varieties have low winter chilling requirements. “Chilling” is a measure of accumulated hours of temperatures below 45°F in the dormant season. In general, the chilling requirement or rabbiteye and southern high bush type are 250-600 hours, and for northern highbush requirement is 800-1000 hours. Therefore, when buying blueberry plants for your garden, make sure to ask whether you are buying rabbiteye, southern, or northern highbush type. Home growers can find information on chilling hours achieved at a given geographic location for blueberry growing season at: https://climate.ncsu.edu/cronos/blueberry/chill_model?- State Climate Office of North Carolina. This site uses a slightly more complex model for calculating chilling hours as compared to the one described above.

Variety Selection

To provide adequate cross-pollination and to increase chances for a good crop of fruit, two or more varieties that bloom at the same time should be planted. The following varieties suggested below for planting, ripen over a six- to eight-week period, beginning in early June and continuing through July. Most are vigorous and productive under good growing conditions and produce berries of large size and good quality.

Rabbiteye varieties

Alapaha, Climax, Premier, Titan, and Vernon are early season varieties. Brightwell, Powderblue and Tifblue are mid-season varieties. Centurion and Ochlokonee are late season varieties. In central and southern Virginia, planting early, mid, and late season Rabbiteye varieties will allow you to harvest fruits during the July-August months.

Titan is a new variety; it is the largest fruited rabbiteye variety that has been developed to date. Vernon also has large berries. Alapaha and Ochlockonee have medium sized berries with good eating quality and less pronounced seeds than other Rabbiteye varieties.

Southern Highbush Varieties

Most of the southern highbush varieties blooms early in the season and may be damaged by frosts in late spring. Southern highbush varieties are recommended for central and southern Virginia. Suziblue, Palmetto and O’Neal are early season varieties. Suziblue has very large fruit and it has excellent flavor. Palmetto is a medium sized berry and it has an outstanding flavor. O’Neal is a popular variety with medium size and very good flavor fruit. Camellia, Jubilee and Magnolia are mid-season southern highbush. Camellia has a very large size fruit. Jubilee and Magnolia are smaller fruited varieties with good plant vigor. Bird and deer feeding may be a problem with southern highbush varieties.

Northern Highbush Varieties
Northern highbush blueberries are self-fertile; however, larger and earlier ripening berries result if several varieties are planted for cross-pollination. In Virginia, the northern highbush varieties should be planted in northern Virginia and in the mountain region with adequate soil conditions.

Duke, Earliblue, Patriot and Spartan are early season northern highbush varieties. Duke is a popular variety with medium-size fruit and very good flavor. Earliblue produces very early in the season; it is not as heavy a producer. Patriot is a heavy producer with very large berry size. Spartan has large berry size and good flavor.

Bluecrop, Blueray and Legacy are mid-season northern high bush blueberries. Bluecrop, although lacking in vigor, is very hardy and drought-resistant. The fruits are medium sized. Blueray is very hardy, and productive, and is recommended for planting. The fruit is large, dark blue, flavorful. Legacy is a highly adaptable variety, slower in production in the first few years, however, yields can be very high once the plants become established.

Elliott and Jersey are late season northern highbush varieties. Elliott has a good, mild flavor when fully ripe (if not fully ripe the flavor will be very tart). It is winter hardy and bears firm, medium sized fruits. Jersey, one of the leading commercial varieties, is also a favorite in the home garden. The plants are vigorous and hardy, producing heavy crops of medium, dark berries of good quality. Since these are picked fully ripe, they are also more susceptible to damage caused by spotted winged drosophila.

Establishing the Planting

Soils. Blueberries are shallow-rooted plants and must either be irrigated, heavily mulched, or planted in a soil with a high water table. Adequate drainage must be provided, because they cannot tolerate saturated soils. High water table in clay soils promote root rot diseases. Raised beds with drip irrigation is preferable. They grow best in porous, moist, sandy soils, high in organic matter, with a pH range of 4.2 to 5.2. Have the soil tested, and if the pH is not in the 4.2 to 5.2 range, work such materials as peat moss, pine needles, pine bark, or sulfur into the area where the plants are to be set. This should be done six months to a year before planting. To acidify sandy soils, sulfur is recommended at the rate of three-fourth pound per 100 square feet for each full point the soil tests above pH 4.5. On heavier soils use one and half to two pounds. Once proper soil pH is established, it can be maintained through the annual use of an acid fertilizer, such as ammonium sulfate or cottonseed meal. pH of the soil should be tested every three years.

Planting. Vigorous, two-year-old plants about 15 inches high are recommended for planting. Set in early spring about three or four weeks before the average date of the last frost. For rabbiteye varieties, plant every four to five feet in row, and ten feet between rows. For northern and southern high bush verities, plant three to four feet in row, and six to eight feet between rows.

Give the roots plenty of room. Where the plants are to be set, dig the holes wider than and as deep as necessary to accommodate the root systems. It is not necessary to incorporate organic matter or other soil amendments into the backfill soil. Trim off diseased and damaged portions of the top and roots, and set the plants at the same depth that they grew in the nursery. Spread the roots out, and carefully firm the soil over them. Water thoroughly after planting.

Maintaining the Planting

Soil Management. Mulching is the preferred soil management practice in the blueberry planting. The entire area around and between the plants should be mulched. Hardwood or softwood bark and sawdust, applied to a depth of four or five inches is recommended. Many growers use a combination mulch - a layer of leaves on the bottom, with two or three inches of sawdust on top. Renewed annually, this heavy mulch retains moisture,

keeps the soil cool, and adds needed organic matter. If soil pH is an issue, make sure to mulch with pine bark or apply sulfur on top of mulch. Mulches provide a relatively warm environment, and can attract voles particularly during winter season. In areas where voles are a problem, mulch application should be less thick and be applied more frequently. Control through trapping and chemical baiting may be needed.

Fertilization. No fertilizer should be applied at planting time, and usually none is needed during the first growing season. On poor soils, however, the application of two ounces of ammonium sulfate around each plant about the first of June is beneficial.

Ammonium sulfate, at the rate of two ounces per plant, should be spread in a circle around each plant, about six to eight inches from its base, just before the buds begin to swell the second spring. Increase the amount each succeeding spring by one ounce, until each mature bush is receiving a total of eight ounces annually. Cottonseed meal has proven to be an excellent fertilizer for blueberries and is used by many home gardeners. It supplies the needed nutrients and helps maintain an acid soil. Use it at the rate of one half pound per plant. Where sawdust is used as a mulch, it will be necessary to apply additional nitrogen to prevent a deficiency as the sawdust decays. Usually about three-fourth pound of ammonium sulfate for each bushel of sawdust is sufficient.

Pruning. Until the end of the third growing season, pruning consists mainly of the removal of low spreading canes, and dead and broken branches. As the bushes come into bearing, regular annual pruning will be necessary. This may be done any time from leaf fall until before growth begins in the spring. A mature blueberry plant should produce three to five new canes per year. During pruning, clean out old, dead wood, and keep three best one-year-old canes. Locate the oldest canes and prune out one of every six existing canes; cut as close to the ground as possible. A mature blueberry bush should have ten to fifteen canes: two to three canes each of one-, two-, three-, four-, and five year old canes.

Pest Control. Birds are by far the greatest pests in the blueberry planting. Covering the bushes with wire cages, plastic netting, or loosely woven cotton fabric cloth (tobacco cloth), is perhaps the best method of control. Aluminum pie tins have been used successfully. They are suspended by a string or wire above the bushes, such that they twist and turn in the breeze and keep the birds away. Spotted wing drosophila will lay eggs on ripe or ripening fruits, and infestation on fruits can be minimized by picking fruits as soon as they are ripe.

Illustration 2. Unpruned blueberry plant on left. After pruning, a mature blueberry bush should have ten to fifteen canes as seen on right side.

Harvesting the Planting

Some varieties of blueberry will bear the second year after planting. Full production is reached in about six years, with a yield of four to six quarts per plant, depending on vigor and the amount of pruning. Blueberries hang on the bushes well and are not as perishable as blackberries or raspberries. Picking is usually necessary only once every five to seven days; more frequently if bird pressure is high. Blueberries will keep for several weeks in cold storage.

Caneberries

Both raspberries and blackberries (often, commonly referred to as caneberries or brambles) will usually yield a moderate crop of fruit the second year after planting, and a full crop the third season. With good management, it is possible for gardeners to extend the productive life of well-maintained plantings beyond 10 years.

Variety Selection

For blackberry and raspberry, there are two fruiting types; primocane and floricane. Primocane type raspberry and blackberry bear fruits on the first year cane (shoot) which are ready for harvest in late summer. After harvest, if the cane is pruned at the point below where it produced fruit in the first year, the lower part of the cane will produce another crop (second harvest) next summer after the cane is exposed to chilling during the winter months. Therefore, the primocane fruiting blackberry and raspberry varieties can produce two crops (harvests) each year. The second crop is usually ready for harvest in Central Virginia in

first week of June. It is important to prune and remove canes after the second harvest, and allow the new canes to grow.

Of the many varieties of blackberries and raspberries available, few have proven totally satisfactory for growing under Virginia conditions. Only top-quality, virus-free, one-year-old plants of the best varieties should be planted.

Blackberries

Of interest to home owners would be the thornless blackberry varieties that would allow children and adults to pick berries without the concern of being scratched on the skin. However, there are some very tasty and productive thorny blackberry varieties. Some popular blackberry varieties include:

Chester is a thornless, late bearing, semi-erect variety, high in yields with a medium fruit size. The variety is resistant to cane blight.

Kiowa is a thorny, early-season, blackberry variety that bears the world's biggest blackberry fruit. Kiowa blooms earlier and longer than other blackberry varieties. The berry ripens in early June.

Navaho is a thornless, erect, mid to late season blackberry, that produces better quality fruits when trellised. The fruit shape is conic; the berry size is medium, but very firm; and the flavor is excellent.

Natchez is a thornless, early bearing variety that produces large fruit that ripens in early June. When fully ripened, it is very sweet and tasty. Natchez is a semi-erect variety and needs trellising for improved production and better fruit quality.

Prime-Ark® 45 is thorny primocane variety that produces firm berries, free of molds and diseases. Berries are large in size, with good flavor, and are suitable for long distance shipping.

Prime-Ark® Freedom is the world's first thornless primocane, released in 2013. This is an erect type, producing very large fruits, and has a good flavor. The fruit is harvested in the fall and is good for fresh consumption. As a primocane type blackberry, the Prim Ark° Freedom can produce two crops per year.

Dewberries and boysenberries are also included under blackberries. Dewberry is a trailing form of blackberry, and boysenberry is a hybrid of loganberry (Rubus loganobaccus) and various blackberries and raspberries. The boysenberry plant is easily winter killed and should be planted only in areas of mild winters. Plants are extremely vigorous and productive and the berries are large and flavorful when fully ripe. Thornless boysenberries are also available. Recommended varieties of dewberry and boysenberry include:

Lucretia dewberry, best of the trailing blackberries, is relatively winter hardy, vigorous, and productive. The fruits are very large, often an inch and half long, shiny, sweet flavor berry.

Lavaca, a seedling of the boysenberry, is superior to its parent in production, size, and resistance to cold and disease. The fruit is also firmer, less acidic, and of slightly better quality.

Raspberries

Raspberry types are based on berry color: red, black, and purple. Chances for success with raspberry plantings are better if the plantings are located in the cooler mountain sections of the state. Fruit production and quality can be improved if trellises are used when planting raspberry.

Red raspberries have generally been more successful in the warmer areas of the state than have the other types.

Caroline is an early primocane bearing variety. The conical fruit is medium sized, firm, and has excellent flavor. The variety has medium vigor and good disease resistance.

Heritage is primocane bearing variety. Fruit of Heritage is medium sized, firm, and of good quality. This variety is resistant to most diseases, but is susceptible to late leaf rust.

Himbo Top is a primocane raspberry variety, with high tolerance to Phytophthora root rot disease. This variety produces a large, firm, conic fruit, bright red in color, with very good flavor.

Joan J is a very productive, spine free, primocane bearing variety. Fruit is very firm, glossy, and dark red in color used for fresh consumption.

Jaclyn is the earliest of the primocane bearing varieties. Fruits are dark red, large, and have an excellent flavor. Used primarily for fresh consumption.

Josephine is a primocane bearing variety that has an upright, vigorous plant. Berries are dark red in color, large, have excellent flavor, and long shelf life. Plant is resistant to potato leaf hopper.

Killarney is a high yielding, floricane bearing variety. Fruit is medium-sized, bright colored, but is soft in warm weather. This is a hardy cultivar and suitable for colder climates. Susceptible to mildew and anthracnose. Good flavor and freezing quality.

Latham is a standard, floricane bearing variety. Plants of this variety are vigorous, with few spines, moderately productive, and susceptible to fire blight and powdery mildew. The berries are small in size and soft. The flavor is somewhat tart.

Nova is mid-season, floricane bearing variety. Fruits are somewhat acidic in taste. Considered to have better than average shelf life. Plants are hardy and resistant to cane diseases and late leaf rust, but are susceptible to cane botrytis.

Black raspberries are very susceptible to viral diseases and are readily infected when grown near red varieties carrying a virus. Plants of red and black raspberries should be separated by at least 700 feet.

Cumberland, a floricane bearing variety, ripens about one week later than New Logan. Cumberland has long been a favored variety due to its attractive, firm berries with fair flavor. The plants are vigorous and productive, but not particularly cold hardy.

Jewel, a floricane bearing variety, has firm, glossy, large and flavorful fruits. Plants are vigorous, cold hardy, upright, and resistant to most diseases. Jewel is a high yielding variety.

New Logan yields heavy crops of good quality, large, glossy-black fruits. Plants hold up well during drought, and are relatively tolerant to mosaic and other raspberry diseases.

Purple raspberries are a hybrid of the red and black types. The fruits have a purple color and are usually larger than the parent varieties. They are tarter in taste compared to either the reds or black raspberries, and are best used in jams, jellies, and pies. They are excellent for quick freezing. Plants are less hardy than the parents, but are vigorous, and very productive.

Brandywine is the best purple raspberry available. It ripens later than most red or black varieties. The fruit is large, firm, and quite tart, but of good quality. This variety is resistant to most diseases, but is susceptible to crown gall.

Royalty, has a delicious sweet flavor, soft fruit, and high productivity. It is excellent for fresh use, and for jam and jelly. Royalty is resistant to mosaic-transmitting aphids and raspberry fruit worm. Canes have thorns.

Establishing the Planting

Soil. Caneberries grow best in deep, sandy loam soils, rich in organic matter. Ideal soil should have a pH of 6.0 to 6.5, and be well drained to a depth of at least three feet. Caneberries are sensitive to excess waterlogging, and even temporary water accumulation can weaken canes, hinder plant growth, and increase incidences of diseases, particularly root rots. Therefore they are best grown on raised beds.

Planting. Caneberries should be planted late in fall, or early in the spring, about four weeks before the average date of the last frost. Work the soil as for garden vegetables, particularly where the plants are to be set. When planting in rows, allow at least eight feet between rows to facilitate cultivation. Red and purple raspberries may be set three feet apart within the row; set erect and semi-erect blackberries plants five feet apart. Black raspberry rows should be no less than four to five feet apart, and trailing blackberry rows no less than six feet apart.

Set the plants at about the same depth they grew in the nursery. The crown should be at least two inches below the soil line. Spread out the roots, and firm the soil carefully around them. Do not allow the roots to dry out. Most caneberry fruits come with a portion of the old cane attached. This serves as a handle in setting the plants. Soon after new growth begins, the handle can be cut off at the surface of the ground and destroyed, as a safeguard against possible anthracnose infection.

Maintaining the Planting

Soil Management. Caneberries grow best in soils containing three percent or more organic matter. Organic matter in soil can be maintained using a permanent mulch. Mulch should be applied soon after setting the plants, and maintained throughout the life of the planting by replenishing annually, or as needed. Hardwood or softwood bark should be applied at least five or six inches in depth. If mulch material is unavailable, or if cultivation seems necessary, keep the cultivation very shallow to avoid disturbing the roots, and repeat cultivation often as necessary, to control weeds until the beginning of harvest.

Fertilization. If materials low in nitrogen are used, it may be necessary to add sufficient nitrogenous fertilizer to prevent a temporary deficiency as the mulch begins to decay. Usually about one half pound nitrate of soda, or three-fourth pound of 10-10-10, for each 100 square feet of mulched area will be enough. On fertile soils, or where good mulch is maintained, it is usually unnecessary to make an application of fertilizer in the caneberry planting. Additional fertilizer should be added after soil test has been done, and on basis of recommendations. If growth is poor, addition of two to three pounds of ammonium nitrate to each 100 feet of row, when growth begins in the spring, will be beneficial. Adjustments to fertilizer grades and amount should be made based on plant growth and soil type. However, do not over fertilize, because it may result in too much vegetative growth, burning of foliage, yield loss, injury to roots, a decrease in fruit quality, and an increase in disease.

Training and Pruning. Trailing and erect-growing blackberries and black and purple raspberries need some kind of support. They may be grown on a trellis, trained along a fence, or tied to stakes. Other caneberries may either be trained to supports, or with more severe pruning, grown as upright, self-supporting plants. Red raspberries sucker so are frequently grown in hedgerows. On vigorous sites some type of minimal containment trellising may be needed in some seasons.

A simple trellis, used in many home gardens, consists of two wires stretched at three and five foot levels between posts set 15 to 20 feet apart. Fruiting canes are tied to these wires in the spring. The erect varieties are tied where the canes cross the wires. Canes of trailing varieties are tied horizontally along the wires, or fanned out from the ground and tied where they cross each wire.

Where stakes are used for support, they are driven into the ground about one foot from each plant, and allowed to extend four or five feet above the ground. Canes are tied to the stake at a point about midway between the ground and the tips of the canes, and again near the ends of the canes.

Caneberry plants are biennial in nature; the crowns are perennial. New canes grow from buds at the crown each year. The new shoots called ‘primocanes’ will produce vegetative growth the first season, go through a dormant winter season, and then are referred to as ‘floricanes’ the second year. Primocane bearing varieties produce fruit on first year canes (shoots). The base of these primocanes will survive, while the top portion of the cane will die off after fruiting.

Dormant pruning is usually delayed until danger of severe cold has passed, and accomplished before the buds begin to swell in spring. Dormant pruning consists of the removal of all dead, weak, diseased, and severely damaged canes, and the selection and pruning of the fruiting canes for the coming season. At the dormant pruning, thin each plant until only four or five of the best canes remain. Where possible, fruiting canes one-half inch or more in diameter are selected. Cut the lateral branches of the black raspberry to nine to 12 inches long; those of the purple raspberry to 12 to 15 inches long and the blackberry to 15 to 18 inches long (See illustration 3). At the dormant pruning, where supports are used, head the canes to four or five feet in height. Canes grown without support should be headed to three feet. All dead and weak canes should be removed after harvest or at the dormant pruning. They should be thinned to seven or eight of the best canes per hill, cut to about five feet in length, and tied to either a stake or trellis.

Summer top pruning stimulates lateral branching. Summer top pruning consists of removing the top three to four inches of the new shoots by snapping them off with the fingers, or cutting them with shears or a knife. Where trained to supports, let them grow six to eight inches taller than the support before topping. Blackberry

plants should be summer-top pruned when the young shoots (primocanes) are about five feet tall. For, black raspberries and purple raspberries summer-topping should be done when young shoots are about three to four feet tall. To prevent the planting from becoming too thick and reducing yields, it may be necessary to remove excess sucker plants as they appear. This can be done either with a hoe or by hand. In the hedgerow type of culture, leave only three or four shoots per running foot of row. Grown in hills, four to five new shoots may be allowed to develop in each hill.

Illustration 3. An unpruned blackberry plant (left). Once plants are dormant, only retain four to five best canes (right).

Primocane bearing red raspberries should not be summer-topped, as this will reduce potential of canes to bear fruits in summer. Canes of primocane bearing varieties are handled in the same manner as the others during the dormant season. At the dormant pruning, where the hill system of culture is used, thin until only five to seven of the best canes remain per hill.

If the plants are grown in hedgerows, keep the width of the rows to 18 inches or less and remove all plants outside the row areas. Thin the canes within the hedgerows to six to eight inches apart, saving the best canes (See illustration 4.).

Illustration 4. For plants grown in hedgerows, thin canes to 6 to 8 inches. Illustration shows before (left) and after (right) thinning.

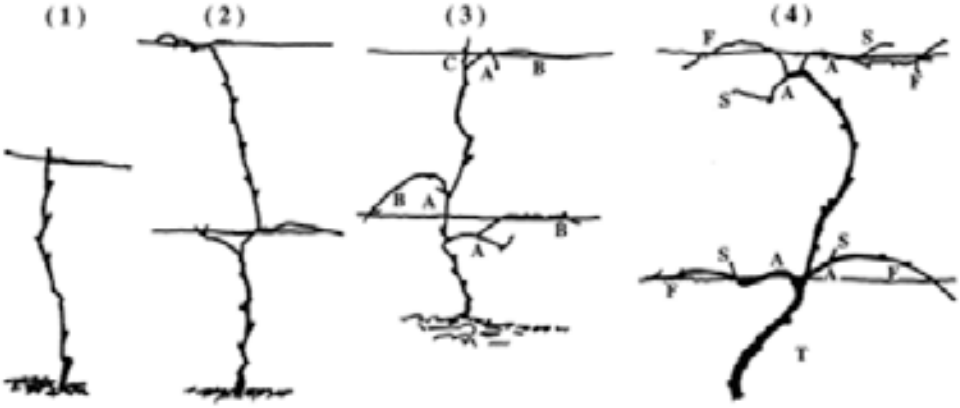


Illustration 5. Four-arm Kniffin system.
Stages in training the young vine to the single trunk, four-arm Kniffin system.
(1) After pruning the first winter. The single cane is cut back and tied to the lower wire. If the cane has grown less than three feet during the first summer, it should again be cut back to two buds.
(2) After pruning the second winter. Two new canes of four or five buds each are tied on the bottom wire. A third new cane is tied up to the top wire and cut off.
(3) After pruning the third winter. Three of the arms (A) and the fruiting canes (B) have been formed. A cane (C) with four or five buds is left to establish the fourth arm.
(4) A fully formed vine after pruning the fourth winter. The arms (A) should be shorter than those shown. The vine consists of a single permanent trunk (T), four semipermanent fruiting arms (A), four annual fruiting canes (F), and four renewal spurs (S), with two buds on each.

Where the canes are supported either by a trellis or stakes, cut the canes back to a convenient height for berry picking, usually about five feet. Grown as upright, self-supporting plants without use of trellises or stakes, the canes should be cut back to about three feet in height whether in hills or in hedgerows. Any lateral branches should be cut to about 10 inches in length.

Grapes

Grapes of some type can be grown almost anywhere. Careful selection of cultivated varieties compatible with local soil and climatic conditions has led to successful production in home gardens and commercial vineyards.

Table grapes

Grape varieties should be selected for their intended use. Some seeded varieties such as Concord or Niagara may be used either for fresh table consumption, home juice or jelly production, or for wine production, but most varieties were developed or selected for a specific use. The following varieties are generally classified by intended use and have fared reasonably well over a wide geographic area of Virginia, with certain noted qualifications. All American, hybrid and *Vitis vinifera* grapes are self-fertile, meaning that a different pollenizer is not required for them to adequately set fruit.

Concord is by far the most widely planted blue-black grape. The good-quality fruit ripens unevenly in the hotter areas of the state. A similar variety called 'Sunbelt' was developed in Arkansas to ripen more uniformly in hot climates. Concord is an excellent and versatile variety for the home gardener! The vines are vigorous and productive and, except for black rot, they are relatively disease tolerant.

Delaware is a high-quality, red grape ripening about one week before Concord. Quite susceptible to downy mildew, this variety produces clusters and berries that are rather small and vines that grow slowly. Delaware has an unusually good balance of sweetness and acidity. It yields fine-quality white wines and is often used in blends for sparkling wine.

Himrod, a golden-yellow grape, has good flavor and is considered seedless, although vestigial seeds can be present. Hardy, vigorous, and productive, it has been superior to its sister seedling, Interlaken, in areas where both have been grown.

Mars has medium-sized, seedless, blue-black berries of the slip-skin type, and is sweet and enjoyable. It is a cold-hardy plant with high resistance to black rot, powdery mildew, and downy mildew.

Niagara has green-white berries and is used in wine and as a table grape. It is the most widely planted white American grape in the United States and is used extensively for white juice.

Seneca, an early season yellow grape, is noted for its good flavor and tender pulp. It holds well on the vine and will keep in cold storage for about two months after harvest. Vine vigor and productivity are only moderate, and this variety is quite susceptible to black rot and powdery mildew.

Steuben is a blue-black variety ripening about one week after Concord. The berries are medium in size with a sweet, spicy flavor. They keep well in storage. The vines are hardy, vigorous, and productive. Steuben makes a very nice wine in addition to its use as a table grape.

Wine grapes

American and hybrid varieties

Chambourcin is a black grape that produces a red wine often compared to Merlot. Although Chambourcin can be grown on its own roots, graft to a rootstock, such as C-3309, 101-14, or 420-A, for best performance.

Chardonel is a mid-season, white wine grape. It is productive and generally more disease resistant than one of its parents, Chardonnay. Chardonel must be purchased from a grapevine nursery as a grafted grapevine. We recommend any commonly used rootstock variety, such as C-3309, 101-14, or 420-A.

Norton is a late ripening American type wine grape hybrid of *Vitis aestivalis*. Norton is a black grape with small clusters and small berries. The fruit can be very acidic and vines should be trained to a high wire cordon, affording excellent fruit exposure to help reduce fruit acidity.

Traminette is a mid-season white wine grape with good productivity and partial resistance to several fungal diseases. It produces a wine with some of the spicy, rose-like characteristics similar to one of its parents, Gewürztraminer.

Vidal Blanc is a mid- to late-season, white wine grape. It is moderately susceptible to downy mildew and powdery mildew, as well as aerial phylloxera. Vidal should be purchased from a grapevine nursery as a grafted grapevine. We recommend any commonly used rootstock variety, such as C-3309, 101-14, or 420-A.

Vitis vinifera varieties

Vitis vinifera grape varieties are the most important and the most abundant grapes grown globally for wine and raisin production. They are, however, difficult to grow in the backyard situation. Vinifera varieties are extremely susceptible to many diseases; most are susceptible to winter cold injury below 5 F, and all vinifera varieties must be grafted to rootstocks tolerant of grape phylloxera. If you choose to grow vinifera grape varieties, pay particular attention to the disease management described under "Pest Management", below.

Cabernet franc is a black grape that produces fine red wine. Vines are vigorous and more cold hardy than other black vinifera types.

Chardonnay, considered by many to be superior to all other varieties for dry white wine, is only moderate in hardiness, vigor, and productivity. It is a medium-sized, white grape in a compact cluster ripening three to five days ahead of Concord. Vines are extremely sensitive to fungal diseases such as powdery mildew, downy mildew, and black rot.

Muscadine varieties

In areas where it is adapted, the muscadine grape is a favorite for home plantings. It is highly desirable for juice, jam, and jelly, and some varieties are cultivated for the unusual style of the wine. Muscadine grapes are cold-tender and should not be planted where temperatures fall below 5 F. In Virginia, plant only in USDA cold hardiness zones 7b or greater.

Many muscadine varieties have imperfect flowers and require pollination from either male or perfect-flowered varieties. Of those suggested for planting, Carlos, Magnolia, and Nesbitt are perfect-flowered and will supply adequate pollination for female-flowered varieties such as Scuppernong.

Carlos, a 1970 introduction from North Carolina, is a perfect-flowered bronze variety, ripening with Scuppernong and similar in size and flavor. It makes excellent white wine and is relatively cold hardy, disease resistant, and productive. It is recommended for both commercial and home garden plantings.

Magnolia is a perfect-flowered, bronze variety of large size and very high quality. The vine is vigorous and very productive.

Nesbitt is a large, black, perfect-flowered variety from North Carolina. Fruit ripens over a three-week period and vines are relatively cold-hardy.

Scuppernong, a name commonly applied to all bronze-skinned muscadine grapes, is the oldest and best-known variety. Berry clusters are usually small and shatter badly, but the grape quality is good, and it has a very distinctive flavor. As a female flowered variety, Scuppernong would require a pollinator variety that blooms at roughly the same time.

Establishing the Planting

Site and Soil Essentials

Grapes should be planted where they have benefit of the sun for most of the day. They are deep-rooted plants, frequently penetrating to a depth of 6 to 8 feet under good soil conditions. Most grapes require 160 or more frost-free days to ripen the crop, so the site should be relatively high to surrounding topography to allow cold air drainage, and the general climate of the area should afford at least 160 frost free days. Good air movement aids disease management. Avoid use of volatile herbicides, such as those that contain 2,4-D or dicamba, in the vicinity of the grape planting, as grapevines can be severely damaged by drift from such herbicides.

Grapevines grow best on well drained, sandy loam soils with two to five percent organic matter and moderate fertility. Sandy or heavy clay soils may be used, however, if provisions are made for adequate fertilization, moisture,

and soil drainage. Grapes are tolerant of a wide range of soil acidity, but prefer a 6.0 to 6.8 pH range.

Planting

Dormant grapevines are usually set in early spring, at or slightly before the average date of the last frost. Vigorous, one-year-old plants are preferred. Allow plenty of room between plants within a given row; at least five feet for the American bunch varieties and eight feet or more for the vigorous-growing muscadine type. Trim the roots to about six inches in length to encourage formation of feeder roots near the trunk. Where the vines are to be set, dig the holes large enough so the roots can be spread without crowding and the plants can be set at about the same depth that they were grown in the nursery. For grafted vines, use care in firming the soil around set vines to ensure that the graft union remains about three inches above the final, settled soil line. Prune the planted vine to a single cane, and head it back to two buds, after buds have broken and all risk of frost has passed.

Maintaining the Planting

Soil Management

Mulching is the preferred soil management practice in home grape planting as mulch will suppress weeds and conserve soil moisture. Hardwood or softwood bark mulch to a depth of four to six inches is recommended. There have been cases where mice have girdled vines with mulch up to the trunk, so it is best to keep some space between the trunk and mulch through the winter.

Although grapes are deep-rooted plants, they do not compete well with weeds and grass, especially shortly after planting. If mulch material is unavailable, some cultivation should be done. Cultivation should be shallow and only as necessary to eliminate undesired vegetation.

Fertilization

Like all fruit plants, grapes usually require nitrogen fertilization. Except in sandy soils, this element may be the only one needed in the fertilization program. In the home garden, two ounces of calcium nitrate (15.5 percent N) per vine should be applied after growth begins in the spring. Spread the fertilizer in a circle around the plant, 10 to 12 inches from the trunk. Repeat the application about six weeks later. Repeat this fertilization at the same timing and rates in the second and third seasons. A blended fertilizer, such as 10-10-10, applied at three ounces per vine may be substituted where phosphorus and potassium are also needed.

Fertilizer applications to mature, bearing vines should be based on the growth and vigor of the plant. If the average cane growth is only three feet or less, additional nitrogen may be needed. Where proper pruning is practiced and competition from weeds and grass is kept to a minimum, however, it is doubtful that you will need to go beyond the amount recommended for a three-year-old vine.

Training and Pruning

Much attention is given to the training and pruning of grapes. To be most productive, they must be trained to a definite system and pruned rather severely. There are several training systems used. Two that are commonly used are the vertical trellis and the overhead arbor. Both of these are satisfactory in the home planting if kept well pruned.

Of the many variations of the vertical trellis, the single trunk, four-arm Kniffin system is the most popular. Posts are set 15 to 20 feet apart and extend five feet above the ground. Two wires are stretched between the posts, the lower being about two-and-half feet above the ground and the upper at the top of the posts. Set between the posts, the vine is trained to a single trunk with four semipermanent arms, each cut back to six to ten inches in length. One arm is trained in each direction on the lower wire.

During annual winter pruning, one cane is saved from those that grew from near the base of each arm the previous summer. This cane is cut back to about ten buds. The fruit in the coming season is borne on shoots developing from those buds. Select another cane from each arm, preferably one that grew near the trunk, and cut it back to a short stub having two buds. This is a renewal spur. It should grow vigorously in the spring and be the new fruiting cane selected the following winter. All other growth on the vine should be removed. This leaves four fruiting canes, one on each arm with eight to ten buds each, and four renewal spurs, one on each arm cut back to two buds each.

The same training and pruning techniques may be effectively used in training grapes to an arbor system. Arbors are generally overhead structures occasionally used in home plantings to add a decorative feature to the garden or lawn. Many variations can be found by browsing the Web. The principal difference between trellises and arbors is that the wires supporting the grapevine arms are placed overhead and parallel with each other on the arbor instead of vertically on trellis posts. Overhead wires or wooden frames are usually placed six to seven feet above

the ground, well within reach.

If an arm dies or for any reason needs to be replaced, choose the largest cane that has grown from the trunk near the base of the dead arm and train it to the trellis wire. To renew the trunk, train a strong shoot from the base of the old trunk to the trellis as though it was the cane of a new vine. Establish the arms in the same manner as for a new vine, and cut off the old trunk.

A high-wire cordon training system can be used with varieties such as Norton that have trailing or procumbent shoot growth habits. The top wire of the trellis is placed about six feet above the ground. Trunks are trained up to this wire and then horizontally extended along the top wire to which they are loosely tied. These horizontal trunk extensions are termed "cordons" and are annually pruned to short, two- to four-node "spurs" derived from the previous season's canes. It is important to train or comb the current growing season's shoots downward from the cordons if using a high-wire system.

Pruning may be done at any time after the vines become dormant. In areas where there is danger of winter injury, pruning should be delayed until early spring. Vines pruned very late may bleed excessively, but there is no evidence that this is injurious.

Pest Management

Grapes and grapevines are subject to diseases and insect pests. Certain varieties, such as Norton, as well as most muscadine varieties, are relatively resistant to common fungal diseases. On the other hand, all of the *Vitis vinifera* varieties and many of the hybrid grape varieties are either moderately or highly susceptible to one or more fungal diseases, including black rot, downy mildew, and powdery mildew. Chief insect pests include Japanese beetles and grape berry moth. If acceptable to the grower, a fungicide spray program will likely be minimally required for American and hybrid grapes, and mandatory for *Vitis vinifera* varieties to avoid crop loss to these diseases. Japanese beetle and grape berry moth infestations vary from year to year and may or may not require insecticide sprays. For further information on chemical pest control, please consult Virginia Cooperative Extension's spray program for home fruit production (http://www.pubs.ext.vt.edu/456/456-018/456-018.html). In addition to potential disease and insect threats, ripe grapes are attractive to birds, deer, and raccoons. Bird netting can be used to exclude birds, but must be applied to the planting soon after grapes begin to acquire color and ripen. Vertebrate pests such as deer and raccoons can be excluded with woven wire, electric fencing, or combinations of fencing small enough to exclude raccoons and tall enough (eight to ten feet) to discourage deer.

Harvesting the Planting

For best quality, bunch grapes should be fully ripe when harvested. They will not improve in sugar content or flavor after being removed from the vine. Most varieties should be used immediately because they do not keep well after ripening. Cut the clusters off with a knife or shears to avoid bruising the fruit and damaging the vine.

Muscadine grapes grow either singly or in small, loose clusters. Some varieties may be shaken off easily when ripe, others have to be handpicked. The grapes should be used soon after harvesting, since their storage life is relatively short.

Strawberries

Strawberries are the most widely cultivated small fruit in America. They are the favorite of many for pies, jams, jellies, preserves, and for eating fresh. Strawberries are adaptable to a greater range of soil and climatic conditions, and are well suited to the home garden, (where supplemental watering is readily accessible).

Variety Selection

Strawberry varieties vary in their adaptability to soil and climatic conditions and can be classified into short-day or June bearing types, and day-neutral or everbearing types. The short-day strawberries will initiate flower buds when days are shorter than 14 hours or when temperatures are below 60 F. Most of the varieties that fruit solely in May-June are short day varieties, with flower buds initiated from late August to early November, however the short days in spring (March) will also initiate flower buds. Day-neutral varieties will initiate crown growth and flower buds throughout the season except when temperatures are very high (above 86 F). These varieties will bear fruits in May-June somewhat yielding lower than short-day varieties. Day-neutral varieties will yield a second crop in midsummer at most locations, and a third heaviest crop in late summer and early fall. The varieties suggested for planting in Virginia have been selected on the basis of plant vigor, productivity, and quality of the fruit. Virus-free plants of the varieties are available and should be purchased. To keep disease pressure low, it is recommended to replace strawberries each year, and plant new berries at a different location in the garden than

previous year.

Short-day or June bearing varieties:

Camino Real has a compact growth habit, and a darker fruit color compared to Camarosa. Fruit is attractive and conical in shape. The variety is suitable for both fresh market and processing, and is resistant to Verticillium wilt, and root and crown rots.

Camarosa is a widely grown cultivar in the world. It has good disease profile resistance but is susceptible to verticillium wilt. Fruit is large, firm, and holds well in the rain. The fruit tastes better when it is picked past its glossy red stage.

Chandler is another variety popular throughout the world and is greatly adaptable to the eastern United States. Fruit is medium to large in size, with medium firmness. Chandler has good taste, is high yielding, and is suitable for fresh consumption and processing. This variety is susceptible to diseases, but harvests over a long period.

Delmarvel is productive on a variety of different soil types. It is an attractive large sized berry, with good aroma and flavor. Plants are disease resistant except for Rhizoctonia, but exhibit good winter hardiness.

Earliglow is a variety noted for its superior dessert quality and disease resistance. The medium-large berries are very attractive, with a glossy appearance and deep-red color. It is one of the best for eating fresh, as a frozen product, and in jams and jellies. The plants are very vigorous and productive; however, they bloom early and are subject to frost injury, and late berries are small in size.

Flavorfest is a mid to late-season variety, with sweet tasting berry, and a medium size fruit. This variety is resistant to anthracnose disease.

Sweet Charlie is a winter tender variety with overall lower yields for the season. This variety has small fruit size. It is grown for its early bearing capacity, excellent flavor, and sweet taste. The plants are susceptible to Phytophthora.

Lateglow was developed for its production of late-season fruit and good disease resistance. Its berries are very large, symmetrical, and attractive. It is a good dessert variety, can be eaten fresh, or frozen.

Day-neutral or everbearing varieties:

Albion has a relatively open plant canopy. It is resistant to wilts and rots, and is one of the most widely grown varieties in northern California. Berries are cone shaped, with a dark red hue, and sweet flavor. The variety is good for fresh consumption and processing.

San Andreas has good disease resistance. This variety produces high quality fruit, has an outstanding flavor, and an exceptional appearance. Fruits are medium to large in size, and symmetrical conic in shape. Fruit color is slightly lighter than Albion. This variety is suitable for fresh market, processing, and home gardens.

Establishing the Planting

Soil

Although strawberries grow best in a fertile, sandy loam soil, with a pH of 5.9 to 6.5, they may be successfully grown in any good garden soil that is well drained and well supplied with organic matter. Soil for strawberries should be thoroughly prepared for planting, should be loose, and free of lumps; again raised beds are preferable.

Planting

Virus-free plugs should be set out late fall or dormant crowns in early spring- about three or four weeks before the average date of the last frost. Plants should be placed no less than 12 inches apart in rows that are two to three feet apart. Take care to set each plant so the base of the bud is at the soil level. Spread the roots out, and firm the soil carefully around them to prevent air pockets which allow them to dry out.

Maintaining the Planting

Soil Management

Cultivation for weed control in strawberries should begin soon after planting, and continue at approximately two to

three week intervals throughout the first growing season. Cultivation must be shallow to prevent root injury. Hoe as often as necessary, to remove grass and weeds growing between the plants.

In colder areas, home garden strawberry plantings should be winter mulched. Any organic material free of weed seeds makes acceptable mulch. Hay, straw, and pine needles are most frequently used. Mulch should be applied two to four inches deep over and around the plants after the first freezing weather in the fall when the soil is below 50 F (usually around mid-December). This protects them from injury due to freezing, and heaving of the soil during the winter. After the danger of frost is over in the spring, about half the mulch should be raked off the plants into the area between the rows. Mulch left around the plants will help keep the berries clean, conserve moisture, reduce diseases, and check weed growth.

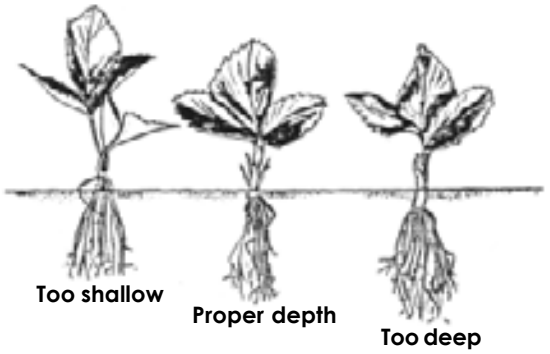


Illustration 6: Planting depths- Left: Too shallow; Center: Correct; Right: Too deep

Fertilization

Broadcast four pounds of 10-10-10 fertilizer per 100 linear ft. of row, two to three weeks before planting. If leaves appear light green in color after three to four weeks of transplanting, side dress with one and half pounds of ammonium nitrate per 100 ft. of row. The limited shallow root systems will not initially benefit from fertilizer placed in the row middles. In coastal plains in late January or February, apply three-fourth pound of ammonium nitrate. In spring, choose a fertilizer grade with higher P and K and apply one-half pound of nitrogen per 100 ft. of row.

Production system

There are two popular training systems used in strawberry production. Modifications of these systems can be found.

In the hill system or plasticulture system, plants are spaced 12 to 16 inches apart in a single or staggered double row. All runners are removed as soon as they appear, and the plants are encouraged to multiply in large crowns. This system is desired by many because the planting is easier to cultivate and harvest, and produces larger, better berries than other systems. However, many plants are required and the initial cost of the planting is high. Black plastic mulch is particularly effective with this training system, but requires drip irrigation lines for optimum performance. This "plasticulture" system is currently popular with commercial growers.

Under the matted-row system, used by many home gardeners, runner plants are allowed to set freely in all directions. The original plants should be set 18 to 24 inches apart in the row. Keeping the width of the plant bed narrow (16 to 18 inches), results in a good grade of fruit that is easy to pick. During the planting season, all flower stems on the plants should be removed as soon as they appear. This strengthens the plants and allows early and vigorous runner production. Early-formed runner plants bear the best fruit the following year.

Renovation

If your strawberry planting is in a vigorous condition, it may be retained for fruiting the second year. However, allowing a planting to fruit more than two years often results in smaller berries and weak plants. If retaining plants, remove the mulch and clip the tops of the plants to within 1 inch of the crowns with a scythe or mower soon after harvest (mid-July). If insects and foliage diseases are prevalent, move the leaves and mulch material out of the planting, and burn them. Apply a quickly soluble nitrogen fertilizer such as ammonium nitrate (NH_4NO_3) at one-fourth to one-half pound, or one to two pounds of 10-10-10 per 100 feet of row, to encourage vigorous top growth. Any good garden fertilizer supplying an equivalent amount of nitrogen may be used if desired.

Some plant thinning may be needed, particularly in the matted-row system. Thin plants (remove oldest) to six to eight inches apart after new foliage appears. Keep the planting free of weed throughout the summer, irrigating when necessary during the dry season, to keep the plants growing vigorously. Fertilize again in the early fall as recommended for the first year, and renew the mulch after freezing weather begins.

Pest Control

Birds are one of the biggest pests in the strawberry planting. It may be necessary to cover the plants with

plastic netting to keep the crop from being eaten before the berries are ripe enough to harvest. Aluminum pie tins or used metallic compact discs (CD's), suspended by a string or wire above the plants in such manner that they twist and turn in the breeze, may be successful in keeping birds away.

Culture of Everbearing Varieties

Irrigation is particularly important for everbearing varieties because the late-summer/early fall crop ripens during a period when soil moisture is usually quite low. Soil preparation and fertilizer requirements before planting are the same as for regular varieties. Best yields are obtained from everbearing varieties if they are set in early spring in the hill system about one foot apart, cultivated for the first ten days to two weeks, then mulched to a depth of one to two inches with sawdust. As the sawdust decays, the development of a nitrogen deficiency could occur. It can be quickly overcome with the application of one pound of 10-10-10 to each 100 square feet of mulched area.

Remove runners as soon as they appear, to encourage the plants to multiply in large crowns. Blossom clusters should be removed until the plants have become firmly established and are growing vigorously, usually about the first of August. Berries will begin to ripen about a month later, and plants will continue to bear fruit until frost, if weed growth is kept down and adequate moisture is supplied. Allow the plants to bear fruit for the spring and fall crops the second year, then replant the following spring.

Harvesting the Planting

In the home garden, strawberries should be allowed to develop an overall red color and become fully ripened before harvesting. Sometimes the tops (sun exposed) are red but the bottoms are still white and not ready for harvest. It is at the fully ripe stage that the sugar content is highest and the flavor is best. It may be necessary to harvest every day during the peak of the season, especially in warm periods.

Harvest the berries carefully by the stems just above the caps to prevent bruising. Pick all that are ripe. Ripe fruits when left unpicked on the plant, increase infestation of strawberry sap beetle and spotted wing drosophila. Ripe strawberries may be held for a day or two in a refrigerator.

Strawberry Growing in Pyramids and Barrels

In a garden where space is extremely limited or where the gardener wishes to use the strawberry planting as a novelty or decorative feature, the strawberry pyramid or the strawberry barrel can be useful and interesting. Pyramids may be square or round. The frames for a square pyramid can be constructed out of landscaping wood. A suggested soil mixture for the pyramid is two parts good garden soil, one part peat, and one part sand.

In preparing a strawberry barrel, one-inch diameter holes are made in the sides of the barrel at approximately eight-inch spacing. As the barrel is filled with successive layers of soil, strawberry plants are carefully inserted through the holes, so that the roots are held firmly in contact with the soil. A porous tile inserted down the middle of the barrel will facilitate water reaching all of the plants (see diagram). Though the strawberry barrel may be a successful novelty, yields of fruit will be smaller than those in open field culture, and much more attention to

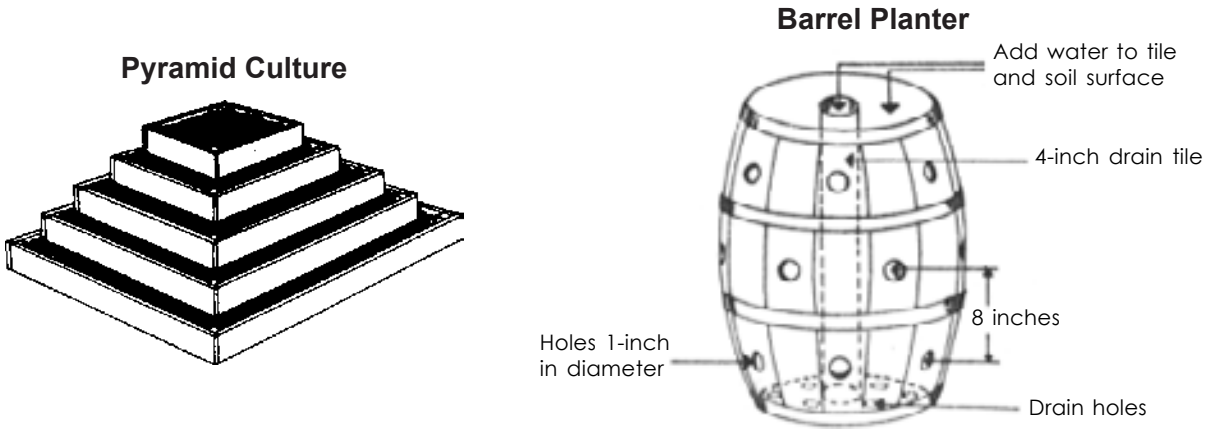


Illustration 7. Plants can be grown in pyramid setting, or a barrel in home garden.

planting, watering, and winter protection are required.

Damage to the strawberry plants growing under normal cultural conditions can be expected if they are not protected from extreme cold during the winter. Owing to the fact that plants growing in a pyramid or barrel are elevated above normal ground level and therefore are highly exposed, additional winter damage can be expected to roots, crowns, and fruit buds. Consequently, care must be taken to provide adequate winter protection. Pyramids can be mulched with 6 to 8 inches of straw after the soil is frozen. In the coldest part of the state, strawberries in barrels will survive better if protected with burlap covering. In cold winters, enclose straw in the burlap for added insulation. However, even with careful mulching, some plant injury can be expected during severe winters.

Study Questions

12. Overcrowding of small fruit plants can lead to: a) difficult disease and insect control b) larger plants c) higher yields d) all of the above

13. Strawberries should not be placed in storage with _____, which release damaging eyes.

14. Strawberries should not be planted where tomatoes, potatoes, or eggplants have been because of their high susceptibility to _____.

15. The training system where runners are removed is: a) matted-row system; b) spaced-row system; c) hill system; d) none of the above

16. Everbearing varieties are best grown in the _____ training system.

17. Strawberries grown in barrels and pyramids are more susceptible to: a) birds; b) soil pathogens; c) winter injury; d) sunscald

18. The grape varieties that lack winter hardiness, are susceptible to fungal diseases, and are susceptible to Phylloxera are: a) American bunch grapes; b) hybrids for wine; c) vinifera grapes; d) muscadine grapes

19. The following characteristic is NOT true of grapes: a) they are deep rooted; b) they prefer full sun; c) they grow best on fertile, sandy soils; d) they prefer soils with a pH of 7 to 7.8

20. Fertilizer application to mature grapevines is based on: a) plant growth and vigor; b) desired size of fruit cluster; c) presence of soil pathogens; d) the training method used

21. Erect, semi-erect, and trailing are growth habits of _____.

22. The types of raspberries that need to be separated due to viral diseases are: a) red and black; b) red and purple; c) black and purple; d) native and hybrid.

23. In general, brambles: a) are not susceptible to verticillium wilt; b) grow best where there is a lot of humus and organic matter in the soil; c) do not perform well when mulched; d) do best in the warmest parts of the state.

24. In general, blueberries: a) grow best when nights are cool during the ripening season; b) are very susceptible to numerous landscape pests; c) are difficult to grow in the home garden; d) are not vigorous plants in Virginia.

25. A good soil for blueberries would: a) have good drainage; b) have a pH range from 4.2 to 5.5; c) be high in organic matter; d) all of the above.

26. The greatest pest of blueberry plantings is _____.

Answers: 12 - a, 13 - apples and pears, 14 - Verticillium wilt, 15 - c, 16 - hill, 17 - c, 18 - c, 19 - d, 20 - a, 21 - blackberries, 22 - a, 23 - b, 24 - a, 25 - d, 26 - birds

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Lawns

Chapter 15

Lawns

Chapter 15

Revised by *Mike Goatley, Jr., Extension Specialist, Turfgrass (2015)*
Thomas P. Kuhar, Professor, Department of Entomology (2015)

Producing quality lawns in Virginia can be challenging. Virginia is located in what is known as the climatic transition zone. This means the climate can be hostile to both cool-season and warm-season grasses. However, with proper cultural practices, a good lawn can be established and maintained.

Contents

Establishing a Lawn

Turf may be established from seed, sprigs, plugs, or sod. The method used depends on the type of grass desired, the environmental and edaphic conditions, time constraints, and financial considerations. These factors are discussed more in the section on Seed vs. Sod. The same basic requirements for lime, fertilizer, and seedbed preparation apply for both seeding and vegetative establishment. After the new lawn is established and growing well, begin a good, comprehensive maintenance program to keep it healthy and attractive.

Soil Test

The first step in establishing a new lawn is to have the soil tested. Test results will determine which basic nutrients are available in the soil, and will allow recommendations to be made for liming and fertilization. Forms and sample boxes, along with instructions for obtaining good samples, are available from your Extension office. Samples should be taken from several areas in the lawn. Samples from areas that have similar soil types should be combined. For most yards, one combined sample is adequate. Large yards with widely varied conditions may require more samples. There is no need to submit more samples than

you are willing to individually treat, if turf areas do not exceed 5 acres.

Pre-Plant Weed Control

Observe the topsoil or lawn area to be planted and determine if there are weeds present that should be controlled prior to planting. Grassy weeds that are particularly troublesome in lawns of Kentucky bluegrass, perennial ryegrass, or fine fescues are dallisgrass, quackgrass, tall fescue, orchardgrass, and bermudagrass. These weeds can be controlled prior to planting by properly applying a non-selective herbicide such as glyphosate.

Controlling troublesome perennial broadleaf weeds prior to establishment can be beneficial. Refer to the most current version of the Home and Grounds Pest Management Guide for recommendations on chemical controls and timings specific to individual species.

Pre-plant weed control needs to account for the wait time between when a chemical control is applied and when the area can be seeded to prevent residual herbicide damage to newly planted turf. Refer to product labels for the appropriate wait time.

Pre-Plant Installation of Irrigation and Drainage

If possible, the irrigation system and drainage tile should be installed prior to topsoil application in order to avoid contamination of topsoil with subsoil. Stockpiling of topsoil is advisable if considerable subsoil grading is necessary.

Soil Preparation

Remove building debris and other trash from the lawn area during all stages of construction. Such material causes mowing hazards and blocks root system development. Rotting wood is often the host for troublesome "fairy ring" diseases which are difficult to control. The subgrade should be sloped away from the house, and the area should be allowed to settle for 2 or 3 weeks before seeding or sodding. Several wetting and drying cycles will aid settling and help you locate low spots in the lawn which should be filled. Topsoil depth after settling should be a minimum of 6 to 8 inches. Therefore, 8 to 10 inches of loose topsoil should be called for in the establishment specifications.

Lime

Soils in most areas of Virginia are acid, and lime recommendations will be made from the soil test to raise the soil pH to 6.5, as based on Virginia Tech Soil Testing lab recommendations (http://www.soiltest.vt.edu/). Lime rates are based on the target pH and the buffer index from the soil analysis. The lime should be tilled into the soil to a minimum depth of 4 to 6 inches. If soil tests indicate low available magnesium levels, dolomitic limestone should be used. Otherwise, use ground agricultural limestone.

Have Soil Tested

The soil analysis will determine lime and fertilizer needs. The soil should be tested at least a month before the lawn establishment is started.

When to Establish

Seed will germinate only under proper conditions. There are certain periods each year when temperature, moisture, and day length are most favorable for establishing turfgrass. In general, early fall seeding of cool season grasses is much preferred over spring seeding to allow maximum establishment and growth before the turf's first full summer. Early spring seedings may also bring good results if moisture is adequate, but it is likely the lawn will need supplemental irrigation to survive the first summer. In Northern Virginia and the areas of Western Virginia at lower elevations, the best seeding dates are mid-to-late March for spring seeding, and the last week of August to mid-September for fall seeding. It may be possible to get good results as late as the middle of October for fall seeding. At higher elevations (greater than 1200 feet) in Western Virginia, the best seeding dates are April and early May in the spring and mid-August to mid-September in the fall. In southern and southeastern Virginia, February 15 to March 30 is the best period to plant. In the fall, September 15 to October 15 is most suitable. Sod of Kentucky bluegrass and tall fescue can be installed throughout the year except in mid-winter when the ground is frozen. When extreme heat and drought conditions exist in summer, sodding operations should be delayed. If done under drought conditions, the turf must be kept moist and cool.

Improved strains of warm-season grasses such as zoysiagrass, bermudagrass, centipedegrass, (possible use from Southside through the southern coastal plain of Virginia) and St. Augustinegrass (used on the coast in Southeast Virginia) which are normally sprigged, plugged, or sodded, should be established during May

after the soil is warm. There also are improved quality, cold tolerant seeded bermudagrasses and zoysiagrasses now commercially available. May and June plantings will have the greatest chance of surviving the first winter, especially for seeded establishments. These grasses have been successfully planted as late as July; however, late summer plantings are not recommended because there is not sufficient time for proper root and rhizome establishment before cold weather.

Seed versus Sod

A quality lawn containing the recommended mixtures of grass varieties and species can be established with either seed or sod. Both seed and sod of recommended varieties are available, and the soil preparation for the two methods does not differ. The latest recommendations for top performing turfgrass varieties in Virginia can be found under the publications links at http://www.ext.vt.edu/.

Initially, seed is less expensive than sod. However, soil erosion potential and heavy weed pressure are both more likely with seeded establishments than with sod. If reseeding of certain areas or even an entire lawn is necessary, the overall expense may be less with sod. Also, because of the time required for seed to germinate and become well-rooted in the soil, there is often excessive potential for erosion. Sodding practically eliminates such problems, a consideration which may be especially important on steep hills or banks.

Sodding provides an immediately pleasing turf that is quickly functional and will compete with viable weed seed already present in the soil. When using seed, an intensive weed control program may be necessary to reduce weed competition.

Seed establishment is only recommended in the early fall or early spring, whereas sod may be established in nearly any season if moisture is available.

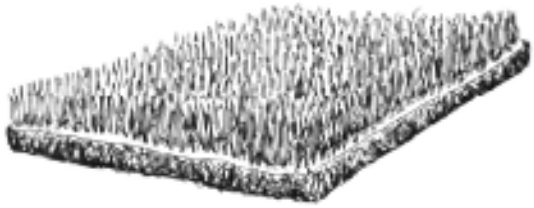
Seeding and Mulching

A well-prepared seedbed is essential for the establishment of turfgrasses. The seedbed should be tilled to a depth of 6 inches if possible, with lime (if needed), compost and fertilizer worked into the soil prior to seeding. Tilling 1-2 inches of compost into the soil improves soil structure and helps the turf establish more quickly. Prepare a smooth, firm seedbed; then divide the seed and sow in two directions, perpendicular to each other. If low rates of seed are being sown (typical with smaller-seeded grasses like Kentucky bluegrass, bermudagrass, or zoysiagrass), mixing the seed with a dry carrier such as sand, calcined clay, or a granular organic fertilizer will aid in gaining uniform coverage. Cover the seed by raking lightly and rolling. Avoid a completely smooth surface that promotes the washing of the seed. A finished seedbed should have shallow, uniform depressions (rows) about 1/2 inch deep and 1 to 2 inches apart, such as those made by a corrugated roller. Uniformly mulch the area with straw or other suitable material so that approximately 50% to 75% of the soil surface is covered. This is normally accomplished by spreading 1 bale of straw per 1000 square feet. This amount of mulch should simply be chopped up with the mower the first few times the new lawn is mowed. Heavier rates of mulch that might shade the turf should be removed when the seedlings are about 2 inches tall, being careful not to remove the young, recently rooted seedlings.

Sodding

Soil preparation should be similar to that described for seeding. Take care not to disturb the prepared soil with deep footprints or wheel tracks. These depressions restrict root development and give an uneven appearance to the installed sod. During hot summer days, the soil should be dampened just prior to laying the sod. This avoids placing the turf roots in contact with an excessively dry and hot soil. Premium quality, certified sod is easier to transport and install than inferior grades. Such sod is light, does not tear apart easily, and quickly generates a root system into the prepared soil. Before ordering or obtaining sod, be sure you re prepared to install it. Sod is perishable, and should not remain on the pallet or stack longer than 36 hours. The presence of mildew and distinct yellowing of the leaves is usually evidence of reduced turf vigor.

Sod



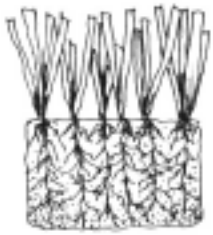
To reduce the need for short pieces when installing sod, it is generally best to establish a straight line lengthwise through the lawn area. Working from the edge of a sidewalk or driveway is a logical starting point. The sod pieces are then staggered as when laying bricks. A sharpened masonry trowel is very handy for cutting pieces, forcing the sod tight, and leveling small depressions.

Immediately after the sod is laid, it should be rolled and kept very moist until it is well-rooted in the soil.

Plugging and Sprigging

The highest quality cultivars of the zoysiagrass, bermudagrass, and St. Augustinegrass must be vegetatively established using either plugs or sprigs. The soil should be prepared as described for seeding or sodding. Rooted plugs of zoysiagrass are commonly available, and are 1 to 2 inches in diameter with 1 to 2 inches of soil attached. St. Augustinegrass usually requires 4 inch diameter plugs. The plugs should be fitted tightly into pre-cut holes and tamped firmly into place. Plugs are normally planted on 6- to 12-inch centers. Planting plugs on 6-inch centers requires 4000 plugs per 1000 square feet. On 12-inch centers, only 1000 plugs are required per 1000 square feet. Sprigs (the stems from a shredded sod) can be broadcast over a previously disked area and covered lightly with soil by disking again. They can also be planted in shallow depressed rows on 6 to 12 inch centers, then covered with soil. In either case, the sprig should root at the nodes. Sprigs can be purchased as sod and then shredded, or can often be purchased by the bushel. Generally, one bushel of sprigs is produced from shredding one square yard of sod. Sprigging rates for bermudagrass and zoysiagrass range from 7 to 10 bushels per 1000 square feet.

Plug



Sprigs

Post-Planting Irrigation

New seedings and spriggings require intensive irrigation to ensure successful establishment. Seedings require light and frequent watering to ensure that the seed and surface of the soil are constantly moist. Plan to keep the soil moist for 30 days following planting. During hot days this may necessitate 3 or 4 light waterings during the day to provide adequate moisture for rapid and successful germination. If the soil dries out during the germination or sprigging process, the plant material is likely to die. Areas sodded and plugged also require intensive irrigation initially. However, frequent light watering is only required until the sod or plug is rooted. Once sod or plugs are rooted, irrigation applied every second or third day, wetting the soil to a 6-inch depth, is adequate. As a rule of thumb, once the lawn requires mowing, it is time to change the irrigation strategy to a 'deep and infrequent' approach.

Renovating an Old Lawn

A lawn of less than satisfactory appearance but fair condition may be renovated without having to be completely tilled. Advantages of renovation include less expense and mess, since minimum tilling of the soil is required. The lawn will be able to take light traffic during the renovation period. Some conditions reduce the chances of successful renovation. If a lawn is extremely compacted, has a pH below 5.2, very low soil phosphorus availability, or the grade is very uneven, complete re-establishment with plowing or disking may be a better choice.

Determine Cause of Poor Quality

Lawns usually require renovation because of one or more of the following reasons: poor soil chemical and/or physical properties, poor fertilization practices, inadequate drainage, excessive traffic, poor selection of grass variety or species, weed invasion, compaction, drought, insect or disease damage, or excessive shade.

Have Soil Tested

The soil analysis will determine lime and fertilizer needs. The soil should be tested at least a month before the lawn renovation is started. Simply put – don't guess, soil test!

Control Weeds and Undesirable Grasses

If possible, control perennial grass weeds such as tall fescue (in warm season turf), bermudagrass (in zoysia and cool season turf), nimblewill, and quackgrass prior to the soil preparation process. Glyphosate, applied in accordance with label directions, will control most perennial grassy weeds. Begin treatment with glyphosate 30 to 45 days prior to renovation to provide the opportunity for re-treatment if regrowth occurs. Perennial broadleaf weeds can be controlled either prior to renovation or after the new seed has been mowed two times. If controlling broadleaf weeds prior to renovation, pay attention to any planting restrictions that might be indicated on the label. In most situations, apply the broadleaf weed control at least 30 days prior to soil disruption and seeding.

Dethatch and/or Aerify if Necessary

Thatch is an organic mat of stems that forms between the mineral soil and the turfgrass canopy. It is primarily comprised of rhizomes (below-ground stems, stolons (above-ground stems), and/or seedheads. Grasses that don't spread by lateral stems typically do not produce a lot of thatch. Due to the high cellulose content of grass, thatch is slow to decay and forms a hydrophobic mat between the soil and grass leaves. Thatch layers greater than ½ inch in thickness will eventually cause a decline in turfgrass performance and will make renovations using seed very difficult. Use a vertical mower or dethatching machine(many rental businesses will have these machines available) to remove thatch (if it is a problem). Even if the existing lawn is not thatch, these machines are great renovation tools because they promote good seed to soil contact. Seed planted on top of the thatch layer is largely wasted since thatch is a hydrophobic layer of undecomposed organic matter that is not conducive to root establishment. Aerification with a coring aerifier (often called a 'plugger') helps prepare a lawn for renovation by inoculating the thatch with soil, reducing compaction, and creating moisture collecting holes in the soil. Dethatching after aerification helps bust the cores and provide a better seedbed by promoting more soil to seed contact.

Apply Lime and Fertilizer

Consult soil test recommendations. (See Chapter 19 for information to protect water quality.)

Sow the Seed

Renovated lawns can be drill-seeded and/or broadcast-seeded. Drill seeding provides the best seed-soil contact and the highest germination rate. Drill seeding alone generally leaves a "row effect," which can be masked by also broadcast seeding. The best method involves drill seeding in two perpendicular directions and then broadcast seeding. Lightly rake or drag the area after seeding.

Crabgrass?

One very important weed competitor that is a serious problem with spring plantings is crabgrass. Standard preemergent (PRE) herbicides for crabgrass control will also control any grasses that are planted from seed, so there must be a very well defined plan of when grasses will be planted and how one is going to manage the weeds. The VCE Pest Management Guide should always be the resource to consult for the latest information on these pesticides. Two very popular herbicides that fit crabgrass control programs for most (not all) grass establishments from seed are mesotrione and quinclorac. Consult the PMG for the rates and timing of their applications in order to optimize grass establishment and crabgrass control.

Water Frequently

Water lightly and frequently every day until the seed has germinated and developed a 2- to 4-inch root system. Then water less frequently but more deeply to keep the soil moist.

New Lawn Maintenance

Begin mowing the new lawn when the 1/3rd rule applies. This mowing rule of thumb says to never remove more than 1/3rd of the leaf blade during any mowing event. For instance, if the desired maintenance cutting height of a new tall fescue stand is 2 inches, cut the grass when it reaches 3 inches tall. Be sure that the lawn mower blade is sharp. A dull mower tends to pull grass seedlings out of the ground. Try to minimize traffic on the new lawn until it is mature. Broadleaf weed control may be necessary. Do not apply broadleaf weed control to new lawns until they have been mowed three or more times (often indicated on the herbicide label). Begin a good, comprehensive fertilization program based on the recommendations in Virginia Extension publications found at http://www.ext.vt.edu/.

Study Questions

1. The first step in establishing a new lawn is to: a) irrigate the site; b) fertilize the site; c) apply herbicides to kill weeds; d) get a soil test done
2. When preparing soil for seed or sod, topsoil depth should be: a) 4-6 inches deep; b) 6-8 inches deep; c) 8-12 inches deep; d) it doesn't matter
3. Soil tests have indicated low pH and low available magnesium levels, so _____ should be applied.
4. Benefits of aerification include: a) reducing compaction; b) pest control; c) removing excess fertilizer; d) all of the above
5. On a site where erosion is a problem, the best method of lawn establishment would be _____.

Answers: 1 - d; 2 - b; 3 - dolomitic limestone; 4 - a; 5 - sodding

Recommended Turfgrass Varieties for Virginia

D.R. Chalmers, Extension Agronomist, Virginia Tech

The Maryland - Virginia Turfgrass Variety Recommendation Work Group meets each spring to consider the previous year's data from the Virginia and Maryland National Turfgrass Evaluation Program trials and to formulate these recommendations. To qualify for this recommended list, turfgrass varieties: 1) must be available as certified seed, or in the case of vegetative varieties, as certified sprigs or sod; 2) must be tested at sites in both Virginia and Maryland; and 3) must perform well, relative to other varieties, for a minimum of two years to make the list as a "promising" variety and for three years to make the recommended category. All test locations in Virginia and Maryland are considered in making these recommendations. The Virginia Crop Improvement Association (VCIA) will accept the turfgrass mixtures listed in the current recommended turfgrass varieties publication, which can be found at pubs.ext.vt.edu/CSES/CSES-17/CSES-17_pdf.pdf. All seed or vegetative material must be certified and meet minimum quality standards prescribed by the VCIA. Varieties can be considered for removal from these lists due to declining performance or insufficient recent data relative to other varieties. Varieties can also be considered for removal from these lists due to seed availability problems and/or due to seed quality problems. Varieties specific to certain locations in the state due to temperature extremes etc. will also be denoted on the list.

Many seeding specifications (for municipalities, counties, state and governmental agencies, landscape architects, and professional organizations) state that varieties used for turfgrass establishment must come from this list, and that blends or mixtures follow the guidelines for certified sod production. Specifications for state highway seeding are now developed from this list, but their specifications may may require some species and/or varieties not normally recommended for uses other than roadside seeding. Seed availability may vary between turf seed suppliers.

Turfgrass varieties fall into two basic categories: cool-season and warm-season. Cool-season grasses, such as Kentucky bluegrass, tall fescue, fine-leaf fescue and perennial ryegrass, have a long growing season in most areas of Virginia and provide green winter color. Warm-season grasses, such as zoysiagrass, bermudagrass, centipedegrass, and St. Augustinegrass go dormant after the first hard frost and stay brown through the winter months. Zoysiagrass greens up around mid-May in northern Virginia. While the winter color of the warm-season grasses may make them less desirable, maintenance costs are somewhat reduced since water requirements are less and the shorter growing season requires fewer mowings per year.

Selecting a Variety

The following recommendations are developed from research conducted in Virginia and Maryland. Turf and seed specialists from the University of Maryland, the United States Department of Agriculture, the Virginia Department of Agriculture and Consumer Services, and Virginia Tech concur in making these recommendations.

Kentucky Bluegrass

Best suited to areas in and west of the Blue Ridge Mountains and north of Richmond, this grass provides lush, blue-green, fine-bladed lawns. It is a fairly aggressive creeper having an extensive rhizome system. This makes it a desirable cool-season grass for heavily trafficked turfs. In the transition zone, bluegrass lawns may require irrigation in the summer to keep from going into summer dormancy. It does not perform well in heavy shade or on poor soil. Kentucky bluegrass is best suited to a well-drained soil and moderate to high levels of sunlight. It can be established from seed or sod.

While classified as Kentucky bluegrasses, there are a number of hybrid bluegrasses (crosses between Kentucky bluegrass and Texas bluegrass) now commercially available. These grasses have similar maintenance requirements to standard Kentucky bluegrasses, but appear to be better suited in the warmer climates of Virginia than standard bluegrasses.

Blends of Kentucky bluegrass varieties are recommended in Virginia, as it is thought they are more likely to provide good quality turf over a wide variety of management and environmental situations. There are two categories of blends.

When seeding a mixture of Category I seed, individual varieties should make up no less than 10 percent nor more than 35 percent of the total mixture by weight. Category II seed includes Kentucky bluegrass varieties that can be blended for use in special situations. They can be mixed with Category I varieties at the rate of 10 to 35 percent. Perennial ryegrass is mixed at the rate of 10 to 15 percent by weight with bluegrass in erosion control situations.

Where erosion is a concern or seedings are being made outside of recommended dates, the addition of Virginia Tech recommended, certified perennial ryegrass varieties to the Kentucky bluegrass mixture at 3 pounds per 1000 square feet (10% to 15% on a weight basis) is recommended.

Categories I and II Seeding Rates: one and one-half (1-1/2) to two and one-half (2-1/2) pounds per 1000 square feet.

Tall Fescue

Tall fescue is a fine to moderate coarse-textured turfgrass which is tolerant of a wide range of soil types and climatic extremes. It provides very good quality turf under low to moderate management levels and can be established from seed or sod.

Tall fescue does not have the recuperative potential of Kentucky bluegrass since it does not spread by rhizomes (rhizomatous tall fescues are in their early stages of development, but lateral growth rates are still not comparable to those of bluegrass at this time). Therefore, infrequent overseeding may be necessary to maintain desirable turf density in tall fescue lawns.

The fine-bladed turf-type tall fescues dominate the home lawn market in this area. The leaf texture is now so fine that they are commonly mixed with Kentucky bluegrass in sod production. A 90% tall fescue / 10% Kentucky bluegrass mixture, whether planted as seed or sod, provides increased recuperative potential and may be advantageous where traffic is expected.

Seeding rate: 4-6 pounds per 1000 square feet of tall fescue blends, 3-4 pounds per 1000 square feet for standard mixtures (90-95% tall fescue plus 5-10% Kentucky bluegrass).

Creeping Red, Hard, and Chewing Fescues

These grasses are known collectively as the fine-leaf fescues. As a group of grasses, they exhibit the best tolerance of shade, drought, low-nitrogen, and acid soil. These cool-season grasses require the least intensive maintenance of any of the grasses adapted to Virginia. They perform best in shady lawns in mixtures with shade-tolerant Kentucky bluegrasses as noted earlier. They are excellent choices for reduced input turfgrass areas such as highway rights of way, cemeteries, etc. They have very poor tolerance of intensive traffic or poorly drained soils. Choices in seed are quite limited for all species of fine-leaf fescues. Seed is more limited for fine fescues than any other turfgrass in this area, but for the first time, there is now fine-fescue sod available from a limited number of growers in the state. Seeding Rate: 3 to 5 lbs. per 1000 square feet.

Perennial Ryegrasses

Perennial ryegrass is a fine-medium textured grass that mixes well with Kentucky bluegrass. Some strengths of the perennial ryegrasses are their quick germination and establishment rate, good traffic bearing characteristics as a mature turf, and early spring green-up. They blend well with Kentucky bluegrasses to provide quick erosion control. However, they tend to be susceptible to disease in hot weather and exhibit poor heat and drought tolerance. At present in Virginia, monostands of perennial ryegrass are not capable of providing the level of season-long quality normally associated with a good Kentucky bluegrass mixture without fungicide support. They are best utilized in mixtures with Kentucky bluegrass (5-10% by weight), as noted earlier. Perennial ryegrass is only currently recommended in monostands on heavy traffic areas such as athletic fields where the benefits of rapid germination from seed and traffic tolerance as a mature turf are valued. Variety recommendations are listed with the Kentucky bluegrass recommendations. For standard seedings of perennial ryegrass, use 3-5 pounds per 1000 square feet. Perennial ryegrass also has one additional use for lawns and that is as a winter overseeding component, primarily on bermudagrass lawns. The ryegrass is introduced to the lawn in the early fall for winter color and growth. Typical winter overseeding levels are 5-10 lbs per 1000 square feet for lawns. Remember that the ryegrass will be a competitor with the bermudagrass next spring and will cause a delay in spring greening of the bermudagrass. It is not recommended to overseed any of the other warm-season grasses.

Zoysiagrass

Zoysiagrass is a warm-season grass of fine to medium texture that turns brown with the first hard frost in the fall and greens up about mid-May. Zoysiagrass as a whole has the best cold tolerance of the warm-season grasses used in Virginia, particularly the wider-leaf varieties that are *Z. japonica* species. Finer textured zoysias of the *Z. matrella* species are now used throughout Virginia, but they are not generally considered to be as cold hardy as the *Z. japonica* varieties. It spreads by both rhizomes and stolons, but is a very slow creeper. It is well-suited for lawn use in Virginia and has a low fertility and irrigation requirement. It does well in full sun and has moderate

shade tolerance. Its density as a mature turf precludes much weed control and when managed properly, it has very few disease and insect problems as well. The grass has a slow recuperative potential and, therefore, is not recommended for heavily trafficked lawns or athletic fields. It can be established from sod, plugs, or sprigs and with recent developments, a few improved varieties can be established from seed. However, its rate of establishment is extremely slow regardless of the establishment method. Zoysia plugs planted on 12-inch centers will normally require two or three growing seasons to provide full cover. If established from seed, 2-3 lbs of pure live seed per 1000 square feet are recommended, anticipating it will take a full growing season to gain coverage from a mid-spring/early summer planting.

Planting Rate: 2-inch diameter plugs on 6- to 12- inch centers or sprigs broadcast at 7 to 10 bushels per 1000 square feet will require 2 to 3 growing seasons for 100% cover. Planting Dates: May 1 to July 15. Moderate winter damage can be expected on bermudagrasses once every 6 or 7 years in Virginia.

Bermudagrass

Bermudagrass is a fine-bladed, warm-season grass that aggressively creeps by both rhizomes and stolons. Bermudagrass has exceptional drought tolerance and its aggressive growth habit and tolerance to mowing heights of a low as ½ inch make it a great grass for athletic fields and golf course fairways. Its use as a lawn is best suited to the warmest areas of Virginia, but recent releases in cold-hardy varieties (both seeded and vegetative) have expanded the possibility of it being used anywhere in the state. Hybrid bermudagrass can be established by sod, sprigs, or plugs. Two-inch diameter plugs of bermudagrass planted on 12-inch centers will normally provide 95% to 100% cover in one growing season. Seeded bermudagrasses are established at 0.5 to 1 pound of pure live seed per 1000 square feet. Sprigging Rate: 7 to 10 bushels per 1000 square feet.

Centipedegrass

Centipedegrass is a coarse-textured stoloniferous warm season grass that is adapted in southern Virginia from Martinsville to the coast. It is the lowest maintenance, highest density warm-season grass available. Centipedegrass is established primarily from seed, but sod is available (most coming from farms in the Carolinas). It has a characteristic yellow-green color and prefers acidic soil conditions. Its shade tolerance is moderate and it has very poor traffic tolerance. It is an excellent low-input turf for the warmest climates of Virginia. Centipedegrass is established at levels of ¼ to ½ pound of pure live seed per 1000 square feet.

St. Augustinegrass

St. Augustinegrass is a coarse-textured stoloniferous warm-season grass that has the best shade tolerance of this category. It is grown almost exclusively on the coast of Virginia where the climate is moderated by the ocean and does not persist in any area that has extreme winters. St. Augustinegrass is a very aggressive creeper that has the highest pest pressure (insect and disease) of any of the warm-season grasses. Its use in far southeastern Va will primarily focus on shaded lawns and general purpose turfs. St. Augustinegrass can be established by plugs or by sod.

Purchasing Quality Seed

The purchase of lawn seed is a long-term investment, as the seed you buy will influence your success in developing a beautiful lawn. It is not possible to evaluate the quality of seed by looking at it. Information that will help you make a wise choice is printed on the seed packages.

There are differences in lawn seed, and it pays to compare. The price you pay for seed will represent only a small portion of the total cost of planting, fertilizing, mowing, etc. Don't let low cost be the only factor you consider when purchasing lawn seed. Choose those varieties that have been tested and proven to be the best for your area of Virginia.

Virginia has a seed label law that is basically a truth-in-labeling law. The label on the package must include an analysis of the seed it contains. This analysis enables the purchaser to determine the kind of seed contained in the package, estimate how well it should perform, and compare its cost-effectiveness with other brands.

Example Seed Label Analysis:	
Kind: Kentucky bluegrass	Variety: Super-Duper
Pure Seed: 98%	Germination: 85%
Inert Matter: 1%	Date of Test: (month and year)
Other Crop Seed: 0.7%	Lot# - 1A
Weed Seed: 0.3%	
Noxious Weeds: 120 Annual Bluegrass per pound	
John Doe Seed Co., Richmond, VA	

Germination - The percentage of viable (live) seed. The date of test should be within the last 12 months.

Pure Seed - The percentage (by weight) that is actually seed of the crop specified.

Inert Matter - The percentage (by weight) of chaff, dirt, trash, and anything that is not seed.

Weed Seeds - The percentage (by weight) of all weed seeds in the sample and the number of noxious weed seeds present. If possible, avoid seed lots with noxious weeds.

Other Crop Seeds - The percentage (by weight) of crop seed other than the crop specified. For example, in tall fescue, this includes orchardgrass and ryegrass. In Kentucky bluegrass, it can include bentgrass, ryegrass, tall fescue, or perennial ryegrass contaminants.

Cost Effectiveness

When considering seed lots of similar quality, compare the amount of Pure Live Seed (PLS) in the package. The only thing you really want to pay for is seed that will grow. To determine the amount of PLS, look at the analysis on the label; multiply the germination percentage by the percentage of pure seed and then multiply by 100 to get the percentage Pure Live Seed.

Calculating Pure Live Seed Example	
Germination:	= 85%
Purity:	= 98%
0.85 x 0.98	= 0.833
0.833 x 100	= 83.3% Pure Live Seed (PLS)

To obtain the cost per pound of PLS, divide the price per pound by the PLS. If the seed costs $2.25 per lb, then 0.833 into 2.25 = $2.72, the actual cost per pound of Pure Live Seed.

Similarly, when it comes to planting rates, use the PLS value. If the recommendation is to plant 2 lbs of pure live seed per 1000 square feet, and the PLS 5 is 83.3, then one needs 2 ÷ 0.833 = 2.4 lbs of seed from the package per 1000 square foot.

Quality

Certified seed is a guarantee from the seller that you will get the kind and variety of lawn seed named on the label. Buying certified seed is a good practice. If the seed is certified, a blue certification label will be attached to the seed package.

Label colored orange

Label colored yellow

Label colored green

The Virginia and Maryland Cooperative Extension Services have worked with the U.S. Department of Agriculture, seed nurseries, and the Virginia Crop Improvement Association to develop a program that helps purchasers recognize quality lawn seed. In both states, special labels are placed on packages containing seed that meets very high standards of purity, germination, and freedom from weed and other crop seed. Seed in a package that carries one of these labels is certified and recommended for use in both states.

Purchasing Quality Sod

There are several types of sod being grown in Virginia. The basic types are Kentucky bluegrass blends, tall fescue-Kentucky bluegrass mixtures, bermudagrass, and zoysiagrass. Each of these types of sod is best suited to particular uses and geographic areas of Virginia. Some sod producers grow sod in the Virginia Crop Improvement Association (VCIA) certified sod program, which means that the sod produced must meet established standards of quality.

VCIA-certified sod is high-quality and meets rigid standards which require preplanting field inspections, prescribed varieties and mixtures, periodic production inspections, and a final preharvest inspection. This program provides the consumer with guaranteed standards of quality. Sod in the VCIA program which cannot quite meet program standards may be classified as VCIA approved sod and sold at a lower price than sod in the certified category which meets all VCIA standards.

VCIA certified sod can be identified by its label. High quality sod is also available outside the VCIA certified sod program, but it is not graded by standards and quality can only be ensured by pre purchase inspection. 98% of Virginia's sod market is comprised by the following four products.

Kentucky Bluegrass Blends

Kentucky bluegrass blends contain three or more varieties of Kentucky bluegrass. They are best suited for the north central Piedmont region and areas along and west of the Blue Ridge Mountains of Virginia. They will require moderate to full sunlight, periodic fertilization and irrigation, and good soil drainage in order to provide quality turf. Kentucky bluegrass blends function well on lawns, athletic fields, recreational areas, and in situations where year-round erosion control is necessary. They have the potential to provide excellent turfgrass quality under higher input (more aggressive fertilization and irrigation) management conditions.

Tall Fescue or Tall Fescue-Kentucky Bluegrass Mixtures

These sods generally contain from 90% to 100% fine-bladed tall fescue and 5% to 15% Kentucky bluegrass. Tall fescue is a broader-bladed grass than Kentucky bluegrass and, therefore, has a coarser texture than Kentucky bluegrass sod. Tall fescue sod is drought and heat tolerant and performs well throughout Virginia. Tall fescue sod is adapted to a wide range of soil conditions and management programs. It is not well-suited to areas of heavy traffic, but performs well in lawns, recreational areas, and in situations where year-round erosion control is necessary.

Bermudagrass

Bermudagrass is a warm-season grass that goes dormant during winter in Virginia. It is best suited for areas in the south central Piedmont and coastal plain regions east of the Blue Ridge mountains. It is very drought-tolerant, requires full sunlight, and grows most actively in the summer months. It functions well on lawns, athletic fields, and other areas where excessive winter traffic is not anticipated. When using it north of Richmond or at elevations above 1500 feet, be certain to use cold tolerant varieties.

Zoysiagrass

Zoysiagrass is a warm-season grass that goes dormant in the winter in Virginia. It is best suited for areas in the south central Piedmont and the coastal plain regions east of the Blue Ridge Mountains. It is very cold and drought-tolerant and slightly more shade-tolerant than bermudagrass. It functions well on lawns and recreational areas where excessive winter traffic is not anticipated.

Study Questions

6. Cool-season grasses include: a) KY bluegrass, tall fescue, and bermudagrass; b) KY bluegrass, tall fescue, and perennial ryegrass; c) bermudagrass, zoysiagrass, and fine-fescues; d) zoysiagrass, KY bluegrass, and perennial ryegrass

7. _____ is/are a type of grass that does best in shady areas.

8. A seed label does NOT contain information on: a) the percentage of viable seed; b) the percentage of dirt, trash, or any other matter that is not seed; c) the presence of noxious weeds; d) the cost per pound of pure live seed

9. Sod in the VCIA program which meets guaranteed standards of quality is called _____, while sod that doesn't quite meet these standards is called _____.

Answers:
6 - b; 7 - creeping, red, hard, and chewing fescues; 8 - d; 9 - certified, approved

Lawn Maintenance

The wide variety of microclimates and soil types make it difficult to formulate a uniform program for lawn maintenance. The basic factors required for maintaining a lawn are discussed; however, the recommendations may need to be modified for your particular location. As mentioned earlier, the first thing to do is have the soil tested.

In addition to considering the genetic potential of the turfgrass in your lawn, important factors in maintaining high turfgrass quality include an annual program of mowing, fertilization, weed control, irrigation, and leaf management. In addition to these, the following cultural practices may be necessary in some years: dethatching, pH adjustment, aeration, disease control, and insect control.

Virginia Cooperative Extension

PUBLICATION 430-523

Maintenance Calendar for Cool-Season Turfgrasses in Virginia[1]

Mike Goatley, Extension specialist, Crop and Soil Environmental Sciences, Virginia Tech
Shawn Askew, Plant Pathology, Physiology, and Weed Science, Virginia Tech

Maintenance activity[2]	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Seeding[3] (Initial establishment and/ or renovation)			••••••••••••••••••••••					XXXXXXXXXX				
N Fertilization[4]			••••••••••••••••••••••••••					XXXXXXXXXXXXXX••••••••••••••••••••				
PRE herbicides[5]			XXXXXXXX					XXXXXXX				
POST herbicides[6]			XXXXXXXXXXXXXXX					XXXXXXXXXXXXXX				
Cultivation/ dethatching			••••••••••••••						XXXXXXXXXX			

[1] Predominant cool-season turfgrasses for Virginia lawns are Kentucky bluegrass, tall fescue, perennial ryegrass, and fine-leaf fescues.

[2] Preferred timing for maintenance activity is indicated by an upper case '**X**'. Second best timing indicated by a '•'.

[3] Recommended seeding rates per 1000 sq ft are 2-3 lbs for Kentucky bluegrass; 4-6 pounds for tall fescue; 3-5 pounds for perennial ryegrass; 3-5 pounds for fine-leaf fescues. Sod is also available for most of these grasses. Consult Virginia Cooperative Extension (VCE) publication 426-718 *Establishing Lawns* for more information.

[4] Levels of 0.5-1 lb water soluble N/1000 sq ft every 3-4 weeks are recommended during the preferred timing period of fall. Levels of 0.25-0.5 lb water soluble N/1000 sq ft every 4-8 weeks are recommended for second best timing periods. Controlled release N sources (those containing ≥ 50% water insoluble N) can be applied at 1.5 to 2x recommended N levels on approximately 6-8 week intervals. Apply other nutrients and/or lime based on soil test results. Note: it is recommended to test homelawn soils every 3-4 years.

[5] Spring preemergent (PRE) herbicide applications are primarily targeting summer annual weeds such as crabgrass, goosegrass, or foxtails. Fall applications are primarily targeting annual bluegrass and winter annual broadleaves such as henbit, deadnettle, chickweed, and geranium. Before applying any PRE herbicide consider possible effects it will have on seeding desirable turfgrasses in the future.

[6] Weeds must be actively growing to achieve control with postemergence (POST) herbicides. For cool-season weeds, treat when temperatures are ≥ 50° F. For warm-season weeds, temperatures ≥ 80° F are required for maximum control. Proper identification of the weed is critical in selecting appropriate control strategies. Consult your area horticultural agent or other VCE resources (such as www.turfweeds.net) for assistance in weed or grass identification. For chemical recommendations, refer to the *Pest Management Guide: Home Grounds and Animals,* Virginia Cooperative Extension publication 456-018 (*w*).

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VirginiaTech Invent the Future

VIRGINIA STATE UNIVERSITY

Virginia Cooperative Extension

PUBLICATION 430-522

Maintenance Calendar for Warm-Season Turfgrasses in Virginia[1]

J.M. Goatley Jr., Crop and Soil Environmental Sciences;
Shawn Askew, Plant Pathology, Physiology, and Weed Science

Maintenance activity [2]	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Planting[3] (Initial establishment and/ or renovation)					XXXXXXXXXXX••••••••••							
N Fertilization[4]					XXXXXXXXXXXXXXXXX••••••••••••••••••							
PRE herbicides[5]			XXXXXXX					XXXXXXX				
POST herbicides[6]	••••••••••••••		XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX									••••
Winter overseeding[7]								XXXXXXXXX				
Cultivation/dethatching					XXXXXXXX•••••••							

[1] Warm-season turfgrasses grown in Virginia are primarily bermudagrass and zoysiagrass, with St. Augustinegrass and centipedegrass included in the Tidewater region.

[2] Preferred timing for maintenance activity is indicated by an upper case '**X**'. Second best timing indicated by a '•'.

[3] Cultivars vary in establishment methods. Several improved bermudagrass and St. Augustinegrass cultivars can be established by vegetative means (sod, sprigs, or plugs) only. Recommended seeding rates per 1000 sq ft: 1 to 1.5 lbs for bermudagrass or zoysiagrass; 0.25-0.5 lbs for centipedegrass. If plugging, bermudagrass and St. Augustinegrass plugs should be planted on a maximum spacing of 12", while zoysiagrass should be plugged at 6" spacing. Consult Virginia Cooperative Extension publication 426-178, *Establishing Lawns* for more information.

[4] Levels of 0.5-1 lb water soluble N/1000 sq ft every 3-4 weeks are recommended during the preferred timing period of late spring through summer. Levels of 0.25-0.5 lb water soluble N/1000 sq ft at 4-8 weeks intervals are recommended for second best timing periods. Controlled release N sources (those containing ≥ 50% water insoluble N) can be applied at 1.5 to 2x recommended N levels on approximately 6-8 week intervals. Apply other nutrients and/or lime based on soil test results. Note: it is recommended to test home lawn soils every 3-4 years.

[5] Spring preemergent (PRE) herbicide applications are primarily targeting summer annual weeds such as crabgrass, goosegrass, or foxtails. Fall applications are primarily targeting annual bluegrass and winter annual broadleaves such as henbit, deadnettle, chickweed, and geranium. Before applying any PRE herbicide consider possible effects it will have on seeding desirable turfgrasses in the future, whether they be spring/summer plantings of seeded grasses or fall plantings of ryegrass for winter overseeding. If turf is not overseeded, there is potential for winter weed control with non-selective POST (postemergent) herbicides during winter dormancy of the warm-season turfgrass.

[6] Weeds must be actively growing to achieve desirable control with POST herbicides. For cool-season weeds, treat when temperatures are ≥ 50° F. For warm-season weeds, temperatures ≥ 80° F are required for maximum control. Proper identification of the weed is critical in selecting appropriate control strategies. Consult your area horticultural agent or other VCE resources (such as www.turfweeds.net) for assistance in weed or grass identification. For chemical recommendations, refer to the Pest Management Guide: *Home Grounds and Animals*, Virginia Cooperative Extension publication 456-018 (www.ext.vt.edu/pubs/pmg/).

[7] Ryegrass (annual or perennial) can be overseeded at rates of 5-10 pounds of pure live seed/1000 sq ft in order to have a green, actively growing winter turf. However, warm-season turf performance in the late spring of the following year will be compromised because of competition with the cool-season turf.

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VIRGINIA STATE UNIVERSITY

Annual Maintenance

Genetic Potential

The potential for a lawn to provide a quality surface is very dependent upon the varieties of grass in the lawn. New, improved varieties are being released each year. Periodic infusion of improved varieties will increase the chances of producing a high-quality lawn. The best maintenance program is not likely to overcome the limitations of inferior turfgrasses in the stand.

Mowing

Mowing grass is one of the major time-consuming practices in turfgrass management, and yet the total impact of mowing management is seldom considered. To appreciate the true impact of mowing on turfgrass, it is necessary to understand the physical, environmental, and physiological effects of mowing on the turfgrass community.

The most obvious physical effect of mowing is the decrease in leaf surface area of the grass plants. The grass plant's leaves are the site of photosynthesis, and any decrease in leaf surface area proportionately decreases the plant's ability to produce the carbohydrates essential for root, shoot, rhizome, and stolon growth. If more than 1/3 of the grass vegetation is removed during mowing, root growth is temporarily slowed by the plant's inability to produce carbohydrates at the previous rate. Carbohydrates can be pulled out of reserve to enhance extensive root, rhizome, and stolon development. However, carbohydrate reserves can be called upon to these structures only a limited number of times while the grass plant is recuperating from the shock of a severe mowing. We need to think of mowing primarily as a carbohydrate-depleting management factor. Improper mowing habits can weaken the plant as the mowing season progresses, reducing its recuperative potential and predisposing it to insect, disease, and drought susceptibility. It has been shown that severe defoliation of the grass plant has extreme effects upon root growth. For example, in cases where 50% of the existing Kentucky bluegrass foliage was removed by mowing, only 35% of the roots were producing growth 33 days after mowing.

Wound hormones are produced every time grass is cut. These compounds along with phenol oxidase enzymes are involved in wound-healing. The production of compounds involved in healing mowing wounds occurs at the expense of food reserves. If you are cutting grass with a dull mower, you are creating severe wounds that require more wound healing compounds and therefore more use of stored food reserves. Be sure to keep your mower blades sharp! Continuous use of dull mowers depletes the plant of stored reserves necessary for survival during the stress-filled months of July and August. Eventually the plant's ability to heal the mowing wound is impaired by a lack of food reserves, and the open wound becomes a site of fungal entry leading to serious disease problems. Every unit of plant energy that must be utilized to heal dull mower wounds is simply one less unit that will be available for healing during periods of stress.

Nothing is more mismanaged in lawns than their cutting height. Lowering the mowing height beyond those for which a grass is adapted severely disrupts the environmental and competitive forces that exist in the turfgrass community. In a mixed community of turfgrass plants, some plants will become less competitive as the mowing height is lowered. It is essential to realize that lowering mowing heights to 1 inch or less decreases the amount of leaf area intercepting sunlight. Lower mowing heights increase the number of plants per unit area for some grasses (for instance, some bermudagrass varieties), but it is highly likely that the individual plants in the crowded community become weaker, and for such types of mowing, specialized mowing equipment (i.e. reel mowers) are required. Weaker plants require more intensive management to be able to withstand periods of stress. Suboptimal mowing heights in Kentucky bluegrass and tall fescue often lead to increased weed populations of annual bluegrass and crabgrass. The table below shows recommended mowing heights for turfgrasses commonly used. The lowest ranges of these heights should only be used during the most optimal growing periods of the year (e.g. summer for bermudagrass or zoysiagrass, late summer/early fall and early to mid-spring for tall fescue or Kentucky bluegrass). Mowing at these lower ranges during optimal growing periods can actually improve turfgrass density. However, it is very prudent to begin raising the cutting height of a respective grass 4-6 weeks before the onset of a predictable environmental stress period such as summer or winter. As a rule, raise the cutting height of cool-season grasses in mid-May and raise the cutting height of warm-season grasses in early September so that the grasses are better prepared to survive the coming environmental stress period.

Turfgrass Mowing Heights for Lawns (inches)*	
Kentucky bluegrass	1.5-2.5
Tall fescue	2-3
Creeping red fescues	2-3
Perennial ryegrass	1.5-2.5
Bermudagrass	0.5-2
Zoysiagrass	0.75-2
Centipedegrass	1-2.5
St. Augustinegrass	2-3
Heights of 1 inch or lower are best achieved with a reel mower	

Selecting higher mowing heights for cool-season grasses helps to maximize the amount of food being produced by photosynthesis. Higher mowing heights will reduce stress levels on the turf and, at the same time, increase the likelihood of the grass surviving drought, since root development potential is increased by the higher mowing height.

Frequency of mowing can have severe effects on turfgrass communities. Excessive mowing frequency reduces total shoot yield, rooting, rhizome production, and food reserves. Mowing frequency should be determined by seasonal growth demands, and should be often enough that no more than 1/3 of the existing green foliage is removed by any one mowing.

Collecting clippings on home lawns is not advised. There is no significant benefit to the lawn derived from the collection of clippings if the lawn is being mowed with the proper frequency. Clippings are not a major contributor to thatch buildup. They do provide significant amounts of nutrition to the lawn as they decompose. Three years of returning clippings to a lawn has been shown to increase the growth rate 38% over lawns where clippings were not returned. In addition, earthworm populations increase where clippings are returned, improving aeration and water infiltration.

In summary, mowing is the most frequently necessary maintenance practice in the production of a good lawn. For good results, mow as high as is reasonable for the desired appearance and use of the turf, use a sharp blade, and don't mow more often than necessary - but do mow often enough so that plant height is being reduced by not more than 1/3 each time. A final thought – keep the clippings on the lawn to utilize this 'free fertilizer' and protect water quality that can be endangered from clippings that enter storm water drains.

Fertilization

The time table for fertilizing cool-season grasses is completely different from that of warm-season grasses. Warm-season grasses go dormant during the time when the cool-season grasses make the most effective use of fertilizer for root growth and development.

Fall fertilization is essential in the maintenance of quality cool-season grasses. The advantages of fall fertilization observed in research and field observation are increased density, increased root growth, decreased spring mowing, improved fall-to-spring color, decreased weed problems, increased drought tolerance, and decreased summer disease activity. The amounts of fertilizer to apply and the time periods when they should be applied are critical.

The ideal lawn fertilization program provides the nutrition that maximizes the chances of producing a quality lawn. Temperature and moisture vary greatly and affect turfgrass growth. Therefore, nutritional needs vary from month to month. Excessive stimulation of growth from nitrogen fertilizers can be more detrimental than no fertilization at all. The source of nitrogen in fertilizers influences nitrogen availability to the turfgrass plant. There are two types of nitrogen sources: quickly available and slowly available. Quickly available materials are water-soluble and can be immediately utilized by the plant. Slowly available nitrogen sources release their nitrogen over extended periods of time and, therefore, can be applied less frequently and at higher rates than the quickly available nitrogen sources.

The numbers on the fertilizer bag (such as 10-10-10 or 46-0-0) indicate the percent of Nitrogen (N), Phosphate (P_2O_5), and potash (K_2O) in the fertilizer. If your soil test indicates low or medium levels of phosphorus or potassium, complete fertilizers should be used. If high levels of phosphorous and potassium are present in the soil, then fertilizers supplying only nitrogen will be adequate.

Fertilizers can provide nitrogen to plants immediately or over an extended period of time. The amount that can be safely applied at one time depends upon the availability of the nitrogen. The portion of the nitrogen that is slowly available is listed on the fertilizer bag as Water Insoluble Nitrogen (WIN). For example, a 20-10-10 fertilizer with 5% WIN actually provides 5/20 or 1/4 of its nitrogen in the slowly available form. A 50 lb. bag of this material would provide 10 lbs. of total Nitrogen (.20 X 50 = 10 lbs.) of which 2.5 lbs. (.05 X 50 = 2.5) would be slowly

available (WIN).

A Fertilizer Label Will Provide the Following Information:	
Guaranteed Analysis	
Total Nitrogen	16%
Water Insoluble Nitrogen (WIN)	5.6%
Available Phosphoric Acid (P_2O_5)	4%
Soluble Potash (K_2O)	8%

To find the % nitrogen that is WIN, use the following calculation:

$$\frac{\%WIN}{\%\ Total\ N} \times 100 = \text{\% of total N that is WIN or slowly available}$$

$$\frac{5.6}{16} \times 100 = \text{35\% of the total nitrogen is WIN or slowly-available}$$

WIN may also be listed in the asterisked fine print of a water soluble source. For Example:

Guaranteed Analysis	
Total Nitrogen	35%
35.0% Urea Nitrogen*	
Soluble Potash (K_2O)	8%
*Contains 12% Slowly Available Nitrogen from coated Urea	

Nitrogen Fertilization of Cool-Season Grasses

PROGRAM I - Nitrogen fertilization of cool-season grasses using predominantly quickly-available nitrogen fertilizers (less than 15% slowly-available nitrogen or WIN)

	Nitrogen Application by Month (lbs N/1000 sq ft)			
Quality Desired	*Sept.*	*Oct.*	*Nov.*	*May 15 to June 15*
Low	0.7	0.7	0	0
Medium	0.7	0.7	0.7	0
High	0.7	0.7	0.7	0-0.5

PROGRAM II - Nitrogen fertilization of cool-season grasses using predominantly slowly-available fertilizers (15% or more slowly-available nitrogen or WIN)

	Nitrogen Application by Month (lbs N/1000 sq ft)			
Quality Desired	*Sept.*	*Oct.*	*Nov.*	*May 15 to June 15*
Low	0.9	0.6	0	0
Medium	0.9	0.9	0-0.2	0
High	0.9	0.9	0.9	0-0.5

Important Comments about Programs I and II:

* Fine fescues perform best at 1-2 lbs of nitrogen per 1000 sq ft per year.
* Applications in successive months should be at least 30 days apart and deliver no more than 0.7 lb of N per 1000 square feet per active growing month.
* Natural organic and activated sewage sludge products should be applied early in the August 15 to September 15 and the October 1 to November 1 application periods to maximize their effect since they release N due to microbial activity.
* Up to 0.7 lb of nitrogen in Program I and up to 0.9 lb of nitrogen in Program II may be applied per 1000 sq ft in the May 15 to June 15 period if nitrogen was not applied the previous fall or to help a new lawn get better established.

Nitrogen Fertilization Of Warm-Season Grasses

PROGRAM III - Nitrogen fertilization of warm-season grasses using predominantly quickly-available nitrogen fertilizers (less than 15% slowly-available nitrogen or WIN)

	Nitrogen Application by Month (lbs N/1000 sq ft)			
Quality Desired	*April*	*May*	*June*	*July/August*
Low	0.9	0.9	0	0
Medium	0.9	0.9	0.9	0
High	0.9	0.9	0.9	0.9

PROGRAM IV - Nitrogen fertilization of warm-season grasses using predominantly slowly-available nitrogen (15% or more slowly-available nitrogen or WIN)

	Nitrogen Application by Month (lbs N/1000 sq ft)			
Quality Desired	*April*	*May*	*June*	*July/August*
Low	1	1	0	0
Medium	1	1	1	0
High	1	1	1	1

Important Comments about Programs III and IV:

* If overseeded for winter color, add 1/2 to 1 lb of readily available nitrogen per 1000 sq ft in Sept./Oct. and/or Nov.
* Applications in successive months should be approximately four weeks apart.
* Centipedegrass and mature zoysiagrass perform best at 1 to 2 lbs of nitrogen per 1000 sq ft per year.
* Improved winter hardiness on bermudagrass will result from the application of potassium in late August or September.

If no WIN is listed on the fertilizer label, assume that it is

all water-soluble or quickly available nitrogen, unless the fertilizer label indicates that it contains sulfur-coated urea. Sulfur-coated urea fertilizers provide slowly available nitrogen, but the fertilizer label does not list it as WIN. If the fertilizer contains sulfur-coated urea, include that portion as water insoluble nitrogen when determining the portion of the fertilizer that is slowly available.

Statements on a fertilizer bag such as "contains 50% organic fertilizer" do not mean that the fertilizer is 50% slowly available. It is impossible to calculate the amount of WIN from this information. For example, Urea (46-0-0) which contains carbon, hydrogen, oxygen, and nitrogen, is in fact an "organic" fertilizer, yet it contains no slow release nitrogen.

Weed Control

Weed control can be minimized by good mowing and fertilization management, since this makes grass more capable of competing with weeds. If chemical control should be necessary, care should be taken to apply chemicals at the time of year when they will be most effective. Follow label directions closely and never exceed recommended rates. Improper application of weed control chemicals can result in damage to desirable grasses, ornamental plantings, and the environment.

There are two basic groups of weeds: broadleaf weeds and weedy grasses. Broadleaf weeds consist of the familiar dandelions, chickweed, clover, ground ivy, wild onions, oxalis, plantain, and anything which is not classed as a grass. Examples of weedy grasses are nimblewill, quackgrass, crabgrass, and goosegrass. Of course, even what is a desirable turfgrass for some can be a serious weed for others (e.g. bermudagrass in tall fescue, creeping bentgrass in Kentucky bluegrass). Control for each of the two groups varies.

There are good selective herbicides available for broadleaf weed control. In general, broadleaf weeds respond best to weed killers when they are most actively growing and/or in the seedling stage. This is usually in early to mid fall and mid to late spring. When equally effective, fall applications are preferable because fewer ornamental and garden plants are in an active state of growth. Applications of high rates of weed killer during hot, dry conditions may brown desirable grasses. Annual weedy grasses such as crabgrass, foxtail, and goosegrass are controlled with preemergence herbicides that are applied in the spring, prior to germination. Pesticide recommendations for control of specific broadleaf and grassy weeds are contained in the lawn section of the Home Grounds and Animals Pest Management Guide.

Control of perennial weedy grass such as common bermudagrass, nimblewill, and quackgrass is more difficult because selective herbicides that have activity generally can not control the weed in single applications. Therefore, persistence in weed treatment is required and in some instances spot spraying, physical removal, or total kill of existing lawns is often necessary.

Sedges are often called 'nutgrass' but they are not in the grass family. They can easily be identified by their triangular stem. Sedges can be controlled with use of herbicides that specifically target sedges. These herbicides do not damage mature turfgrass. Sedges are warm season in nature and there are both annual and perennial biotypes. They are best controlled soon after their emergence in early-mid summer.

Control of mosses is usually done through cultural means. Improving surface drainage, reducing compact, improve soil fertility and adjusting the pH can improve the ability of turf to out compete moss. While some selective to pruning can increase exposure to sunlight, lack of sunlight is often the main reason for moss to out compete turf in soil that has improved to otherwise favor turf. In this case, alternative ground covers are a better option than turf. Virginia Cooperative Extension features a publication devoted to both how to grow and how to control moss in lawns at http://www.ext.vt.edu/.

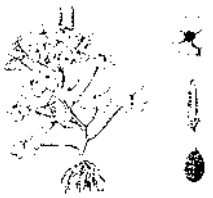
Weed Identification

The following tables outline the most common lawn weeds found in Virginia. *Condensed reprint of Penn State Extension publication 407, Weed Management in Turf.* Grateful acknowledgement is made to the O.M. Scott & Sons Company for permission to reproduce drawings of broadleaf weeds from *Scotts® Guide to the Identification of Dicot Turf Weeds*. *Reviewed by Jeffrey Derr, Weed Science*

Virginia Cooperative Extension also offers free weed identification services through its Weed ID clinic. For more information on weeds, see the Virginia Extension publication 456-018, *Pest Management Guide for Home Grounds and Animals*.

Grasses and Grass-like Weed Identification	
	**Crabgrass**: Two species of crabgrass, large and smooth, are commonly found in Virginia. Both species are summer annuals and have wide (1/4- to 1/2-inch), sparsely hairy, pale-green leaves that taper to a sharp point. Seedheads are divided spikes that project fingers from the stem, producing thousands of seeds in late summer. Crabgrass plants die after the first frost in early fall.
	**Goosegrass**: Goosegrass, also known as silvergrass crabgrass, has leaves that are darker green and narrower than crabgrass (1/8 to 1/4 inch) and sheaths have a silvery-green color (especially near the center of the plant). Goosegrass has a divided spike-type seedhead bearing seeds in straight rows on the seed stalks. Goosegrass seeds germinate four to six weeks later than crabgrass and germination continues throughout the summer.
	**Foxtail**: Two species of foxtail are found in Virginia- yellow and giant. Foxtail is a light-green, leafy, summer annual grass weed that reaches maturity in midsummer. It is often confused with crabgrass. As a weed in turf, foxtail is much less common than crabgrass, but it can proliferate under low-fertility conditions and high mowing heights as well as in spring seedings.
	**Orchardgrass**: Orchardgrass is a bunch-type perennial grass that forms light green clumps in lawns. Leaves are wide (1/4 to 1/2 inch), light green, and pointed at the tip. The sheaths of orchardgrass are strongly compressed and flattened.
	**Nimblewill**: Nimblewill is a blue-green perennial grass that is common in Virginia lawns during summer. It spreads over existing turf by stolons and forms dense patches. Leaf blades have a medium texture (about 1/4 inch wide) and are short (1-1/2 to 2 inches) with leaf tips tapering to an abrupt point. The stems are long, slender, and wiry with prominent nodes. Seedheads are long, slender, and inconspicuous. Nimblewill grows rapidly during the warm summer months and turns brown or tan in winter.

Broadleaf Weed Identification	
	**Common Chickweed**: Common chickweed is most often classified as a winter annual, but it can grow and flower at any time during the growing season. Leaves are small and elliptical (tapering to a point), and occur opposite one another on square stems that have a single row of hairs. Leaf surfaces are smooth (not covered with hairs). Common chickweed spreads in turf via branched, creeping, above-ground stems that root at the nodes. Flowers are small and white, and have five petals. Common chickweed forms dense patches in high-cut turf and prefers moist, shaded areas, but it can grow in sunny areas under very low mowing heights (less than 1/4 inch).
	**Broadleaf Plantain**: Broadleaf plantain is a large (3- to 6-inch diameter), low-growing perennial weed. Leaves grow in a rosette fashion and are spoon-shaped with wavy margins. Prominent veins run lengthwise on the leaf surface. Seedheads are long (5 to 10 inches) and are covered with seeds that adhere tightly to the stalk. Broadleaf plantain has a thick taproot that grows deep into the soil.
	**Dandelion**: Dandelion is the best-known and perhaps the most common perennial turfgrass weed. It forms a rosette of long, narrow, and strongly lobed leaves. Dandelions produce thick taproots that can penetrate up to several inches into the soil. Bright-yellow flowers (1 inch in diameter) are produced on the long stems in spring.
	**Ground Ivy**: Ground Ivy is a low-growing, creeping, perennial broadleaf weed. Leaves are oppositely arranged on stems and are round or kidney-shaped with scalloped margins. The upper leaf surface has distinct veins and is sparsely hairy. Stems are square, creeping, and long. Ground Ivy produces nodes that root at leaf and stem axils and that can form new stolons. Flowers are blue or purple and trumpet-shaped. This weed is most common in shaded areas, but it can also grow in full sun.

Broadleaf Weed Identification	
	**White Clover:** Clover is a very common weed in nearly all turfed areas. Although some homeowners do not find clover objectionable, its creeping growth habit can overtake turf and form large dark-green patches. Clover leaves are composed of three leaflets, each with a small white mark in the center. Stems grow above ground and root at the nodes. Clover produces white, compact flowers that are 1/2 inch in diameter.
	**Yellow Woodsorrel**: Yellow woodsorrel (sometimes called oxalis) is a light-green, upright perennial weed. Like clover, each leaf has three leaflets. Leaflets of yellow woodsorrel can be distinguished from other weeds by their distinct heart shape. Flowers are bright yellow with five petals. As flowers mature, they lose their petals and form banana-shaped seedpods that forcibly eject seeds.

Irrigation

Lawns can use an inch or more of water per week in hot, dry weather. If rainfall does not provide this much water and soil moisture reservoirs are depleted, irrigation will be necessary to keep the lawn green. The lawn should be watered when the soil begins to dry out but before the grass actually wilts. At that stage, areas of the lawn will begin to change color, displaying a blue-gray or smoky tinge. Also, loss of resilience can be observed; footprints will make a long-lasting imprint instead of bouncing right back. Alternate wetting and drying periods are normal and beneficial to developing balanced microbial activity in soils. Ideally, the lawn should be watered shortly after the development of the blue-grey cast noted above.

Cool-season grasses usually go semi-dormant in the hottest part of the summer, returning to full vigor in cooler fall weather. If you want to keep the lawn green through the summer, regular deep watering will be necessary. If the lawn does go dormant (turns brown), let it stay that way until it naturally greens up again. Too many fluctuations between dormancy and active growth can weaken the lawn.

Light sprinkling of the surface is actually more harmful than not watering at all, since this encourages root development near the surface and increases crabgrass germination. This limited root system will require more frequent waterings and will necessitate keeping the surface wet, which is ideal for weeds and diseases. Watering should be an "all or nothing" type of commitment. If you water, do it consistently and deeply. If you don't intend to be consistent, it is better not to water at all and to allow the grass to go dormant until natural conditions bring it back. Encouraging deep root growth by irrigating infrequently, but heavily, will maximize water use efficiency and turfgrass quality.

The best time to water a lawn is in the early morning. Evaporation is minimized and water-use efficiency is better than during midday. Early evening or night watering is not encouraged because it leaves the blades and thatch wet at night. This maximizes the potential for disease activity.

Study Questions

10. To help reduce stress, _____ grasses should have higher mowing heights during the summer.

11. Mowing should be frequent enough that no more than ___ of the plants' height is taken off at one mowing: a) 1/2; b) 1/3; c) 1X; d) 2X

12. Cool-season grasses should be fertilized during the: a) late-fall; b) early-spring; c) summer; d) late-summer

13. Sulfur-coated urea is a _____ form of nitrogen.

14. Broadleaf herbicides are most effective when applied: a) in the morning; b) at night; c) during the weeds' active growing season; d) when the weeds are dormant

15. A common grass-like weed is: a) nimblewill; b) dandelion; c) ground ivy; d) yellow woodsorrel

16. The best time to irrigate is: a) in the morning; b) at night; c) when the grass is turning brown; d) the same time every week

Answers:
10 - cool-season; 11 - b; 12 - a; 13 - slowly available; 14 - c; 15 - a; 16 - a.

Dethatching

In addition to regular maintenance factors already discussed, in some years it may be necessary to remove thatch from lawns with thatch-forming grasses. Thatch is the tightly interwoven layer of living and dead stems,

leaves, and roots that exists between the green blades of grass and the soil surface. This layer of decomposing organic matter accumulates on the soil surface in an innocuous fashion. During the early stages of thatch development, when it measures less than 0.5 inch in thickness, it can actually be beneficial to the grass. Thin layers of thatch can increase wear tolerance of turf by providing better dissipation of compaction forces; reducing weed populations by providing hostile conditions for germination; reducing water evaporation by blocking sunlight and air exchange with the soil surface; and insulating crown tissue, protecting it from frost and traffic damage. Thatch problems are inevitable with certain grasses under intensive turfgrass management programs unless thatch reduction principles are built into the program. The single cause of thatch buildup is the fact that the accumulation rate of dead organic matter and stems on the soil surface is greater than the decomposition rate. There are many reasons for this imbalance between rate of accumulation and decomposition. Some of the factors involved include excessively high nitrogen levels, the type of turfgrass, excessive irrigation, mowing management, chemical use, and soil type.

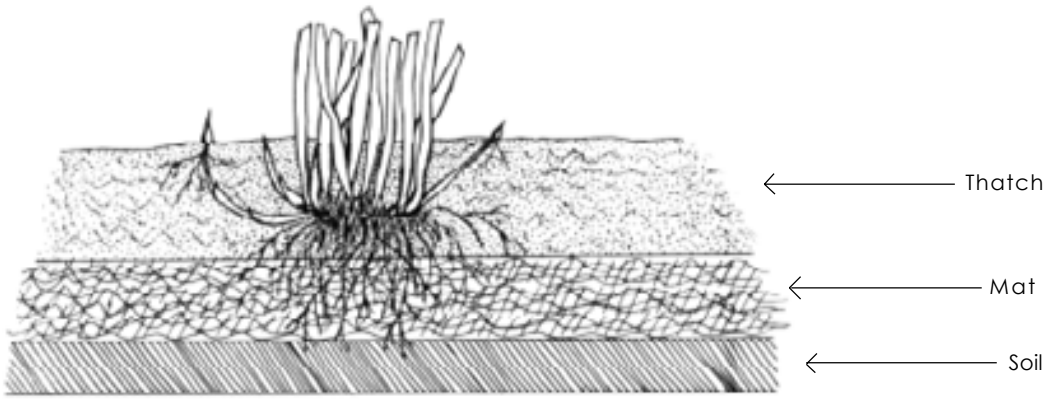
The effect of excessive thatch buildup upon turfgrass quality is subtle but deadly. This layer of undecomposed organic matter is capable of altering pest populations, moisture relations, nutrient utilization patterns, soil temperatures, and other climatic and biotic factors.

For all intents and purposes, thatch is not caused by leaf clippings. Recycle clippings to the lawn to take advantage of their nutrient composition.

The moist microclimate created by the thatch layer favors fungal invasion and allows pathogenic microorganisms to live and sporulate. The probability of insect pathogens surviving the winter is increased by the insulating effect of thatch. Soil-borne fungus and insect pathogens often escape control methods due to the inability of applied pesticides to penetrate the thatch layer. The thatch layer prevents adequate water infiltration, causing reduced root growth and increased potential for wilt damage. When thatch layers are kept moist, roots tend to develop in this zone, and crown regions of the individual turfgrass plants tend to be elevated in the thatch. This elevation of the crown region away from the soil leads to increased exposure to temperature extremes and a greater probability of stress-related damage. Interception of lime and fertilizer applications by thatch layers produces erratic fertilizer response. In some cases, the microorganisms tie up the applied nitrogen, rendering it unavailable to the turfgrass plants.

Preventive thatch management involves turfgrass selection, modification of nutrition, cultivation, mowing, and irrigation practices. Kentucky bluegrass, creeping red fescue, bermudagrass, zoysiagrass, and St. Augustinegrass are all prone to thatch development under intensive management because they produce lateral stems. Tall fescue and perennial ryegrass, bunch type-grasses, are low thatch producers and if they do produce thatch, then they are being mismanaged in terms of N fertilization.

The following illustration shows a block of turf with thatch, mat, and soil layers in profile. Note that the crown of the grass plant is elevated into the thatch layer. The mat is the layer of decomposing thatch which is becoming integrated into the soil. There is no simple method of controlling thatch development. Preventive programs for thatch reduction should be built into the maintenance program. Curative programs involving the labor-intensive process of dethatching may also be required at times.



The pH of the thatch layer appears to be more important to thatch decomposition than soil pH. Researchers have shown that light annual applications of lime (20 to 25 lbs. per 1000 square feet) may be beneficial in speeding the thatch decomposition rate. Moderate use of nitrogen with more frequent small applications appears to decrease thatch buildup. Aerification and topdressing of turfgrass speeds up thatch decomposition by returning microbes into the thatch layer and improving the environment for their maximum activity. Aerobic microorganisms involved in the thatch decomposition benefit from improved oxygen levels as much as the turfgrass. Earthworm castings serve to inoculate the thatch layer with microorganisms and soil to improve moisture retention in the thatch layer, thus increasing microbial activity.

If the thatch layer in your lawn is more than 2 inches thick, dethatching and/or aeration will be beneficial. Timing of these is critical, and is best done during periods when the plants can recover from the treatment. Warm season grasses should be dethatched in early to mid-summer. Kentucky bluegrass and other cool-season grass lawns should be dethatched in early fall or early spring. Spring verticutting can lead to excessive crabgrass invasion if improperly timed. Vertical mowers and aerifiers can be rented. Dethatchers physically remove thatch and deposit it on the surface of the lawn. This material should then be raked up and removed. If overseeding is planned, it is good to do this in conjunction with the verticutting or aerating process, since the grooves cut in the soil will provide good soil contact for the new seed.

pH Adjustment

Soils in Virginia are typically acid, and from time to time it may be necessary to add lime in order to keep the soil pH near 6.2. Soil test results will tell how much lime should be applied.

Aeration

If soil is heavy or compacted, or thatch buildup is a problem, aeration may be necessary. Roots need oxygen as well as water and nutrients; compacted soil restricts the absorption of water and does not allow the soil to exchange oxygen with the atmosphere.

Aeration is best done by a machine which forces hollow metal tubes into the ground and brings up small cores of soil which are left laying on the surface. The soil should be moist, not too wet or too dry, when this is done. Simply punching holes with a spiked roller may improve water retention, but this practice also increases compaction in the soil. Reinoculation of thatch layers with soil and microbes through the aeration process is beneficial in helping to create an environment conducive to thatch decomposition. Another great soil improvement strategy to tie together with core aeration is a surface application of compost. As little as ¼ inch depth of compost one to two times per year is an important way to improve soil physical and chemical properties and reduce fertilizer , water, and pesticide water inputs for the turf over time.

Disease Control

Proper management will greatly reduce a lawn's susceptibility to disease. Disease damage may be difficult to identify, since many of the symptoms may also be caused by improper management or by environmental factors such as competition from tree roots. Nearly all lawn diseases are caused by fungi, and fungicides can be applied to prevent and control them.

Disease or sickness in turfgrasses, as in other plants, develops from an interaction between a susceptible plant, a disease-producing organism (usually a fungus), and an environment favorable for the disease-causing organism to attack. Scientists who work with turfgrass diseases sometimes use a disease triangle to illustrate the concept of disease. The three sides of the **disease triangle** represent three factors that interact to produce turfgrass disease: the disease causer, the susceptible grass, and a favorable environment (Figure 1).

Three factors interact to cause turfgrass disease; therefore we must observe all three factors to gather information for diagnosis of the problem, and we can change any or all of these three factors to combat the disease.

The first step in turfgrass disease management is the identification of the problem. Disease management strategies that are effective against one disease may have no effect on or may even worsen another disease.

The three factors (grass, disease-causer, and environment) provide the sources of information for diagnosis (Figure 2). The *environment* during the onset of the disease is one source of diagnostic information. For example, what were the temperature, the light intensity, and the moisture conditions just prior to and during disease development? The nature of the disease site is also important. Air and water drainage, soil conditions, sun/shade, slope, and nearness of other plantings or buildings may all be important in development of turfgrass diseases. Prior chemical applications to the site, including pesticides

and fertilizers, may be contributive. Heavy thatch accumulation and poor mowing practices that stress the turf may trigger or amplify certain disease problems in turf areas.

Figure 1. Disease triangle

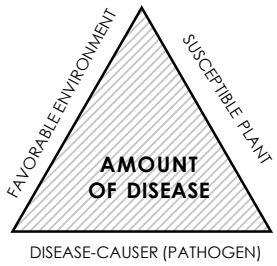
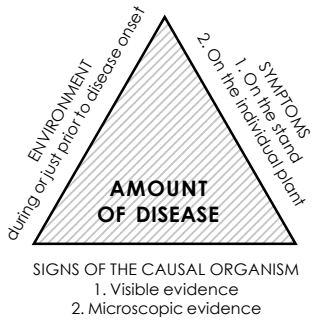


Figure 2. Diagnosis Triangle



The nature of the *symptoms on the grass* is a very important source of diagnostic information. Two kinds of symptoms should be looked for in diseased turfgrass areas- symptoms on the stand, and symptoms on individual plants. A home lawn, an athletic field, and a golf green or fairway are all examples of turf stands. Symptoms on the stand are the appearance and the visible patterns of the disease on the planting. These are extremely important in turfgrass disease diagnosis because different diseases appear differently on turf stands. The visible differences in pattern are often critical factors in identifying particular diseases. Diseases can appear on the turf stand as spots, patches, rings, circles, or may be unpatterned. Certain diseases never appear as rings, while others always appear as rings. Symptoms to look for on individual plants include leaf spots, leaf blight, wilt, stunt, yellowing, and root discoloration or rot. Leaf spots can be very good diagnostic clues because the leaf spots of diseases are usually unique in shape, color, and size. Leaf blighting is different from these unique leaf spots because leaf blighting is rot on the leaf that has no definite form. Leaf blighting can be any size or shape and may involve the entire leaf.

Certain life stages of turfgrass *disease-causers* can be seen without magnification. The fungi that cause most turfgrass diseases are microscopic. But in stripe smut, powdery mildew, and rust diseases, that spores of the causal fungi pile up in such numbers that they become visible as black, white, or orange powder on grass leaves. In red thread disease, the fungus sticks together and forms the pink or red antler-like threads that typify the disease. When the causal fungus can be seen, its appearance is often the most important clue for diagnosis.

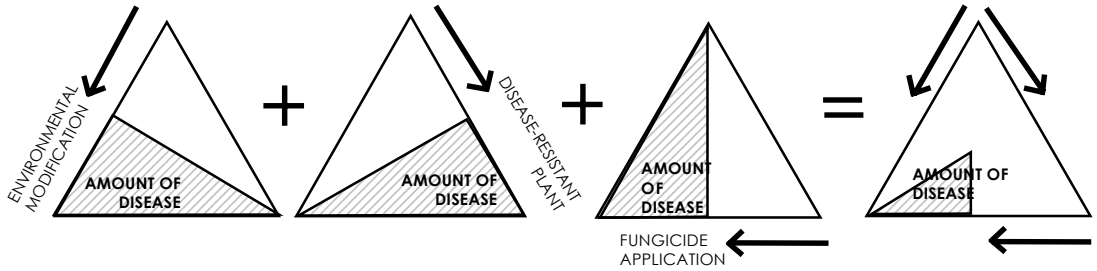
Because the three components of disease development combine to influence the onset of turfgrass disease, the task of disease management on turfgrasses involves manipulation of these three - the environment, the grass, and/or the disease-causing organism - to favor the grass and inhibit the causal fungus.

The *environment can be altered* in many ways. The ones chosen depend on the disease to be managed. Water manipulation can be a valuable tool in disease management. Effective strategies to reduce free water include morning irrigation, removal of dew, and reduction in amount and/or frequency of irrigation. Other management strategies may involve some forms of improved air and water drainage, improved soil conditions by aeration, thatch reduction, manipulation of light conditions, regulation of fertilization levels, and implementation of proper mowing practices.

When establishing new turf areas or when renovating disease-damaged turf, it is important to select grasses that are resistant to diseases known to be common in the area or that have damaged the existing stand. *Disease resistant grasses can be seeded* to minimize turf loss from disease. Disease severity can often be reduced by appropriate changes in the grass that is being grown. It is a bad practice to replant that same grass that has been killed by the same disease year after year, if there is another option. In selecting grasses for turf establishment or renovation, it is preferable, where possible, to use mixtures of different grasses or blends of different varieties rather than seeding a single kind of grass. The seeding of mixtures or blends produces a diverse population of grass plants. Such turf is usually more likely to survive stress caused by disease. Diversity in plantings almost always increases odds of survival.

The causal organism may be attacked by applying chemicals that will either kill the organism or keep it from growing. Again, it is important to have identified the causal organism correctly, so that an appropriate fungicide can be selected. Arbitrary selection and application of fungicides without knowledge of the disease can do as much harm as good. Using the wrong fungicide wastes money, and may increase the amount of disease or produce other undesirable side effects.

Figure 3. Use all three management approaches to reduce the amount of turfgrass disease.



Planning an effective disease management program involves not only "spraying something," but selecting cost effective and environmentally sound disease control strategies. The financial, environmental, and aesthetic costs of disease management strategies must be considered. Good, common sense approaches to disease management should employ all available disease management strategies (Figure 3).

The Virginia Tech Disease Diagnostic Lab provides identification services for samples that are handled through local VCE offices.

Insect Control

There are naturally many different types of insects present in a lawn. Most of these are not harmful to the grass. Control for insects is not necessary unless the pest population builds up enough to cause visible damage to the lawn.

Close examination on hands and knees is the best way to identify insect pests in a damaged lawn. You may be able to see the insect in action. If you think you have an insect problem, your local Extension Office can help in identifying the pest and suggesting recommended control measures.

The most common above-ground insect pests in Virginia lawns are chinch bugs and sod webworms which feed on grass leaves and stems. Below ground, the most common pests are white grub larvae which feed on roots.

Chinch Bugs are small, white and black insects that suck sap from grass, producing yellow and then brown patches. To test for chinch bugs, cut both ends off of a large tin can, push one end into the soil, and fill the can with water. Chinch bugs will float to the surface if present.

Sod Webworms are the larval or caterpillar stage of several species of Lepidoptera. Adults are commonly

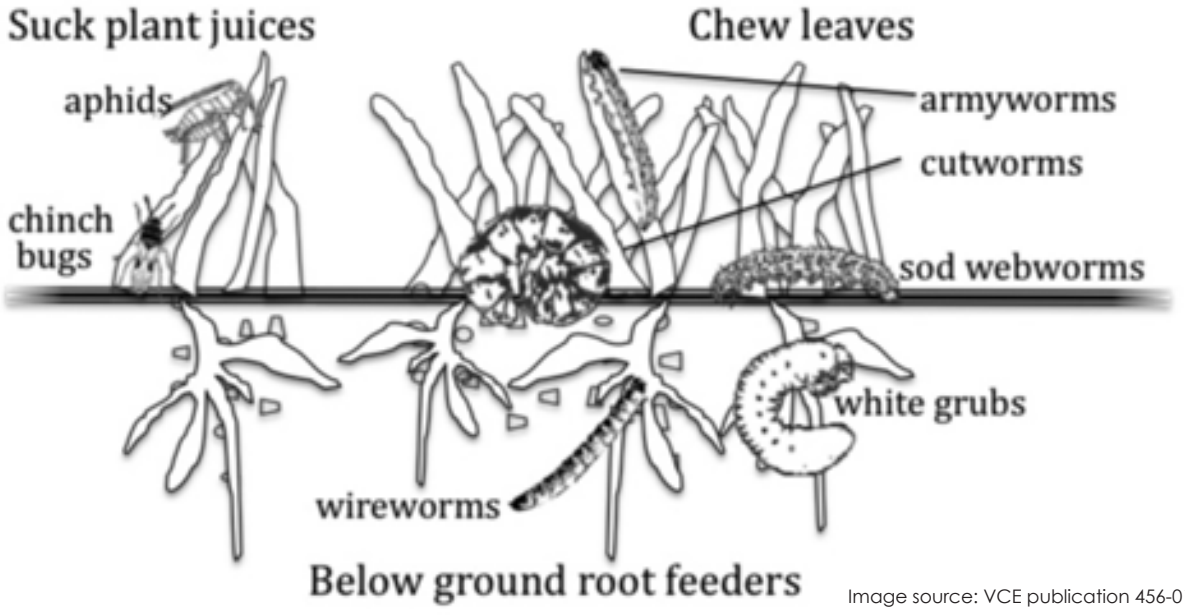


Image source: VCE publication 456-018

seen flying in jerky, short flights as you walk through the grass. Caterpillars do the damage, feeding on the grass blades at night. Sod web worms prefer well-managed lawns. Damage appears as small brown areas in the grass.

White Grubs are the larval or grub stage of several species of beetles and chafers. Typically cream-colored with a brown head and a dark area at the posterior end, white grubs feed on roots, causing brown areas in the lawn. Usually turf can be rolled back like a rug to reveal white grubs.

Study Questions

17. The thatch layer can: a) prevent water infiltration; b) increase wear tolerance; c) provide shelter for fungi and pathogenic microorganisms; d) all of the above

18. One way to reduce problems of an excessive thatch layer is to add a) nitrogen; b) lime; c) water; d) none of the above

19. Nearly all lawn diseases are caused by _____.

20. The disease triangle for turfgrasses DOES NOT include the following factor: a) the environment; b) the disease causing fungus; c) the time of year; d) the grass stand or individual plants

21. A tin can could be used to test for _____ in the lawn.

Answers:
17 - d; 18 - b; 19 - fungi; 20 - c ; 21 - chinch bugs

Grass Choices for Virginia Beach		
	Common Name	*Scientific Name*
Warm-Season Turfgrasses	Bermudagrass	*Cynodon dactylon*
	Centipedegrass	*Eremochloa ophiuroides*
	St. Augustine	*Stenataphrum secundatum*
	Zoysiagrass	*Zoysia japonica*
Cool-Season Turfgrasses	Tall Fescue	*Festuca arundinaceae*

Temperature Ranges (°F)		
	Warm-Season Turfgrasses	Cool-Season Turfgrasses
Ideal Shoot Growth	80-95°	60-75°
Ideal Root Growth	75-85°	50-65°
Upper Limit Shoot Growth	120°	90°
Upper Limit Root Growth	110°	77°
Lower Limit Shoot Growth	65°	40°
Lower Limit Root Growth	50°	33°

Turfgrass Characteristics										
	Leaf Texture	**Shade Tolerance**	**Cold Tolerance**	**Heat Tolerance**	**Drought Tolerance**	**Wear Tolerance**	**Salinity Tolerance**	**Fertility Requirements (Nitrogen)**	**Mowing Height (inches)**	**Optimum Soil pH Range**
Common Bermuda	M	L	L-H	H	H	VG	G	M-H	1	6.0-7.0
Hybrid Bermuda	F	L-M	L-H	H	H	E	G	L	1	6.0-7.0
St. Augustine	C	H	L	H	M	P	G	M-H	3	6.5-7.5
Fescue	F-C	H	H	M	M	G	F	M	3	5.5-6.5
Zoysiagrass	F-M	L-M	H	H	H	E	G	M	1	6.0-7.0
Centipedegrass	M-C	M-H	M-H	H	M	P	P	VL	2	5.0-6.0
F = Fine; M = Medium; C= Coarse. VL = Very Low; L = Low; M = Medium; H= High. E = Excellent; VG = Very Good; G = Good; P = Poor.										
Compiled by Randy Jackson, Unit Director. Funding provided by ES-USDA project #91-EWQI-1-9034 Chesapeake Bay Residential Watershed Water Quality Management										

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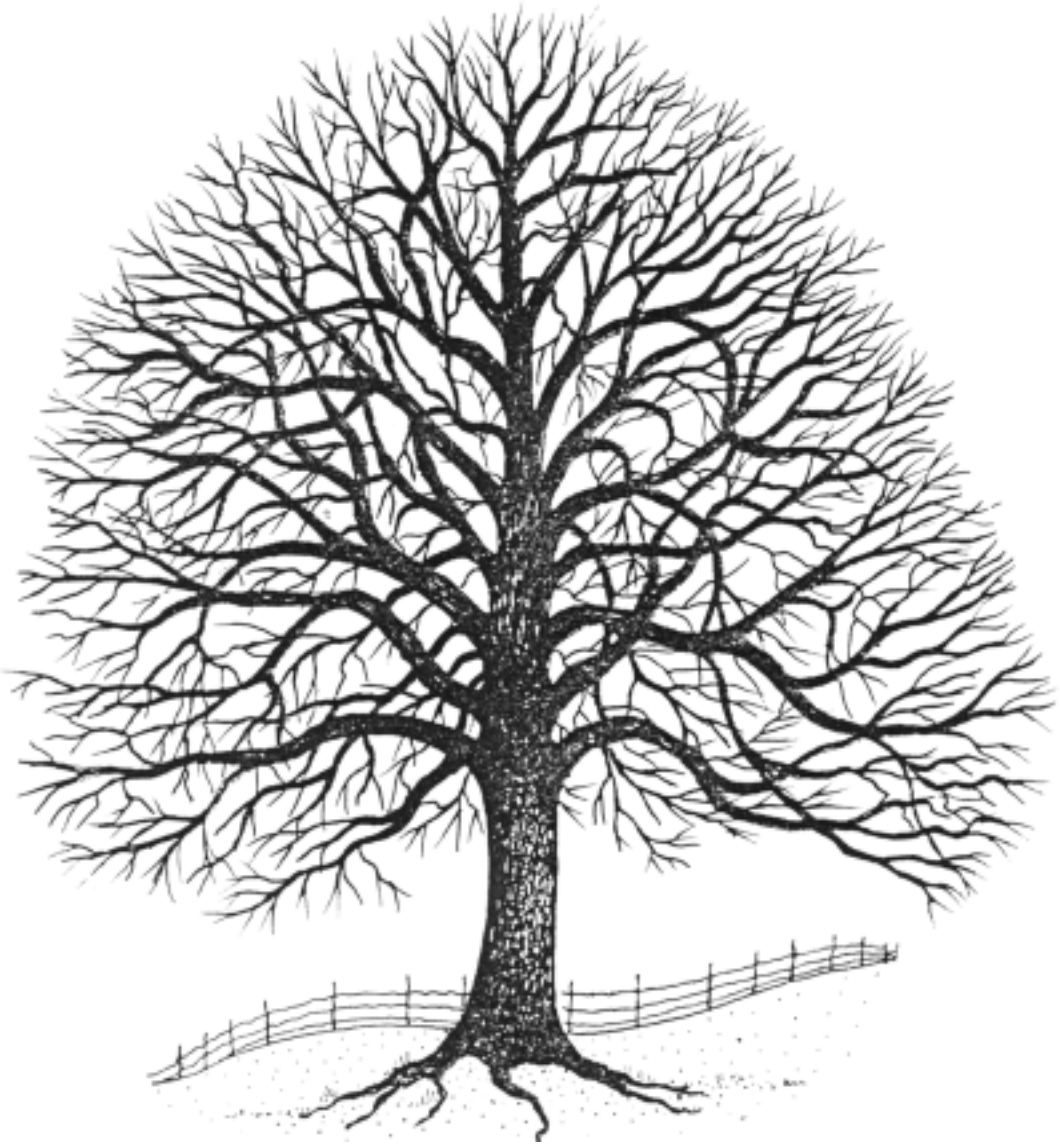
Chapter 16
Woody Landscape Plants

Woody Landscape Plants

Chapter 16



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Chapter 16

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The knowledge of woody landscape plants is essential for anyone in the realm of landscape horticulture; this realm ranges from the completely fabricated urban setting to relatively untouched natural areas. One needs this information to properly design and manage landscapes, as well as to diagnose and solve landscape plant-related problems.

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Introduction

The information presented in this chapter is designed to prepare you for most tasks and issues that you will encounter in dealing with the use of woody plants. Knowledge of fundamental plant aspects such as plant nomenclature, hardiness, and plant biology aspects are key to using and managing woody plants in a landscape.

This chapter will not delve into the identification of woody plants, however, knowing how to identify at least the most commonly used woody landscape species is a great asset to anyone dealing with these plants. A very scholarly and thorough treatment relative to the identification and use of woody plants is the: Manual of Woody Landscape Plants by Michael A. Dirr (6th edition, 2009, Stipes Publishing). This text is an excellent reference and is often considered the "bible" of woody plants.

There are several key terms and concepts that you must know and understand to develop a full appreciation of woody plant subject matter. The key terms and concepts are in **bold** text to signify their importance.

Learning Objectives

The goal of this chapter is to provide you with the fundamental woody plant information to understand the basics of woody plant biology relative to landscape applications, and how to appropriately select and manage woody species in the landscape. Some details such as pruning, fertilization, and soil aspects will only be superficially addressed in this chapter since this information is covered in depth in other chapters. This goal will be accomplished by these learning objectives:

By the end of the chapter, you will be able to:

* Define the noted important botanical and plant-related terms (in bold)
* Describe the plant-related concepts (in bold)

What is a Woody Plant?

Woody plants are perennial (life span ranges from decades to centuries, or in some cases millennia) in which the shoot (above ground portion of the plant) persists during plant dormancy (usually late-autumn to early-spring). For example, an oak tree (*Quercus* sp.) has a trunk that persists for 12 months, year after year for centuries. In contrast, the shoot system of an herbaceous perennial, such as a hosta (*Hosta* sp.), dies to the ground each fall but the root system persists year after year. Because the shoot system of an herbaceous perennial dies at the end of each growing season, no yearly increase in stem/trunk diameter occurs as does in woody plants. Woody plants are described as trees, shrubs, groundcovers, and vines. Technically, wood is composed of xylem tissue, mostly dead lignified vascular cells that transport water from the roots to the trunk, stems, leaves, flowers, and fruit. Wood also serves as the structural support system for plant parts.

As with most issues, there are shades of gray. For example, *Nandina domestica,* common name nandina or heavenly bamboo, is a shrub. However, in the northern part of its adaptable range (USDA Plant Hardiness Zone 6), the shoot system can be killed by low winter temperatures. However, this species will usually produce a new set of shoots (top portion of a plant) the following spring from the root system. Thus, nandina, while typically considered a woody plant, in some years and locations can grow as an herbaceous perennial due to weather-related conditions. We will cover plant hardiness in detail in a future section.

Study Questions

1. How is a woody plant distinguished from an herbaceous perennial?

Answer: The shoot system of a woody plant persists 12 months a year for many years; the shoot system of an herbaceous perennial (usually) does not persist for more than a growing season.

Plant Nomenclature – Naming of Plants

Plants have a common name and a scientific name and the value of these will be soon discussed. Why should we know plant names? Knowing plant names is essential to correctly identify, propagate, sell, purchase, use, assess, and diagnose plants in many horticultural applications. Many garden centers and virtually all wholesale plant vendors list their plants by the scientific name, so knowing both names is important. Knowing plant names also helps you understand the relationships (plant growth relative to light, water, soil, and climate aspects) between plants when observing plants in natural or man-made landscapes. This passage is an artful description of the value of knowing plant names:

"The first reward of tree study – but one that lasts you to the end of your days – is that as you walk abroad, follow a rushing stream, climb a hill, or sit on a rock to admire the view, the trees stand forth, proclaiming their names to you. Though at first you may fix their identity with more or less conscious effort, the easy-to-know species soon become like the faces of your friends, known without thought, and bringing each a host of associations." A quote by D.C. Peattie A Natural History of Trees of Eastern and Central North America, published by Houghton Mifflin Co. page 156.

Plants can be referred to by a common name or by a scientific name. As you will see in the following paragraphs the use of a plant's scientific name is the best and most reliable way to describe a plant.

Common Names

All plants bear at least one common name, a vernacular name that is commonly attached to a plant. Examples of common names are red maple, American beech, white pine, and redbud. The issues of using these familiar names are that 1) a plant often has more than one common name, 2) names can vary from region to region, and 3) names vary from one language to another. Furthermore, two completely unrelated tree species can share the same or similar common name. For example, the common name of a conifer commonly seen throughout Virginia is eastern red cedar (*Juniperus virginiana*). Eastern red cedar is a juniper and not a type of cedar; it is not even in the same plant family as a true cedar (genus = *Cedrus*). **Thus, referring to common names in horticultural plant commerce is a very unreliable way to describe a plant.** Most wholesale plant catalogs list plants by scientific name, and anyone in the horticultural realm needs to know plants by their scientific name. Scientific names are "relatively" stable; botanists occasionally reclassify plants resulting in family and species names being changed. In general, common names are written in lower case with the exception of proper names (e.g., American beech).

Scientific Names

Genus and Specific Epithet = Species

All known living things are given a two-word Latin scientific name, a generic name followed by a specific name. Latin was chosen because it is a dead language (not commonly spoken and no longer evolving). This two-word name (binomial) is descriptive of only one plant (i.e., species) and is composed of a **genus** and a **specific epithet**. For example, humans are *Homo sapiens*; *Homo* is the genus (a generic name) and *sapiens* is the specific epithet (a specific name). **Collectively, the genus followed by the specific epithet is a species.**

The scientific name is very important to know in most situations since there is no ambiguity on the interpretation of the name. For example, the common name of red maple is *Acer rubrum*. However, red maple is also called scarlet maple and swamp maple. Adding to the confusion is that there are a few maples that can have red foliage. However, if the *Acer rubrum* name is used, then one knows exactly which species is being referred to.

A **genus** is a group of somewhat closely related individuals (a group name) comprising one or more species. For example, the genus name for all maples is *Acer*, and the genus name for all oaks is *Quercus*. The **specific epithet** is the second word of the Latin binomial that usually functions as an adjective (or sometimes named after an individual) and indicates or describes the member of the genus. For example, the species name for sugar maple is *Acer saccharum* and the species name for white oak is *Quercus alba*. Again, **the genus followed by the specific epithet comprises a species.** A species is somewhat of an elusive concept and there are many definitions of the species concept. For the sake of this chapter, a species is group of individuals that can be characterized by a set of identifiable characteristics that distinguishes it from other types; thus, all sugar maples (*Acer saccharum*) look more or less alike and can be differentiated from other maple species.

There are rules for writing a species name. **The genus name is capitalized and either italicized or underlined.** For example, the genus for maples is written as *Acer* (or Acer). The plural of genus is genera. **The specific epithet is written in lower case and is italicized or underlined.** For example, the Japanese maple is *Acer palmatum* (or Acer palmatum). Italics or underline designates the names are in a foreign language. The plural of species is species; the abbreviation for a species (singular) is sp. and the abbreviation for more than one species is spp. (plural); for example, one maple species is *Acer* sp. and more than one species is *Acer* spp. In paragraph style, after the first mention of a species, e.g., *Acer palmatum*, the following references to that species use a first letter abbreviation of the genus term, e.g., *A. palmatum*. Here is review example for the proper designation of a scientific plant name, *Acer palmatum*:

Acer	*palmatum*	red maple
genus	specific epithet	common name

Knowing the Latin meaning of the binomial can often help one remember the species name. For example, in the species *Cornus florida*, flowering dogwood, the genus *Cornus* means horn, referring to the very hard wood of this species. The specific epithet, *florida*, means flowering referring to the very showy flowers. Not all binomial names have meanings that are linked with tangible nouns or adjectives. For example, the genus *Pinus* (pine) refers to the name historically given to pine trees. There are several websites that have lists of Latin botanical names and their English translation; here are two of the websites: http://davesgarden.com/guides/botanary/ and http://alumnus.caltech.edu/~hollin/botany/latin/dictionary.html.

A **family** is composed of a one or more species that share a set of characteristics. **Family names end in aceae.** For example, apples, cherries, and peaches are in the Rosaceae family (rose family). Historically, plants have been grouped into families based on flower and fruit characteristics; currently, DNA sequencing is being used to clarify the true identity of plants and their relationships to other species/genera.

While the family concept is not generally used in the nursery and landscape industries, knowledge of the family can prove to be helpful. For example, species in the Rosaceae family may be prone to pest problems, and species in the Ericaceae (heath) family (e.g., azaleas and blueberries) generally require well drained acid soils.

Plant Classifications Subordinate to a Species

Plants of a particular a species are not identical. They may have a different form, leaf size, flower color, growth rate. To appreciate this phenomenon, consider the wide variety of phenotypic (visual appearance as a result of DNA expression) traits that makes each one of us who we are; hair, eye, and skin color, height, hand size, and body type are a few traits that make each one of us unique. The

same phenotypic variation occurs in plant populations. So, in a population of 1,000 seed-grown redbud trees (*Cercis candensis*), most plants will have the typical leaf size, flower color, and tree height. A small proportion will, however, have large leaves or small leaves, some have light pink flowers and some will have dark pink/purplish or even white flowers, some will have a showy yellow fall foliage color and others not, and so on. This variation is termed **intra-specific (within a species) variation**. The reason for this variation is sex, all offspring derived from seeds are the result of the mixing of male and female genetic material from each parent. In the case of plants, pollen grains (male) unite with an ovule within the ovary (female) to form a seed.

There are a few important nomenclature categories that are subordinate to a species. They are variety, subspecies, and cultivar; these are discussed in the next section.

Variety

A **variety** (mostly synonymous with the **subspecies** term) is a subpopulation of a species that has a distinctive trait that distinguishes it from the rest of the species; the trait may or may not be expressed in plants that are in a particular geographical area. **A woody species variety trait is usually inheritable**, and succeeding seedling generations will express that trait; hence varieties are "true to seed". True to seed refers to the phenomenon where a distinctive trait is usually inherited and expressed when propagated via seeds (sexual propagation). For example, most redbuds (*Cercis canadensis*) produce pinkish flowers in the spring, whereas the variety *alba* of redbud (*Cercis canadensis* var. *alba*) produces white flowers. Thus, seed from C*ercis canadensis* var. *alba* will result in most, but probably not all, of those seedlings ultimately producing white flowers. Another example is the common honeylocust, *Gleditsia triacanthos*, has very large thorns. The thornless subpopulation of this species is the variety *inermis* (meaning thornless; *Gleditsia triacanthos* var. *inermis*). As in the redbud example, most plants produced from seeds from *Gleditsia triacanthos* var. *inermis* will be thornless.

A variety is part of the scientific name and the word variety is abbreviated, var., and placed after the specific epithet and the italicized variety term follows var. Thus, the scientific name for redbud (usually pink-flowered) with white flowers is *Cercis canadensis* var. *alba*. Note that the var. term is lower case and not italicized. Here is review example for the proper designation of a plant variety name, *Cercis canadensis* var. *alba.*

Cercis	*canandensis*	var.	*alba*
genus	specific epithet	variety abbrev.	variety term

Subspecies, an uncommonly used term in the horticultural trade, is very similar to the variety term and abbreviated as subsp.; an example of subsp. use is *Hydrangea anomala* subsp. *petiolaris* (climbing hydrangea).

As previously mentioned, there is usually a wide range of intra-specific variation for numerous traits in a population of a seed-propagated species. In addition to obvious traits such as leaf and flower sizes and colors, vigor, plant form, and dwarfism, there may also be differences in less obvious traits, such as tolerances to external influences such as pests, low and high temperatures, and soil moisture aspects. You should have an appreciation for **intraspecific (within a species) variation**. Why? First, such an appreciation will give you an understanding of the wide degree of variation that occurs in a species. This wide degree of variation is necessary for plants to adapt to the dynamic nature of the environment. For example, the genetic capacity to produce small leaves may be advantageous in climates/environments where rainfall is relatively low since small leaves loose less water via transpiration (water vapor that exits leaf pores) than large leaves. Conversely, the genetic capacity to produce large leaves may be advantageous in climates/environments with ample rainfall to have a larger leaf surface to capture more sunlight and produce more sugars via photosynthesis (conversion of sun energy and carbon dioxide into sugars). Secondly, having a keen eye for this variation may make you rich. You may discover an individual plant that has a particularly unique, attractive, and marketable trait. You can introduce, trademark, and perhaps patent this clone. New-to-the-trade plants are very popular and generate a lot of plant sales and profit.

Cultivar

Another species subclassification is a **cultivar**. The word cultivar is the shortened version of a **culti**vated **var**iety, which, as you will see, can lead to some confusion. A cultivar is an assemblage of plants that has been selected for a particular attribute or combination of attributes and that is clearly distinct, uniform, and stable in these characteristics and that when propagated by appropriate means (asexually or sexually) retains those characteristics. The cultivar name is not in Latin, **first letter of each word (if more than one word) is upper case, and put in single quotes**. For example, the purple-leaved cultivar of redbud is *Cercis canadensis* 'Forest Pansy'.

Cercis	*canadensis*	'Forest Pansy'
genus	specific epithet	cultivar

In some cases there are cultivars of a variety such as in the case of the thornless common honeylocust cultivar ('Sunburst') that has chartreuse new foliage. The name for this plant is *Gleditsia triacanthos* var. *inermis* 'Sunburst'.

There are three main distinctions between a cultivar and a variety.

1) Whereas a variety has a natural connotation, a cultivar has a commercial connotation (used in horticultural commerce).

2) Most woody plant cultivars are not discovered as a subpopulation, but are the result of a bud sport (bud mutation), a seedling plant with a distinctive trait, a witches broom (plant tissue that usually arises from a microorganism invading plant tissue and causing dwarfism), or human-mediated mutagenic alterations. In the case of a bud sport, when a bud (small package of embryonic tissue which becomes a leaf, stem, or flower) is forming, a mutation occurs that can give rise to a distinctive trait.

3) To introduce the third distinction, you should know that grasses and most annuals (non-woody plants) are generally **true-to-seed**. This means that the offspring of true-to-seed species will exhibit the characteristics of the parents (due to "well behaved" gene mixing during reproduction). This is why we can plant seed of corn, turfgrass species, and marigolds, for example, and get plants that will exhibit the cultivar characteristics of those mother plants. In contrast, most woody plant cultivars are generally **are not** true-to-seed (due to a more random mixing of genes during reproduction). Hence, woody plants must be asexually propagated (e.g., cuttings, grafting, layering, and micro-propagation) to maintain their cultivar characteristic. For example, if you plant a seed from a 'Delicious' apple, you will not get an apple tree that produces fruit with the characteristic shape and sweet taste traits of a 'Delicious' apple; you will get an apple that may be round and bitter since the genetic makeup of a 'Delicious' apple was not preserved during seed formation. Accordingly, seedlings from a 'Sunbust' honeylocust (*Gleditsia triacanthos* var. *inermis* 'Sunburst') will not have the chartreuse new foliage characteristic, but most of them will be thornless. This is because the cultivar characteristic is usually not true-to-seed for woody plants, whereas the variety characteristic (thornlessness) is usually true-to-seed. Thus, to propagate a woody plant cultivar with a distinctive trait, one must clone the plant by an asexual propagation technique (by cuttings, grafting, or micro-propagation). The distinction between variety and cultivar gets fuzzy because woody plant varieties are commonly sold in the horticultural trade (sometimes as cultivars), and there are a few (very low percentage) woody plant cultivars that are true-to-seed.

Cultivar Traits and Trait Stability

There are numerous cultivar traits such as variegated (colors other than the species' characteristic green) leaves, plant size/form, flower color/size/petal number/fragrance, fruit size/color, disease resistance, and growth rate. For example, Acer platanoides 'Drummondii' (Drummondii Norway maple) has variegated foliage, leaves with broad white edges. If a cultivar partly or totally ceases to express its cultivar characteristic trait and produces an appearance that is the same as the species, then that cultivar has **reverted (reversion)** to the species characteristics. Portions of an *Acer platanoides* 'Drummondii' tree characteristically revert to the all green leaves. Thus when reversion occurs, the "genetic switch" to control the expression of the cultivar trait (leaf variegation in this case) is turned off, and the "genetic switch" controlling the expression of the normal species leaf color is turned on. Some cultivar traits are very stable and rarely revert to the species form, some cultivars revert occasionally, and some cultivars revert commonly. Commonly, and in some cases occasionally, reverting cultivars make poor landscape plants since they do not retain their unique cultivar trait and plants have to be pruned to remove the reversions. Of courses, if a reversion occurs in the upper portion of a tree, then the reverted branch would be difficult to remove.

The popular dwarf Alberta spruce (*Picea abies* 'Conica'), a dwarf, slow-growing, compact, cone-shaped form of white spruce, will occasionally revert to the species characteristics (medium tree with a faster growth rate, much larger needles and wide-spaced branches). In this case the branch sport (reversion) exhibiting the species characteristics will ultimately outgrow the plant and the result will be a very awkward looking specimen. **To avoid this, the reversion should be cut out as soon as possible to maintain the character of the cultivar.**

Taxon

A **taxon**, an abbreviation of taxonomic group or taxonomic unit, is any taxonomic group/category; the plural is taxa. For example, a genus is a taxon, a cultivar is a taxon, and a genus, species, and cultivars are three taxa.

Trademark

The primary role of a **trademark** is to indicate the source of goods and is not intended to label an individual product or cultivar. For example, the very popular Wave™ petunia series includes Wave™ Blue, Wave™ Misty Lilac, and Wave™ Purple. Cultivar names are the domain of the public, and therefore cannot be trademarked. There are two types of trademarks. The **common use trademark** is designated with the superscript TM, such as in the previously mentioned Wave™ petunia series. Common business use of trademark name grants a business the rights to that name. The second trademark type is a **registered trademark** in which the trademark is registered by the United States Patent and Trademark Office. A registered trademark is designated by a superscript ®, is valid for 10 years, and is renewable. By ascribing a trademark name (either type) to a plant, a company has the sole right to selling a plant by that trademark name. However, another company can sell that plant by its cultivar name.

Unfortunately, some plant catalogs and text books incorrectly put trademark names in single quotes (cultivar designation). Such errors result in considerable confusion between cultivar and trademark names. Due to the proliferation of new plant introductions, many of which have been trademarked, many plants are known by their trademark name, and some of these trademark names are erroneously put in single quotes.

Mr. Tony Avent, proprietor of Plants Delights Nursery, Inc. (Raleigh, NC), has written a very informative and illustrative article on the current troubles in the use of trademark names in place of cultivar names. The article "Name that Plant – The Misuse of Trademarks in Horticulture" is located on the web at: http://www.plantdelights.com/Article/Trademarks-in-Horticulture.

Plant Patent

A plant patent gives the patent owner the sole right to reproduce, sell, or use an asexually propagated plant. A patent grant lasts for 20 years from the date of filing the patent application, and is not renewable. Patented plants are generally trademarked. **Patented plants have the letters PP (plant patent) next to their name.** Plants in the process of being patented have the acronym PPAF (plant patent applied for) which carries no legal validity.

Hybrids

A **hybrid** is the result of a sexual cross, transfer of pollen (sperm) of one plant to the pistil (contains ovary/egg) of another plant, between two or more plants that are somewhat related. An **interspecific** (between species) **hybrid** is the result of a cross between two species of a particular genus. This occurs for some but not all species within a genus. For example, two *Abelia* species, *A. chinensis* and *A. uniflora* were crossed, and the relatively common landscape shrub *A.* ×*grandiflora* (glossy abelia) was produced.

Abelia	*x*	*grandiflora*
genus	multiplication symbol	specific epithet (no space between x and specific epithet

As seen in this example, an interspecific hybrid is designated by placing a multiplication symbol (or lowercase x) immediately (no space) before the specific epithet. An **intergeneric** (between genera) **hybrid** is a cross between two genera and is a very rare occurrence. An intergeneric hybrid is designated by placing the × symbol immediately in front of the genus, for example, ×*Sycoparrotia semideciuda* which is a hybrid between *Parrotia persica* and *Sycopsis sinensis*.

Study Questions

2. Why are common names a poor way to refer to plants?
3. What are the parts of this scientific plant name: *Gleditsia triacanthos* var. *inermis* 'Sunburst'?
4. All family names end in what five letters?
5. For a woody plant, will seeds from a variety produce a plant that will generally exhibit the variety trait?
6. For woody plants, will seeds from a cultivar produce a plant that will generally exhibit the cultivar trait?
7. Is this the correct way to write the scientific name for a hybrid: *Abelia* × *grandiflora*?

8. What are the two types of trademarks and the symbols that designate each?

9. True or false: A plant patent gives the patent owner the sole right to reproduce, sell, or use an asexually propagated plant.

10. True or false: A plant patent lasts forever.

11. Are the following examples of taxa? Plant families, genus, species, varieties, and cultivars.

Answers: 2 - Plants usually have more than one common name and names vary between regions and languages; 3 - Gleditsia = genus; triacanthos = specific epithet; Gleditsia triacanthos = species; inermis = variety; 'Sunburst' = cultivar; 4 - aceae; 5 - Yes; 6 - No; 7 - No because the multiplication symbol directly precedes the specific epithet as: Abelia ×grandiflora (no space between multiplication symbol and specific epithet); 8 - Common business practice, symbol = ™ and federally registered =®; 9 - True; 10 - False, the patent lasts for 20 years; 11 - Yes.

Species Diversity and Monoculture

Species diversity is the use of many varied taxa (family, genus, species) within an area, where an **area** may range from a residential site to municipal or larger sites. Species diversity implies that a landscape (garden size to much larger areas) is composed of a mix of species from a wide range of genera and plant families. Species diversity guards against a disproportionate loss of landscape plants in the event of an insult such as a pest attack (e.g., insect, mite, fungus, or virus) or some damaging environmental event (e.g., drought; excessive rain, wind, or snow; ice storm; or atypically high/low temperatures).

The overuse of any plant taxa (i.e., cultivar, species, genus, or family) in a landscape is regarded as a **monoculture**. There are no research-based values (number and type of taxa per unit land) for determining a monoculture, and "overuse" is a matter of degree. A classic example of monoculture was the American elm (*Ulmus americana*). By the 1930s there were tens of millions of American elm trees planted in North America. The American elm was widely planted as a street tree since it was fast growing, tolerated urban conditions, and had a beautiful vase shape. In 1930, Dutch elm disease, a fungus spread by a beetle, was introduced into the U.S. The disease has killed most of the native and planted American elms and only a very small fraction of American elms have survived this disease. While there are no scientifically determined values for the relative number of plant taxa in a landscape to have a diversified landscape, a landscape should have a sufficient number of plant species in several plant families and genera to ensure genetic diversity. Tree inventories are especially helpful to determine the family and species composition of a landscape/area.

Study Questions

12. Why is species diversity important to the health of a landscape?

Answer: 12 - To broaden the genetic profile of plants so that prevailing insults (e.g., diseases, insects, and storm damage) will only affect a minor portion of the landscape.

Hardiness

Hardiness refers to a plant's ability to withstand low winter temperatures and remain aesthetically pleasing. Plant hardiness is an especially important concept to understand because lack of this understanding can result in some very costly plant use mistakes.

USDA Plant Hardiness Zone Map

USDA Plant Hardiness is a rating system of the average annual minimum temperatures of all counties in the United States. Counties of similar average annual minimum temperatures are combined into zones, as shown on the USDA Plant Hardiness Zone Map; see **the 2012 version at http://planthardiness.ars.usda.gov/PHZMWeb/**. The zone designation refers to the **average annual minimum temperatures** of a particular area. Minimum winter temperatures for all U.S. counties are determined by averaging the annual minimum temperatures recorded from 1976 to 2005 (29 years). **The map divides the U.S. into 13 zones, zone 1 is the coldest and zone 13 is the warmest, with each zone designating a 10° F range of minimum temperature.** For example, the average annual minimum temperature range for zone 6 is 0 to -10° F; the range for zone 7 is 10 to 0° F. **Each zone is equally subdivided into two parts, a colder part (designated by the letter a) and a warmer part (designated by the letter b)**. For example, the temperature range for zone 6a is -5 to -10° F, and the range for zone 6b is 0 to -5° F. Each zone of the map is color coded and the "a" portion of each zone is a lighter shade of that zone's color and the "b" portion is a darker shade of that zone's color. For

example, zone 6 is green, and 6a is dark green and 6b is medium green.

A copy of the USDA Plant Hardiness Zone Map (national) and a hardiness zone map of Virginia can be found as a color insert to the Handbook.

Each woody landscape species has a designated hardiness rating. These ratings may vary depending on the source of the plant information. Redbud (*Cercis canadensis*) has a plant hardiness rating of zone 4 to 9 (often designated by 4 – 9). The first part of this rating (the number 4) refers to the lowest temperatures this species can tolerate (zone 4; -20 to -30° F). The second part (the number 9) refers to the highest temperatures that this species can tolerate. Thus, one can successfully grow redbuds from zone 4 through 9. The hardiness rating of fraser fir (*Abies fraseri*) is 4 to 7, and will perform poorly in zone 8 (and even in zone 7b) due to this fir's lack of heat tolerance (and other heat-related aspects). The American Horticultural Society (AHS) has devised the AHS Heat Zone Map (http://www.ahs.org/gardening-resources/gardening-maps/heat-zone-map) which designates 12 zones, and each zone indicates the number of "heat days" (days with temperatures higher than 86° F) that occur for a zone. While heat zone designations are not as well published as the USDA Plant Hardiness Zone ratings, they are becoming more widely used with time.

Of course, the USDA Hardiness Plant Zone designations are a guide and not an exact tool to rate plant temperature response since plant hardiness is a complicated phenomenon. Factors that are involved with the hardiness of a particular species are the prevailing weather conditions for a particular year, and how established (penetration of roots from root ball into surrounding soil) a plant is following transplanting. In terms of weather, the minimum temperatures and how long these temperatures persist, and how the onset of cold weather proceeds can affect a species' tolerance to low temperatures. In some years, woody species have been damage when there is a mild fall that is followed uncharacteristically low temperatures. In this case, the plants did not gradually acclimate to low temperatures, and did not achieve the necessary degree of hardiness. Late spring frosts are also damaging to some species. In 2007, unseasonably warm weather in March was followed by an early April record or near record low temperatures (https://academic.oup.com/bioscience/article/58/3/253/230872) and many woody species that had initiated bud swell and leaf emergence in March suffered serious stem and trunk damage or were killed in early April. Japanese maples and crape myrtles, commonly used in landscapes, were especially hard hit. So, in addition to the minimum temperature, the manner in which low temperatures prevails has a major influence on plant hardiness. Soil moisture conditions will also affect winter hardiness. In a relatively dry fall and winter, foliage of evergreens (conifers and broadleaved) will experience significant leaf damage. Excessive soil moisture can also negatively impact plant hardiness. Again, plant hardiness is not only related to low temperatures but is the result of interacting factors. The degree of establishment (the amount of root penetration from the root ball to the surrounding soil) also affects winter damage. Plants that are not well established will be much less hardy then an established plant. Although not supported by research, I have witnessed this phenomenon many times.

Provenance

We already noted that the hardiness range of redbud (*Cercis Canadensis*) is zone 4 to 9. In terms of a natural population, we can expect that redbuds, and most other woody plants, in the most northern parts of its population will have the genes to tolerate zone 4 winters (-20 to -30° F). Redbuds, and most other woody species, from the southern portion of its hardiness range will have genes to tolerate the relatively high summer heat of the southern U.S. Seed collected from the southern part of the redbud population may not have the genes to tolerate the minimum winter temperatures in zone 4. Conversely, plants from zone 4 will most likely not have the genes to tolerate the heat of zone 9. Thus, when procuring plant material, the source of the plant material may be an important consideration. The term to describe the geographical source of plants (and other entities) is called **provenance**.

Historic Lows

Remember that the USDA Plant Hardiness Zone Map is based on **average annual minimum temperatures** and were calculated by averaging minimum annual temperature collected over the 29 years that data were recorded. Since the low temperature for any one zone is an average, the possibility exists that the low temperature for any one winter may be lower than the zone indicates. For example, Blacksburg, Virginia is in zone 6b; the USDA Plant Hardiness Zone Map notes that the average minimum temperature range for zone 6b is 0 to -5° F. In fact, the record low for Blacksburg is -18° F (January, 1985). Several zone 6b woody species (and most zone 7a plants planted on a gamble) were killed in January 1985. Thus, knowledge of the historical low temperatures for a

particular area you are landscaping is important to ensure that woody species are selected to survive the extreme low temperatures. This is especially important if you are planting numerous individuals of one species. Keep in mind that the use of hardiness zone ratings is a guide and not an exact science.

Hardiness of Plant Parts

Not all plant parts are equally hardy. **The root system is the least hardy portion of the entire woody plant**. Since roots are insulated by the soil (winter root zone soil temperatures are generally warmer than ambient air temperatures), root zone temperatures are usually not a consideration for landscape plants. However, if one is overwintering container-grown woody plants without protection, or in the case of a roof-top garden, then low temperatures and root hardiness should be taken into consideration.

The temperature that roots will tolerate is species specific. For example, roots of flowering dogwood (*Cornus florida*) are killed at 20° F, whereas roots of white spruce (*Picea glauca*) are killed at -10° F. **There is a rule of thumb for unprotected container-grown plants that prescribes that one must select a species with a hardiness zone rating that is two zones lower than the zone you are in for the roots to tolerate the low winter temperatures.** Thus, one should select a zone 4 species to survive as a container-grown plant in zone 6. Nursery growers in many parts of Virginia overwinter container-grown plants by covering plants in plastic blankets or in plastic-covered hoop houses; such coverings trap ground heat and maintain root zone temperatures above the ambient outside temperatures. There are websites that list root killing temperatures for many woody plant species.

The above ground portion of a woody plant, the shoot system (leaves and stems), gradually acclimates to lower temperatures in the fall with the onset of low temperatures and progressively short periods of daylight. Parts of the shoot system vary in their low temperature tolerance. **Woody plant *flower* buds are usually less winter hardy than *vegetative* buds (produce leaves and stems) and stems.** Thus, low winter temperatures may injure or kill flower buds, but not affect vegetative bud and stems. A classic example of this phenomenon occurs in bigleaf hydrangea (*Hydrangea macrophylla*). Listed as a zone 6 to 9 species, bigleaf hydrangea flower production in zone 6 is commonly less than in zone 7 because typical zone 6 winter temperatures kill the flowers buds which were produced in the summer prior to the year they flower. Unless the minimum winter temperatures are relatively high in zone 6, very few if any bigleaf hydrangea flower buds will survive the winter; even stems are commonly killed in typical zone 6 winters. In response to this zone 6 flowering problem with bigleaf hydrangea, cultivars of *Hydrangea macrophylla* have been selected that flower on new wood (to be discussed) and will flower in the summer even after a low temperature winter.

Microclimate

In any county, city, neighborhood, or area around a house/structure there may be areas that have minimum and maximum temperatures that are atypical for that area's designated hardiness zone. Slope, altitude, compass orientation, proximity to water or a building, the amount of pavement and buildings, overhead canopies such as trees and arbors are some of the aspects that will influence temperature. Zones of atypical high or low temperatures are called **microclimates**. Knowledge of these microclimates will influence how you choose species according to hardiness zones for these areas. For example, since cold air is heavier than warm air, cold air moves down a slope, and air at the bottom of the slope would be colder than the temperature of air at top of the slope. Knowing microclimates that are warmer than your zone (such as a protected location on the south side of a house or under an arbor), will allow you to successfully grow a species that is not typically hardy in your zone.

Study Questions

13. What criterion is the USDA Plant Hardiness Zone Map based on?
14. Which zone has the highest (warmest) average annual minimum temperature range: 6a, 6b, 7a, 7b?
15. True or false: Plant hardiness is only related to the average annual minimum temperatures.
16. What is the least hardy portion of the entire woody plant?
17. What is the least hardy portion of the above ground portion of a woody plant?
18. You want to keep a container-grown woody plant outside all winter long in Zone 7. So, you should choose a Zone __ species so that roots will not be

killed by the winter ambient air temperatures.

19. True or false: A "warm" microclimate around a structure in zone 7 may allow you to successfully grow a Zone 8 species in that microclimate.

13 - Average annual minimum temperatures; 14 - 7b; 15 - False, it is related to several factors; 16 - Roots; 17 - flower buds; 18 - Zone 5 or lower; 19 - True

Flower Buds and Pruning

A **bud** is a small package of partially preformed tissue which becomes leaves/stems or flowers. In some cases, buds contain partially preformed flower tissue (**flower bud**), and usually have a different appearance than a **vegetative bud**, a bud that contains partially preformed leaf and stem tissue. Some buds contain both floral and vegetative tissues. The time of year that flower buds are produced on woody plants will dictate the time of pruning, thus it is important to know whether a species flowers on "old wood" or "new wood".

Flowering and Pruning of "Old Wood" and "New Wood" Species

The majority of woody plants flower on "**old wood**" during the spring or early summer. This means that the flower buds of spring or early summer-flowering species were produced on stems in the year prior to flowering. For example, rhododendrons (*Rhododendron* spp.) that flower in spring produced their flower buds about 10 months earlier in the summer of the prior year. **Therefore, prune spring-flowering shrubs right after they finish flowering; pruning spring flowering shrubs in the summer, fall, winter, or early spring removes flower buds and results in a poor or lack of flower display the following spring.**

In general, spring-flowering and early summer species flower on one-year-old stems; thus, flowering occurs on the outermost portions of the plant. Some shrub species, such as lilacs (e.g., *Syringa vulgaris*) and forsythia (*Forsythia ×intermedia*), require the removal of the larger, older stems on an annual basis to encourage the production of younger, flowering wood. Removing older branches results in the growth of new stems that produce more flowers compared to the amount of flowers produced large, old stems.

Summer-flowering species produce their flower buds on "**new wood**". This means that the flower buds of summer-flowering species were produced on stems during the spring/summer in the same year that the plant bears flowers. For example, crape myrtles (*Lagerstroemia* spp.) that flower in the summer produced their flower buds a month or two prior to flowering. **Plants that flower on new wood can be pruned late in the growing season (after they finished flowering, during the fall, winter, and early spring since the stems removed during these times will not have any preformed flower buds on them.**

Study Questions

20. True or false: A plant that flowers on "old wood" typically flowers in mid to late summer.

21. A plant that flowers on "old wood" should be pruned: right after it flowers OR later that summer?

22. True or false: A plant that flowers on "new wood" produces its flower buds in the same year as it produces flowers.

Answers:
20 - False; 21 - Right after it flowers; 22 - True

Plant Sex

Woody species can be categorized relative to the sex of flowers they produce. If a species produces plants with both male and female flower parts on them (either both sexes in a single flower or separate male and female flowers on the same plant), then that species is termed monoecious (literal translation: "one house"). The majority of woody species are monoecious. If a species has plants that only produce female flowers or plants that only produce male flowers, then that species is termed dioecious (literal translation: "two houses"). Dioecious species require both male and female plants in close proximity to produce fruit/seed. Ilex verticillata (winterberry), a dioecious species, is a popular woody landscape species due to its abundance of showy fruit, and a male plant must be nearby to fertilize (pollinate) female plants for fruit production. If one has a dioecious plant and it has not set fruit, then it may be a male (fruitless by design), or it may be a female with no male in the vicinity. In some cases, a female will produce fruit without sexual fertilization, and this is termed parthenocarpy. There are several popular landscape taxa

that are parthenocarpic such as *Ilex* ×'Nellie R. Stevens' and *Ilex cornuta* 'Burfordii'.

Study Questions

23. Define monoecious and dioecious.

24. Define parthenocarpic.

Answers: 23 - Monoecious means there are both sexes on the same plant. Dioecious means that there are separate sex plants.; 24 - Parthenocarpic means that sexual fertilization is not necessary for fruit set to occur.

Woody Plant Categories

Woody plants can be categorized in several different ways. Three categories, organized by growth habit and foliage type, are;

* Deciduous trees, shrubs, groundcovers, and vines (angiosperm trees that lose their leaves in the fall)
* Broadleaf evergreens trees, shrubs, groundcovers, and vines (angiosperm species that retain foliage in throughout the year)
* Conifers (gymnosperms, mostly evergreen but there are notable deciduous species, that have needle, scale-like, or awl-like foliage)

Briefly, angiosperm species have true flowers. Gymnosperms bear naked seeds in cones and modified cones.

Woody Plant Sizes and Growth Habits

Woody plants are characterized by their height and growth habits. Size characterizations are somewhat arbitrary designations, however, they are useful categories for landscape design and plant selection.

Trees, Shrubs, Groundcovers, and Vines

Trees have single or multiple trunks (usually three or less). Mature trees sizes are:

* **Small trees 15 to 25 feet tall**
* Medium trees > 25 feet to 50 feet tall
* Large trees > 50 feet tall

From a functional perspective, small trees can be distinguished from medium and large trees; medium and large trees are generally not differentiated in landscape use since they are both used in areas that require larger scales or in larger areas. Small trees can be used in relatively small areas or anywhere the scale of the surroundings requires or can accommodate a tree less than 25 feet tall (e.g., courtyard and small residential landscape property). A careful determination of the available volume of space and proximity to other landscape or residential features will dictate the appropriate tree size for an area.

Shrubs typically have multiple trunks (usually more than three). Mature shrub sizes are:

* Small shrubs ≤ 5 feet tall – also considered as a groundcover when less than 3 feet tall
* Medium shrubs > 5 feet tall to 9 feet tall
* Large shrubs > 9 feet tall

As with tree sizes, shrub size should be used to match the existing volume of landscape space to be occupied by plants.

The distinction between a small tree and a large shrub is somewhat arbitrary. Many species, such as cornelian cherry dogwood (*Cornus mas*) for example, can be considered a large shrub or a small tree depending on how it is pruned. An unpruned multi-stem corneliancherry dogwood is shrub-like, however, if one removes the lower branches and some of the multiple trunks, it will look like a small tree. Thus, plant size and category classifications are open to interpretation and affected by pruning.

Groundcovers generally have a horizontal growth habit and are less than 3 feet tall.

Vines, due to their relatively supple young stems, are shrubs that are unable to sustain an upright habit unless they grow on an upright structure. Many vine species can grow as tall as the structure they cling to. In the absence of a structure, a vine will grow on the ground in a prostrate or mound fashion.

Vines have three modes of attachment. They adhere to a structure by:

1) twining (stems wind around a structure or matrix, e.g., *Wisteria floribunda*)

2) rootlets (stems have adventitious roots that attach to a

structure, e.g., *Hedera helix*)

3) tendrils (modified stems that attach to a structure by twining or holdfasts, e.g., *Parthenocissus quinquefolia*).

Vines with rootlets and tendrils (with holdfasts) can grow up a wall (or other vertical surface) since rootlets and tendrils adhere firmly to a surface. Vines that twine will not grow on a wall unless there is a lattice or some other matrix for it to cling to. All vine types can grow up trees regardless of climbing mode.

Factors Affecting Plant Size

Plant size is affected by a plant's genetics and the environment. In terms of the environment, available resources such as water, light, and nutrients, as well as site-related conditions (e.g., soil, climate, competition, pest pressure, and human impacts) greatly influence plant growth. Also remember that within a population of any plant species, there will be a great amount of variability in plant characteristics such as height, width, leaf size, and flower, and fruit characteristics due to genetics. In terms of mature height, one may find individuals that are much taller or shorter than the average individual. Thus, ascribing a plant size, e.g., small tree or medium tree, to particular species is less than precise. For example, American hornbeam (*Carpinus caroliniana*) is generally categorized as a small tree with a mature height of 20 to 30 feet tall. Our definition of a small tree is 15 to 25 feet tall, so one can see that occasionally this species can be classified as a medium tree. There are American hornbeams that are 65 feet tall; by definition such a tree would fall into the large tree category. Such atypical plants may be growing in an ideal site and/or may have the genetic capacity for taller than average height.

Plant Size and Landscape Use

Woody plant size is a very important aspect because one of the most common landscape design/plant installation mistakes is to design/install a species that will grow outside its intended volume of space. Pruning, while a necessary component of tree care, is a generally an ineffective remedy for this mistake (since size-limiting pruning will need to be continually repeated); additionally, it is also time consuming, costly, and creates plant debris which then creates debris disposal issues. In some cases, pruning is not a viable option since the required pruning will significantly distort the tree/shrub form. Trees placed too close to a structure can pose a significant liability when they mature, since limbs/trunks have the potential to fall and damage a structure during snow, ice, or wind storms. Tree pruning/removal is very expensive; so, one must be very careful in designing/placing trees next to structures.

Study Questions

25. What is the size designation for a small tree?
26. True or false: Medium and large trees can be considered as having the same landscape function in terms of size.
27. Which mode of attachment requires a trellis or some other matrix in order for a vine to climb a wall?
28. Why is woody plant mature size a very important consideration?

Answers: 25 - 15 to 25 feet tall; 26 - True; 27 - Twining; 28 - One of the most common landscape mistakes is to plant a plant that grows outside of its intended space; this then results in frequent pruning or plant removal.

Growth Rate

Woody Plant Growth Rate Categories

Woody plants are categorized into three growth rate categories. These are:

Slow	less than or equal to 12 inches per year
Moderate	13 to 24 inches per year
Fast	greater than or equal to 25 inches per year

Woody plant growth rate is an aspect that impacts 1) maintenance, 2) placement/spacing of plants, and 3) how slowly or quickly a plant will fill its intended space in the landscape. Most species have a moderate growth. A fast-growth rate can be an asset if one is planting a row of small plants for a privacy hedge, or can be a liability if one has to prune to control plant size or density. As noted for plant size, growth rate is not only dictated by plant genetics, but also by available resources such as water, light, and nutrients, as well as site-related conditions (e.g., soil, climate, competition, pest pressure, and human impacts).

Conifer Growth Rates

Conifers are best described by their growth rate and NOT by a mature size since mature size designations are generally not accurate. The American Conifer Society (http://conifersociety.org/conifers/conifer-sizes/) has published the following categories, growth rates, and approximate size (height and/or width) of conifers.

Conifer Growth Rates

Category	*Growth per year (inches)*	*Approximate size at 10 years (feet)*
Miniature	<1	<1
Dwarf	1 - 6	1 - 6
Intermediate	6 - 12	6 - 15
Large	>12	> 15

A dwarf conifer, usually a cultivar of a conifer species, has a slower growth rate than the species. Dwarf conifers are valuable components of a woody plant palette since they offer numerous options of using plants with a variety of sizes, forms, textures, and colors in space-restricted landscapes.

Study Questions

29. What are the growth rate designations (feet per year) for slow, medium and fast-growing woody plants?

30. What is the most accurate way to describe the size aspects of a conifer?

Answers:
29 - Slow = < 1 foot per year; Medium = 1 to 2 feet per year; Fast = > 2 feet per year; 30 - By growth rate

Functions of Woody Plants

Woody plants serve aesthetic, architectural, and environmental functions. They also serve specific landscape-related functions.

Aesthetic Functions

Woody plants can have attractive foliage, flowers, fruits, bark, and/or form throughout the year. Because woody plant shoots (stems/trunks) persist in the dormant season, in contrast to most herbaceous plants, characteristics such as branch/trunk structure (form/habit), bark, fruit, and foliage in the case of evergreens (broadleaf and conifers) serve to beautify the landscape when plants are dormant.

The visual characteristics of plants, size, form, color, and texture, are like paints on an artist's palette. Thus, as an artist selects different colored paints to compose a picture, one who selects woody species for a landscape design does so by choosing plant sizes, forms, colors, and textures as manifested by trunk/ branch configuration, bark, foliage, flowers, and fruit characteristics. There are limitless combinations of size, form, color, and textures that will make a landscape attractive for 365 days a year. Because plants are ever-changing throughout seasons and years, the landscape "picture" is dynamic as well.

Plant size and form has a very large impact on where a plant can be grown and how it is used in the landscape. Plant size, as previously discussed, will impact where a species can be placed in the landscape. Large trees, by virtue of their mass, are visually dominant structures in the landscape. Most trees and shrubs have an oval or round form. Some trees can have a **weeping/pendulous** form (branches hang down), a **fastigiate** form (narrow oval), or a **columnar** form (column-like). Some deciduous trees and many conifers (especially in their youth) have a **conical or pyramidal** form. Tree form also influences how one perceives the landscape. In general, round and oval forms have a neutral effect on the eye; conical, fastigiate, and columnar forms bring the eye skyward; pendulous forms bring the eye to the ground plane.

Other sensory aspects are involved in woody plant selection such as smell (e.g., flowers), taste (e.g., fruit), and movement (e.g., leaves fluttering, flower petals falling).

Architectural Functions

Woody plants serve important **architectural functions** in the landscape. Woody plants give a landscape structure, and are likened to the backbone of landscape. **Trees, shrubs, and groundcovers serve as the ceilings, walls, and floors of outdoor spaces**. They also serve to frame views and create outdoor rooms. In addition, woody plants can be pruned and trained to create structures such as walls, doorways, and architectural focal points such as topiaries.

Environmental Functions

Woody plants have numerous significant effects on the

landscape environment. While expounding on these effects is not the focus of this chapter, there are a few noted effects that you should know. **The shade of deciduous trees that are mainly placed on the southeast and southwest side of a structure can cool structures in hot months.** Trees for shade are generally not placed directly on the south side of a house since the sun is at a very high position in the sky at midday, the time at which the sun is due south of a structure. The sun's high position means that a shade tree would have to be very close to a structure to provide shade, and this close placement would be a potential hazard in the event the tree fell on the house. **Evergreen trees/shrubs placed on the northwest side of a structure can prevent heat loss from a structure in cold months by acting as a wind break.**

Woody plants also reduce noise, pollution, runoff, and soil erosion. They serve as wildlife habitats, and can produce food for households (e.g., blueberries, apples, and serviceberries). Of course, trees and shrubs have a marked social effect on humans as noted by their presence and affects in parks, botanical gardens, cemeteries, urban green spaces, and natural areas.

Specific Landscape Uses of Plants

In addition to the previously mentioned architectural and environmental functions, plants are used in the landscape for numerous functions related to various landscape design reasons. These uses are overlapping and are not exclusive to each other. For example, a hedge can function as a border and a barrier. These are the main specific landscape uses of plants:

* **Accent plant(s)**: a plant or plants that are used to add emphasis, draw attention to, or compliment another plant, structure, art work, or any other landscape feature.
* **Barrier**: a row (linear or curvilinear) of plants that separate one area from another and impedes movement (e.g., human, pets)
* **Border**: a row (linear or curvilinear) of plants that separate one area from another
* **Foundation plant(s)**: Use of species or more than one species (usually evergreen) to 1) hide the view of an undesirable sight such as the foundation of a house, or 2) give a structure or landscape element a "base" to avoid the stark transition of the ground with the structure.
* **Hedge**: a living fence to separate areas either for barrier or border functions
* **Massing/Grouping**: use of many plants, usually of a single or two species, to 1) collectively emphasize the features of the species (e.g., form flowers, fall foliage color), 2) to give a natural appearance, 3) create a border or barrier
* **Screen**: plants used to screen a view/object or to provide privacy.
* **Specimen plant: a plant that is featured by itself (or with smaller plants around it) to act as a focal point in the landscape. A specimen plant has sufficiently notable characteristics (e.g., size, form, color, and texture via trunks/stems, foliage, flowers, and fruit) that warrant its use as a focal point.** A plant may be a focal plant 12 months a year, such as a Japanese maple in a courtyard, or for part of a year such as in the case of a conifer amongst deciduous plants; the conifer will be most evident and have a strong visual impact in winter months when deciduous trees are leafless.

Study Questions

31. What are the architectural functions of woody plants?
32. What side of a structure are deciduous trees placed to shade that structure?
33. What side of a structure are evergreen plants placed to serve as a windbreak during the winter?
34. What is a specimen plant?

Answers:
31 - woody plants serve as ceilings, walls, and floors; 32 - Mainly the southeast and southwest sides; 33 - Northwest; 34 - A plant that is featured by itself (or with smaller plants around it) to act as a focal point in the landscape.

Choice of Nursery Stock

Most woody plants purchased at garden centers are sold either as container-grown plants or as balled-and-burlapped, commonly called B&B, plants.

Container-grown Plants

Most shrubs, groundcovers, vines, and young trees are produced and sold in plastic containers with a pine

bark-based potting soil. The advantages of container-grown plants are:

* **Have 100% of an intact root system**
* Convenient to transport
* Relatively light weight

There are two disadvantages of container-grown plants:

* **The pine bark potting soil only holds about a one to two day water supply for the plant**
* **Plants can become root bound**

Relative to the water reservoir capacity of the pine bark, a container-grown plant must be watered daily or every other day (depending on plant water use and weather conditions) during the growing season (or until the root system has grown into the surrounding soil and can support itself without supplemental irrigation). A way to avoid this frequent irrigation of container-grown plants is to plant them in the fall when plant water needs are greatly reduced. Of course, most landscape plants, newly planted or established, will need some degree of irrigation during drought periods.

If a container-grown plant has become root bound (solid mass of circling roots on the perimeter of the root ball), then the plant has stayed in that container too long. This is an undesirable situation since roots most species cannot escape this circular entanglement. In some cases, roots can be pried, teased, or cut from the root ball to encourage growth into the surrounding soil.

Balled-and-Burlapped Plants

Balled-and-burlapped plants are grown in the field. They are then machine-dug and lifted out of the soil. The somewhat round root ball is then covered with burlap (and sometimes with a wire cage) to keep the root ball intact. While some balled-and-burlapped plants are sold in retail garden centers, most of these plants are used in the landscape contracting trade and are planted by landscape contracting company personnel.

Advantages of balled-and-burlapped plants are:

* A less intense production system compared to container-grown plants
* **Root system is surrounded by mineral soil that retains water for long periods and when planted requires irrigation only about once a week**
* Relatively large trees are available via the balled-and-burlapped system

Disadvantages of a balled-and-burlapped plant are:

* **Approximately 80+ % of the root system is removed**
* **Plants take three years to recover from root severance**
* **Root balls are very heavy; transporting and planting are relatively labor intensive compared to transporting and planting container-grown plants**

Regardless of woody plant growing/harvesting system (container vs. balled-and-burlapped), adequate irrigation of recently transplanted plants is extremely important for plant survival. In both systems, one should apply enough water to wet the root ball and very little of the surrounding soil; most mineral soils are very moisture retentive. Applying excessive irrigation (an amount to wet root ball and surrounding soil) can keep the soil around the root ball too wet and this can discourage root growth into the soil; this is especially true for soils with a relatively high clay content.

Study Questions

35. In terms of nursery stock to be planted in a landscape, what is the number one advantage of a container-grown plant?

36. In terms of nursery stock to be planted in a

landscape, what are the two major disadvantages of a container-grown plant?

37. In terms of nursery stock to be planted in a landscape, what is the number one advantage of a balled-and-burlapped plant?

38. In terms of nursery stock to be planted in a landscape, what are the three major disadvantages of a balled-and-burlapped plant?

Answers:
35 - The plant has 100% of its root system ; 36 - 1) Following transplanting, plants have to be irrigated every one to two days during the growing season. 2) Plants may be root bound
; 37 - The root ball has a very high water holding capacity and thus does not need to irrigated very frequently (compared to a container-grown plant); 38 - 1) At least 80% of the root system has been removed; 2) the plant takes three years to overcome the root loss; 3) Plants are very heavy which makes plant transport and planting difficult.

Right Plant for the Right Place

One of the biggest challenges dealing with woody plants is to determine the appropriate species for a landscape. The inappropriate selection of woody plants has major consequences such as:

* Increased cost, time, and effort in woody plant maintenance
* Potential hazards from trees/tree parts falling on people, property, and structures
* Potential hazards from species with thorns or poisonous plant parts
* Incurring major costs of removing trees that pose hazards, are prone to storm or pest damage, or are not suited to the landscape

Steps to Select the Right Plant for the Right Place

There are four steps to choose the right plant for the right place. Following these steps will help you create a beautiful, functional, and environmentally sound landscape.

Step 1. What are the functions and themes of the areas of your landscape?

For example, lawn for recreation, shady area with arbor for relaxation, sunny area for vegetable garden, beds next to a house for foundation plants, and beds near property border for privacy planting. These functional aspects will dictate whether trees, shrubs, groundcovers, or vines are needed. You should also consider the theme of your landscape. Is your area to be more natural or more formal? Formal landscapes usually have a linear and/or modular design and utilize species that are have a distinct symmetry (or are pruned to be symmetrical). Conversely, natural landscapes tend to have curvilinear design and utilize species that are less symmetrical.

One must take into consideration the mature size of trees for four reasons. 1) Trees will ultimately occupy a much larger volume than the initial planting and thus may grow into areas occupied by other plants or structures. 2) Trees will cast a considerable amount of shade to the south, southeast, and southwest and may impact plants that require a full or near full sun exposure such as lawns and conifers. 3) As trees grow the amount of leaf and other plant part litter (e.g., pollen, flowers, fruit, and stems) greatly increases, hence maintenance greatly increases as well. 4) Tree roots can extend a considerable distance beyond the edge of the tree's canopy and can invade nearby septic or drainage systems. Tree roots will also very effectively compete with other plants for soil water and can render a soil quite dry. Once each area of the landscape has a designated function then proceed to the next step.

Step 2. What are the functions of the woody plants to be placed in the functional areas of your landscape?
Determine the specific aesthetic, architectural, environmental, and landscape functions (these topics covered earlier in the chapter) of the trees, shrubs, groundcovers, and vines to be placed in each area and proceed to the next step.

Step 3. What are the existing environmental conditions?
Important aspects to determine are:

* Soil texture, pH, and nutrient content
* Soil moisture aspects/slopes and low areas
* Sun and shade areas
* Wind paths
* USDA Plant Hardiness Zone
* Prevalence of deer and other vegetation-destroying

animals

* Existing plant species
* Access to irrigation
* Existing and future hardscapes, utility conduits and septic systems, warm air vents

Assessing these conditions will allow you to select the species that are suitable for the site to be landscaped.

Step 4. Combine information from steps 1, 2, and 3 to design the landscape and to choose the appropriate trees, shrubs, groundcovers, and vines according to the site conditions.

Woody plants vary greatly in terms of their size, form, texture, and color. They also vary greatly in their growth rate; soil, water, light requirements/tolerances; hardiness/high temperature; pest susceptibility; messiness; and invasiveness. **Thus, examination and determination of the step 3 environmental aspects (site conditions) will dictate the species that should be selected for a particular landscape site. Step 2 will dictate the plant category (tree, shrub, groundcover, and vine) choices.**

Study Questions

39. What are the four steps to select the right plant for the right place?

Answers:
39 - 1) Determine the functions and themes of the areas of your landscape. 2) Determine the functions of the woody plants to be placed in the functional areas of your landscape? 3) Determine the existing environmental conditions. 4) Combine information from steps 1, 2, and 3 to design the landscape and to choose the appropriate trees, shrubs, groundcovers, and vines.

Invasive Plants

The official U.S. definition of an invasive species is **"an alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health"** (1999 Invasive Species Executive Order). The invasive species topic is important and relatively controversial. A discussion of the topic is not warranted in this chapter; however, you may read "Invasive Plants – A Horticultural Perspective at http://pubs.ext.vt.edu/426/426-080/426-080.html for detailed information.

To determine if a plant is documented as invasive, the NatureServe website (http://www.natureserve.org/) contains specific information on numerous but not all invasive species. NatureServe uses an Invasive Species Assessment Protocol (http://www.natureserve.org/biodiversity-science/publications/invasive-species-assessment-protocol-evaluating-non-native-plants) to rank the invasiveness of plants. This protocol is an objective tool to determine the degree of invasiveness based on observations by trained individuals and does not rely on anecdotal reports. In the homepage of this website there is a species search box (right hand side of the page) to enter the name of the plant in question. The name of that plant (and related plants) will then be listed. Click on that name and if the plant is ranked by NatureServe, then you will see: **U.S. Invasive Species Impact Rank (I-Rank); click on Expand.** You will see the overall **impact rank** (I-Rank) that is derived from four criteria (subranks): 1) ecological impact, 2) current distribution/abundance, 3) trend in distribution/abundance, and 4) management difficulty. In the case that NatureServe does not rank for a species, then other state and regional websites can be accessed.

Caution should be used in interpreting the invasive status of a species for two reasons. 1) Invasiveness is often a regional phenomenon. A species that is invasive in one region does not mean it will be invasive in other regions. Invasive species in Florida is a good example. There are numerous invasive plant species in Florida because of Florida's mild climate. Most of these invasive species have very little chance of becoming invasive in the colder more northerly locations of the U.S. 2) A plant species may be invasive but its degree of impact on natural and human-mediated landscapes may be minor or major. For example, Japanese maple (*Acer palmatum*) is ranked as invasive but has a low/insignificant impact rank.

Study Questions

40. True or false: A weedy plant is an invasive plant.

41. What website has a comprehensive and objective invasive plant ranking system?

Answers:
40 - False. By definition an invasive plant must be alien (not native to an area) to be called an invasive plant.; 41 - NatureServe

Summary - Three Main Themes

In light of the topics discussed in this chapter, there are three themes that you should keep in mind as you choose woody plant species for your landscape. These are:

1. **Choose plant material with species diversity in mind**

2. **Choose plant material with year-round interest in mind**

3. **Have an appreciation for intraspecific variation**

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Herbaceous Landscape Plants

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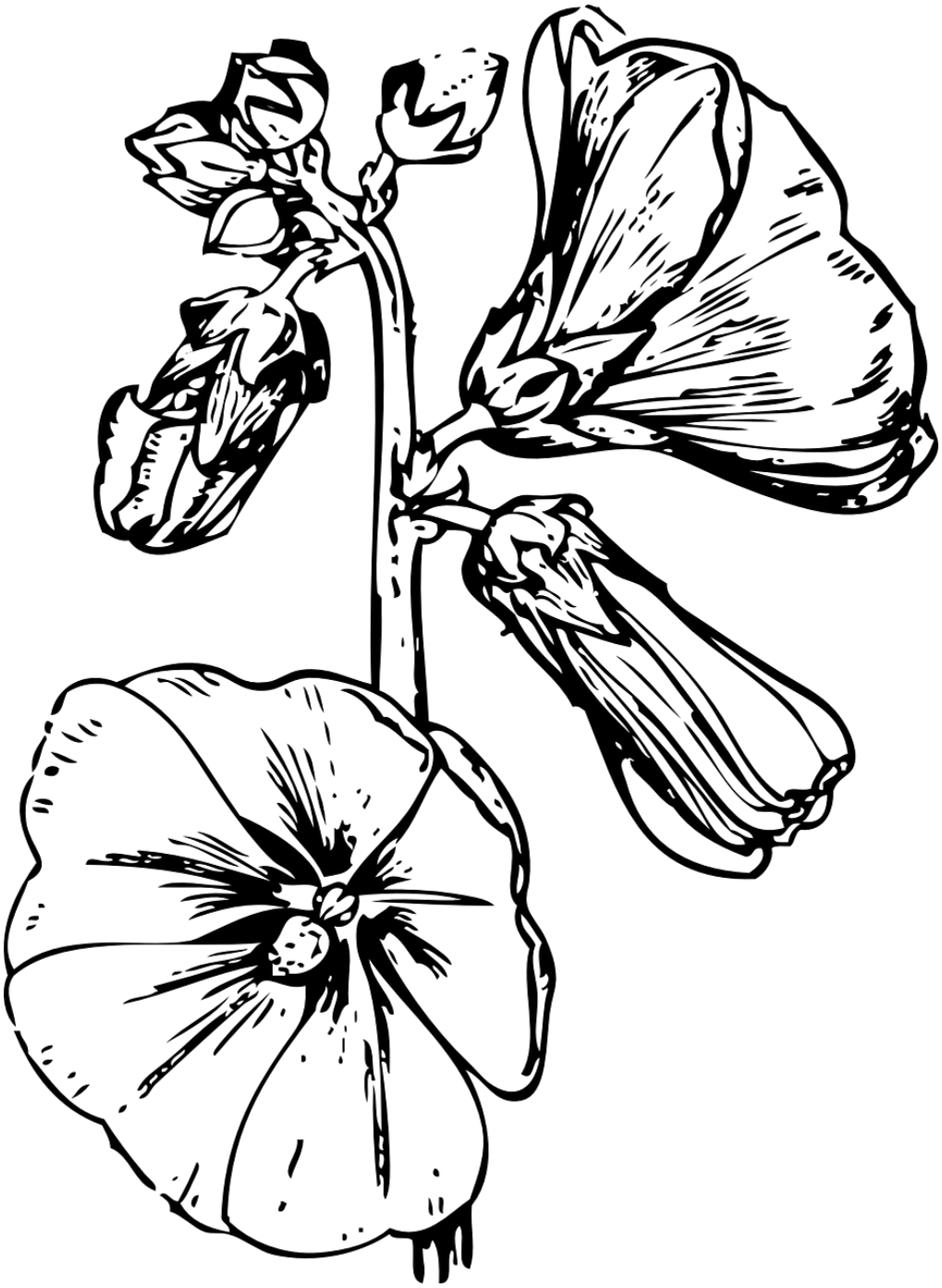

Herbaceous Landscape Plants

Chapter 17

Revised by *Holly L. Scoggins, Associate Professor, Horticulture (2015)*

Diane Relf, Extension Specialist, Horticulture (2009)

This chapter covers ornamental herbaceous plants in the context of the landscape – whether planted in the ground or used in containers and hanging baskets etc. See chapter 16 “Woody Landscape Plants” for detailed treatment of plant nomenclature. For an in-depth discussion of site selection and landscape design, visit chapter 18. We’re going to get straight to the plants!

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Introduction

If woody plants form the garden's framework, then herbaceous plants are the furniture and décor. From annuals to perennials, bulbs to grasses, herbaceous plants bring color, texture, and life to any garden or landscape. Many herbaceous plants also provide ecosystem services as part of a sustainable landscape – a technical-sounding term for benefits you're already familiar with – food source for pollinators, seeds and berries for birds and other wildlife, water and nutrient runoff mitigation, erosion control, removal of excess nutrients. Herbaceous and mixed (with shrubs and small trees) borders and plantings can provide both beauty and benefits beyond the typical home landscape of lawn and foundation shrubs.

Lawn, shrubs, trees, but no herbaceous plants: boring!

As we go through this chapter, think about the possibilities for expanding areas with herbaceous plants within your own garden and also recommending these plants and practices to others – part of your role as an extension master gardener. Also note this is written in context of the mid-Atlantic region.

Much better!

Types of Herbaceous Plants

What, exactly, is an herbaceous plant? Basically, any vascular plant that isn't woody; or if woody, the stems die back to the ground in the winter. Let's break that huge quantity of species down into something a bit more useful. Herbaceous garden plants can be divided up by life cycle and/or physiology.

Annuals

Not as straightforward as you might think. A true **annual** is something you can plant seeds of in the spring; it then flowers and sets seed (if not a sterile hybrid) before the growing season ends. Think "sunflower" (*Helianthus annuus*). However, we use the term annual for a lot of species that are actually perennial in their native environment - wherever that may be - they're just not cold-hardy in your particular location. Nurseries, garden centers, and landscapers will often lump these together under the term color. Another term is **bedding plants**, which encompass a wide variety of non-hardy, seasonal things like annuals, tropicals, herbs, vegetable transplants, etc. There are warm season and cool season annuals as well as those that do better is sun or shade. A vast palette of flower and foliage colors await the creative gardener - so many fun things for beds, hanging baskets

and containers! We'll talk more about annuals throughout this chapter.

Coleus are available in an array of colors and leaf shapes, perfect for sun or shade.

Perennials

Perennial simply means a plant lives for more than one growing season. Trees and shrubs are perennial. Orchids growing in southeast Asia are perennial. But for our purposes, **perennial** will mean "herbaceous perennial," and will refer to herbaceous plants that can tolerate freezing temperatures - a "hardy perennial" (hardy, not hearty!).

A joke I always make is that a perennial's duration of survival is in inverse proportion to the price paid at the garden center.

Most perennials die back to roots/crown each winter but some species may remain evergreen or semi-evergreen, depending on location. Most temperate perennials also require a certain amount of cold, in both temperature and duration, to survive and rebloom. The higher the USDA hardiness zone, (i.e. Zone 9 or 10) the fewer the number of temperate perennials that perform well. Classic perennials include Hosta, daylily (*Hemerocallis*), purple coneflower (*Echinacea*), etc.

There are countless lists available regarding the best perennials for different environmental conditions, as well as deer-resistant, pollinator-attracting, butterfly-friendly, etc. See "Made in the Shade" and "Sure Things for Sun" under the Additional Resources section at the end of this chapter for a few of my favorite and most reliable perennials for Virginia.

The best perennials, such as this native perennial sunflower (*Helianthus divaricatus*) provide color, beauty, and pollen and/or nectar for bees, butterflies, and other pollinators.

Is this perennial hardy or not?

USDA Plant Hardiness Zone Map

The United States Department of Agriculture's Agricultural Research Service (ARS) developed a map of the U.S. as a guide to cold hardiness for gardeners and farmers. The 13 zones are defined as the average of lowest minimum temperatures recorded for a 30-year period. Each of the 13 zones is further split into "a" (cooler) and " b" (warmer). First published in 1990, the map was updated in 2012 with GIS data, providing much more detailed information and revealing microclimates. The new map is online only, is searchable by zip code or one can browse through and zoom in on specific region or state.

The commonwealth of Virginia has a wide range of hardiness zones, due to our "sea-to-mountains" topography. Virginia Beach has the same hardiness zone (8a, 10° to 15° F) that stretches down the coast of the Carolinas and across central Georgia and Alabama. The piedmont region is rated Zone 7; 7b east and south of Richmond, 7a west across central VA. As the elevation

increases, the hardiness zone gets lower. The Blue Ridge and Allegheny mountains are mostly Zone 6b or 6a, with a few spots of 5b at the highest elevations. So while Canna and elephant ears (*Colocasia*) may be reliably perennial in Suffolk, they probably will not survive the winter in Winchester.

These zones are referenced in gardening books, plant catalogues, and on plant tags and labels in order to help gardeners select plants appropriate to there growing area. Again, these zones are defined as average annual extreme minimum temperature - for example, in Zone 6b, -5° to 0°F, it may not reach that low every year (or could drop even lower!). Also keep in mind that cold hardiness is only one of many factors to impact herbaceous plant performance. Proper temperature acclimation, amount of light, soil moisture (too much or too little can be problematic), humidity, and heat tolerance all determine whether your plants thrive or not. You can find the hardiness zone maps at the end of Chapter 16.

Reference: USDA Plant Hardiness Zone Map, 2012. Agricultural Research Service, U.S. Department of Agriculture. Accessed from http://planthardiness.ars.usda.gov.

Perennials - resources

Armitage, Allan M. Herbaceous Perennial Plants: A Treatise on Their Identification, Culture, and Garden Attributes. Champaign: Stipes, 2008. Print.

DiSabato-Aust, Tracy. The Well-tended Perennial Garden: Planting & Pruning Techniques. Portland, Or.: Timber, 2007. Print.

Biennials

A biennial possesses a unique herbaceous lifecycle - vegetative growth occurs the first year; the next, it flowers and sets seed. The cold of winter in between serves to vernalize the plants, triggering the reproductive phase. For some plants, the vegetative phase is desired – herbs and leafy vegetables such as parsley, spinach, and lettuce. The flowering stage is called **bolting**. Ornamentals such as some (but not all) of the foxgloves (*Digitalis*) and hollyhocks (*Alcea*) produce flowers during the second growing season, so planning ahead is required if growing them from seed. If happy with the garden site and situation, many biennials will freely reseed around.

Beyond classifications based on life cycle (annual, perennial, and biennial), there are plenty of other herbaceous plant categories as well.

Tropicals

This refers to plants that, for lack of a better description, invoke that "tropical feeling" – broad or lush foliage from species we associated with tropical climes such as banana (Musa and Ensete), elephant ears (Colocasia, Alocasia), bamboo (Phyllostachas and many others), Canna and many more.

There are a few hardy species in each of these genera; however will not survive beyond Zone 8 or 9. The upside is they all grow rapidly if treated well (plenty of water and fertilizer), making a wonder show for the season. Bananas and elephant ears can be lifted and overwintered as house plants. You may also allow the foliage to be knocked back by frost or freeze then cut back the tops; lift the roots or tubers and store in a cool garage or basement. Plant into beds or containers after the threat of frost has passed.

Geophytes

Geophytes are herbaceous plants with underground storage organs, rather than fibrous root systems. Often lumped together under the term **bulbs**, these storage organs can also be corms, tubers, rhizomes, or other structures. These organs contain reserves of carbohydrates, nutrients, and water. Geophytes typically undergo a dieback or **dormancy** period, which varies depending on season of bloom.

Knowing when the geophyte blooms is key to knowing when to plant them, as well. Many summer-blooming geophytes such as Dahlia and hybrid gladiolus are not

cold hardy and should be planted in late spring after all danger of freezing has passed.

Spring-blooming geophytes include those icons of spring: Crocus, tulip (*Tulipa*), and daffodils (*Narcissus*). Spring bloomers are generally cold-hardy perennials, so are purchased and planted mid to late autumn. Just like holiday décor, spring bulbs are starting to show up in stores earlier and earlier – even in August. Do not plant until the weather is reliably cool and soil temperatures below 50 F. Never store purchased bulbs in the fridge – many veggies and fruit give off ethylene, which will damage the developing flower.

Types of geophytes

Bulbs

Includes those most popular of spring-blooming geophytes: tulips, daffodils, grape-hyacinth (*Muscari*), and many more. The bulb itself is made of modified leaves or scales, with a compressed stem and a basal plate where roots emerge (picture an onion). Once the flower has senesced (petals dropped off), the foliage persists for several weeks and then eventually declines, turning yellow or brown. This next bit of advice goes for ALL hardy geophytes: if you want the bulb to flower again next year, leave the foliage in place for as long as you can stand it. The photosynthetic process taking place in the leaves is putting critical carbohydrates back into the storage organ. Once the foliage is no longer visible, the bulb is not dormant! Floral primordia are forming through out the summer and autumn.

Corms

Storage structure is a modified stem with a basal plate – described as "solid bulbs." Spring blooming (hardy) corms include Crocus; the summer bloomers include Gladiolus, Freesia, and Ixia.

Tubers

Thickened underground stem with no basal plate. Tubers such as Caladium have eyes (potatoes are tubers as well). **Eyes** are meristematic tissue from which roots and shoots emerge (like those potatoes that have been in the bin too long).

Tuberous roots

Thickened root tissue; growth arises from buds at the top (crown) of the root mass . A piece of the crown must be included in any divisions. Includes *Dahlia*, *Anemone* x *coronaria*, and *Ranunculus*.

Rhizomes

Modified stems that grows horizontally at or below the soil surface. Rhizomatous perennials include German (bearded) Iris, lily-of-the-valley (*Convallaria majalis*), *Calla*, and *Oxalis*.

Enlarged hypocotyl

Sounds painful, but the storage organ is simply the swollen portion of the stem below the cotyledon and above the roots. *Cyclamen* and *Gloxinia* are examples.

Geophytes - Resources

Bryan, John E. Timber Press Pocket Guide to Bulbs. Portland, Or.: Timber, 2005. Print.

Brent and Becky's Bulbs. Web. 18 Nov. 2015. https://brentandbeckysbulbs.com/. Mail-order retailer and top experts on bulbs, based in Gloucester, Virginia.

Pond and Bog Plants

Creating an ornamental pond, container water garden, or bog opens the door to another unique suite of herbaceous plants. Pond plants are not only beautiful, they are essential to a healthy pond, in that they take up excess nutrients such as nitrogen and phosphorus (both excreted by fish and created as organic matter such as leaves break down), provide shade to keep water temperatures down in summer, and helps hide fish from predators. A naturally-maintained water garden attracts and nurtures wildlife of all kinds, from salamanders to birds; bees to mammals.

Pond plants categories

Floating plants (free-floating)

These plants have buoyant leaves; no rooting situation is required. The floating roots excel at absorbing excess nutrients. Two popular species are water lettuce (*Pistia stratioites*) and water hyacinth (*Eichornia crassipes*).

Though considered invasive in the deep South and tropics, neither are freeze tolerant, so they're not a problem here.

Submerged plants
These plants root into the gravel and remain under water; provide valuable oxygenation to the water as well as a great shelter for fish and other critters. Canadian water weed (*Elodea canadensis*) and ribbon grass (*Vallisneria americana*) are both native and cold-hardy additions to a Virginia pond.

Floating foliage, rooted to pond bottom (or containers)

Leaves floating on or held at the surface keep water cool and the shade provided reduces algae growth. Two of our most iconic aquatic plants – water lily (*Nymphaea*) and lotus (*Nelumbo*) fall into this category. There are cold-hardy and tropical varieties available of both.

Marginal plants or "emergent"
These are the plants that thrive in shallow water, from a few inches up to 1'). These can be grown either rooted into a gravel substrate or in containers placed in several inches of water. There are many, many species, several of which are native to the Southern U.S., such as alligator flag (*Thalia dealbata*), pickerel weed (*Pontedaria cordata*), and cattails (*Typha latifolia*).

Bog plants
Bog plants are a bit different – they require consistently moist soil but cannot tolerate standing water for long periods of time. Full sun and low soil pH (amended with peat) are also necessary for a successful bog garden. Pitcher plants (*Sarracenia*) are fascinating and easy to grow, once the site needs have been met. Look for cold-hardy species such as *S. purpurea* and *S. flava*.

Proper maintenance of pond plants is important to the health of the pond. Nearly all are deciduous; so once cold temperatures have knocked back the above-surface foliage and flowers, the dead plant material needs to be removed immediately. Organic matter that falls to the bottom of the pond not only forms a layer of glop, but decomposes with the help of bacteria that also use up valuable oxygen. Timely removal of leaves and other debris is essential to a healthy water garden.

Thalia adds vertical interest to any water feature.

Pitcher plants (*Sarracenia*) can be grown in containers as well as bogs.

Pond Plants - Resources

Speichert, C. Greg., and Sue Speichert. Timber Press Pocket Guide to Water Garden Plants. Portland, Or.: Timber, 2008. Print.

Springdale Water Gardens. Web. 18 Nov. 2015. http://www.springdalewatergardens.com/. Mail-order retailer and top experts on water gardening and aquatic plants, based in Greenville, Virginia.

Ornamental Grasses

As landscape plant category, ornamental grasses includes true grasses, that is, members of the Poaceae family; as well as grass-like plants such as rushes (Juncaceae) and sedges (Cyperaceae). Turf-type grasses are not included. How do we distinguish among these? **True grasses** are monocots, with round but hollow stems (called **culms**), and parallel veins in the leaves. There is such a wide range – from towering bamboo to little bluestem. Rushes also have round (and frequently unbranched) stems, but are filled with pith and not hollow. Sedges bear triangular stems - hence the old plant i.d. tip: "rushes are round and sedges have edges." Rushes and sedges prefer moist soil; many grasses are very drought tolerant.

Most ornamental grasses are hardy perennials; but a few are not hardy and should be used as annuals. The most popular non-hardy grass is purple fountain grass (*Pennisetum* x *advena* 'Purpureum' and additional cultivars).

There are a vast number of perennial grasses, sedges, etc. for USDA Zones 5-8. Ornamental grasses can provide three to four seasons of interest. Foliage color and texture for spring and summer, blooms in summer or fall, fall foliage color, and winter structure. Add to the list of positives "deer resistant" and "drought tolerant" for most species. Knowing the growth habit of a species is important when deciding where to plant – many are clumping (caespitose), but a few are either stoloniferous or rhizomatous runners. When planting, allow sufficient space – a good rule of thumb for many is to space as wide as they are tall. An exception would be an extremely narrow/vertical grass such as feather reed grass. Several wonderful native species have extensive root systems, for example, switchgrass (*Panicum virgatum*) roots can extend several feet below the soil surface. Take this into account when deciding where to plant; after a few years, relocation can become difficult.

Purple fountain grass is perfect for containers and landscapes, as it adds a blast of maroon foliage plus foxtails of pink flowers all summer long.

Once planted and established, the only maintenance required for true grasses is to cut back the previous year's growth in early spring, before the new growth gets going. A 6" to 12" "crew cut" made with shears or a string weeder works well for most.

Unlike most true grasses that require at least six to eight hours of full sun each day, there are many shade-tolerant sedges – a textural boon to the shade garden. Most Carex are evergreen or semi-evergreen and rather slow growing. Do not cut them back annually, only trim out dead foliage.

Carex oshimensis 'Evergold' adds wonderful texture and color to the shade garden and is evergreen in the warmer parts of Virginia.

Ornamental Grasses – Resources

The Encyclopedia of Grasses for Livable Landscapes. Portland, Or.: Timber, 2007. Print.

The Color Encyclopedia of Ornamental Grasses: Sedges, Rushes, Restios, Cat-tails, and Selected Bamboos. Portland, Or.: Timber, 1999. Print.

The American Meadow Garden: Creating a Natural Alternative to the Traditional Lawn. Portland, Or.: Timber, 2009. Print.

Ferns (Pterophytes)

Ferns are herbaceous but non-flowering. They have a completely different reproductive physiology, which is fascinating but beyond the scope of this chapter. Hardy ferns are indispensable in the shady or partially-shaded garden. Ferns are deer-resistant and the ultimate mixer – adding wonderful texture and no-fuss foliage. Green goes with everything, and in the case of Japanese painted fern (*Athyrium nipponicum* 'Pictum'), silver and burgundy does as well. Mix ferns in with Hosta, Heuchera, Carex, and other shade perennials to form a shady tapestry of color. There are a wide array of perennial ferns available, from the petite deer fern to majestic cinnamon ferns.

The fresh, bright green fronds of ostrich fern blends well with other shade perennials.

Most do best with reasonably moist soil, but can tolerate short periods of drought. Most are deciduous, but our native Christmas fern (*Polysticum acrostichoides*) is evergreen. Simply cut back dead or tattered fronds in the winter and early spring, before the fiddleheads arise in spring. Note some ferns are slow to emerge in spring, so be patient! This works to your advantage in filling in gaps left by ephemeral shade perennials such as Virginia bluebells (*Mertensia virginica*) and bleeding hearts (*Lamprocapnos spectabile*)

Fern Resources

Olsen, Sue. Encyclopedia of Garden Ferns. Portland, Or.: Timber, 2007. Print

Succulents

Another broad group – some are hardy (Sedum and Sempervivum species); many are not. The popularity of succulents as non-demanding, low water use container and patio plants has soared over the past few years. Sedums form the primary matrix for green roof plantings. Fleshy stems and leaves, a thick waxy cuticle, and other adaptations allow succulents to survive very dry conditions. Many succulents are in the Crassulaceae family, and have the capacity for CAM – crassulacean acid metabolism. In a nutshell, this is a water-saving strategy that allows stomates to close during the day

when hot and dry, thus conserving water, and open at night for gas exchange. Succulents are extremely low maintenance, and terrific for containers, patio gardens, or sunny windowsill plants. Most will suffer if overwatered; use a light hand, especially during cool and cold weather.

Succulents - Resources
Succulents Simplified: Growing, Designing, and Crafting with 100 Easy-care Varieties. Portland, Or.: Timber, 2013. Print.

Planning the Herbaceous Border

(Adapted from previous MG Handbook's Herbaceous Plants chapter by Dr. Diane Relf)

Much of the excitement of creating a herbaceous border or mixed border (herbaceous combined with woody plants) lies in endless options of plant shapes, sizes, colors, and textures. In form, placement, and selection of plants, the contemporary border follows few rigid rules and allows fullest expression of the gardener's taste.

The first step in planning the material for an all- season, mixed border is to select key plants for line, mass, color, and dependability. Line is the silhouette or outline of a plant, mass is its shape or denseness, and dependability refers to its ability to remain attractive with a minimum of problems. There are literally hundreds of gardening websites, blogs, Pinterest pages, books, videos, and catalogues for reference.

The most attractive herbaceous or mixed borders are those which are located in front of a some sort of background such as a fence, shrubbery, or a structure. In some cases, taller ornamental grasses or masses of large perennials such as Baptisia australis may serve a dual purpose as both citizens in the border and as background plants.

A general rule is to avoid a ruler-straight front edge, unless the garden is very spacious or formal. A gentle to boldly sweeping curve, easily laid out with a garden hose, is best even along a fence. The border can taper as it recedes from the main viewing point if an effect of distance is desired. The deeper the curve, the slower the eye moves and the greater will be the visual enjoyment. A border outlined with bricks or flat stones set flush with the soil is better than a steeply cut lawn edge which must be trimmed after mowing.

Even the advanced gardener finds it advantageous to plan a border to scale on graph paper. The hardest task, organizing the selection of plants, will be simplified if only two main mass forms are considered: drifts and clumps. Drifts are elongated groupings of a plant that flow through sections of the border. Clumps consist of circular groupings of a variety, or a single large plant such as a peony. The length of drifts and the diameter of clumps, as well as their heights, should be varied for best effect, and the dimensions should always be in proportion to the overall size of the border.


Masses of Joe-Pye weed, Heliopsis, and grasses make an impact.

Establish plants in groups large enough to form masses of color or texture. As a rule, five to seven plants will create the desired effect. A large peony or grass will be of sufficient size to be attractive, but a random collection of different small- to medium-sized plants will present a disorganized, checkerboard appearance. Each group of flowers should have an irregular shape. These masses of color and texture should blend into a pleasing, natural pattern of color harmony, not rows, blocks, or other symmetrical designs.

Flower borders may be of any width, depending on the space available. In a small yard the bed may be only 2 or 3 feet wide. In a spacious location, the border planting may have a width of 6 or 8 feet. If the border is quite deep, a pathway of stepping stones may be helpful as a means of working among the flowers without compacting the soil.

Tall flowers should be selected for the back part of the bed, with medium-height species in the middle, and dwarf varieties along the front as edging plants. This is very

easily done because the height of all varieties is stated in seed catalogs. Plants along the front edge of the bed should be located far enough back to allow easy mowing of the lawn.

One of everything ("flower confetti") rarely produces desirable results!

Plant height is best limited to 2/3 the width of the border, e.g., no plants taller than 4 feet in a border 6 feet wide. Height lines should be broken up by letting some tall plants extend into the medium height groups, with a few recessed clumps or drifts leading the eye back into the border. This gives a more natural effect than a step profile. Try to vary heights, but in general, keep taller plants in the back and shorter ones toward the front.

Any open space invites weeds! Keep that in mind for the very front of the border as well.

The distance between plants in a flower border depends on the form of the individual plants and the effect which is desired in the landscape. Allow adequate space between plants, but just to a point. Plants will grow; garden are dynamic entities! If they become overcrowded, just remove the excess (and share with your friends).

The enormous color range in perennials, plus their easy relocation if disharmony occurs, gives the gardener great latitude in choosing and combining colors. A border in tones of the same color can be effective, several closely related colors may be used, or the border may be made wildly exuberant with a vast variety of hues in one or more seasons. Hues are modifications of color such as orange-red. The objective is a balanced composition in every season, with no section being at any time too heavily weighted with one color, and the bloom distributed so that it always makes a pleasing pattern through the bed.

Warm, rosy pinks and purples work well together.

Many gardening books give excellent lists of compatible colors; these plus a garden notebook and camera are invaluable for planning and revising color schemes. For real floral artistry, it is perhaps more important to consider intensity, which is the vividness of a color, rather than hue. For example, light tones placed near dark ones, or contrasting palest tones with the most intense, can give new interest and life to the border. Also consider location and color. White is especially good near patios because it shows up well in the evening or dusk hours when patios are often in use. Some colors are suitable only as dramatic accents: deep, pure red clashes with

almost anything (unless softened by dark green foliage), yet properly used it evokes strength and depth. White flowers and gray foliage are indispensable as separators of conflicting colors. Red, orange, and yellow are warm colors. Blue, green, and violet are cool colors.

Again, even in a small border, single plants of different varieties should not be used as it gives a jumbled look. Do not set in precise rows but in groups, as they might grow in nature. Allow enough space for each group to grow comfortably. Pick a few plant combinations and let these be the basis of your planting. Replicating these groupings down the length of the border guides the eye; repetition is pleasing (to a point, but don't overdo any one plant.) Do not confine yourself to material that blooms all at one time; aim for a steady succession of color.

As gardeners become adept at producing color harmony and combinations in the border, they become more aware of the roles played by plant forms and foliage. Good foliage is obviously vital in plants with short blooming periods. Consider how much of the plant foliage will be usable and whether it is a positive or negative attribute. Some plants practically disappear when their blooming season is over (i.e., oriental poppy (Papaver) and bleeding heart), but others stay presentable even when not in flower. Plants with distinctive forms, color, and foliage — airy and delicate, or strong and solid — are wonderfully useful for creating interest. Shrubs with burgundy, maroon, or gold foliage, ornamental grasses, and even handsome-foliaged vegetables like chard and kale can be used for effect.

The most logical way to choose plants is first by location, second by period of bloom, then by height and width, and finally by color. Location takes into account the amount of sun or shade and water required. Again this information is easy to find in books or on the internet.

A last bit of advice: don't be afraid to be bold, even if it results in some mistakes. Flowers are easy to move, change, or take out altogether. There is no need to be conservative or confined. Most herbaceous plants are fast growers and can be transplanted at almost anytime to help create the desired effect.

Containers and Hanging Baskets

Gone are the days of "monoculture" hanging baskets of impatiens or begonias. Mixed baskets and containers present an opportunity to combine foliage and flowers into portable works of art. Tropicals, perennials, annuals, and grasses can all co-exist in the same vessel. Though there are very few rules for containers and baskets, here's a few tips for success:

Confirm that the plants are compatible for the same environmental conditions, mainly light level (sun versus shade) and water (drought tolerant, needs consistently moist, etc.).

Use the largest container or basket possible for the space (and your budget). All those 4" containers of annuals are going to grow throughout the season, so give them some space to flourish. Big containers and big (14" diameter or larger) baskets make wonderful focal points for patios, decks, and borders.

Add some controlled-release fertilizer to the media when filling the container or basket, and be sure to top-dress with a bit more fertilizer later in the summer. Frequent watering will leach nutrients out rapidly, resulting in chlorotic (yellowing) foliage and reduced blooms and vigor.

When picking out plants for containers, look for three components: thriller, filler, and spiller. This bit of wisdom works like a charm. Pick a strong vertical component – grasses, canna, elephant ears, or anything else with a bold upright habit. Add something to fill around the bare soil at the base – coleus (*Solenostemon scutelleriodes*) is ideal but so are dozens of other goodies. Plants that spill from the container soften the edges and complete the picture – chartreuse or maroon ornamental sweet potato (*Ipomoea batatas*) , a cascading petunia, or myriad other options work well.

Kasper, Carol, and Jen Matlack. Container Gardening: 250 Design Ideas & Step-by-step Techniques. Newtown, CT: Taunton, 2009. Print.

Study Questions

Answer each of the follow as true or false.

1. A biennial flowers the first year; only foliage remains the second year.
2. All bulbs are geophytes but not all geophytes are bulbs.

3. Bog plants do best in full shade.
4. Sedges have edges and rushes are round!
5. Ferns usually flower in the spring time.
6. Plant in masses and drifts for the best impact, not single specimens!

Answers:
1 -false; 2 - true; 3 - false; 4 - true; 5 - false; 6 - true

Additional Resources

Here are a couple of fool-proof perennial plant lists that will work for most any part of Virginia. I've grown each and every one of the one, in several locations, across Zones 7 and 6. Note deer resistance is a continuum, depending on deer pressure.

Made in the Shade (or Part Shade)

A simple, three-season (or four-season, depending on severity of winter) garden of non-fussy, easy-care hardy perennials

Scientific name	*Common name*	*Relative height*	*Description*	*Other notes*
Asarum canadense	Deciduous ginger	Low	Wonderful native groundcover with iridescent, kidney shaped leaves. Forms large colonies where happy.	Native
Begonia grandis	Perennial begonia	Low to medium	Bold paisley-shaped leaves with reddish undersides and stems, soft pink blooms mid-summer through frost.	Late to emerge, so don't forget it's there! Non-native.
Eurybia divaricata	White wood aster	Low	Clouds of white aster flowers in late summer and early fall, when little else is blooming in the shaded.	Native, low growing
Helleborus x hybridus	Hellebore, Lenten rose	Medium	Earliest of spring flowers (late winter in warm areas). Cream to lavender to deep purple. Leathery evergreen foliage.	Non-native. Great early pollen source for bees. Extremely deer-resistant.
Hosta species and hybrids	Hosta, plantain lily	Low to medium	It's all about the foliage. So many gorgeous cultivars to choose from – gold to blue-green to variegated.	Non-native. Unfortunately delicious to deer and rabbits.
Polygonatum odoratum 'Variegatum'	Variegated Solomon's Seal	Medium	Cream and green foliage graces arching stems. White bell-shaped flowers dangle from leaf nodes in spring. Great yellow fall color.	Non-native. I cannot garden without this plant.
Matteucia struthiopteris	Ostrich fern	Medium to tall	Vase –shaped clumps of broad, feathery fronds. Wonderful texture and height. Spreads by rhizomes to form new clumps – easy to remove (and share with friends!) if need be.	Native across most of the N. hemisphere. Deer-resistant.
Stylophorum diphyllum	Celandine poppy	Medium	Spring bloom with bright yellow poppy flowers and interesting foliage. Reseeds around where happy.	Native

Sure Things for Sun

Some flowers, some foliage, all easy and wonderful

Scientific name	*Common name*	*Relative height*	*Description*	*Other notes*
Amsonia hubrichtii	Blue star	Medium	Thin foliage forms perfect mounds. Light blue flowers in spring, terrific texture in summer, then stunning gold to bronze fall color.	Native to OK + AR. Give it a year or two to reach full size. Deer resistant.

Sure Things for Sun				
Some flowers, some foliage, all easy and wonderful				
Scientific name	*Common name*	*Relative height*	*Description*	*Other notes*
Asclepias tuberosa	Orange milkweed	Low	Bright orange umbels in summer are beloved by butterflies and avoided by deer.	Native. Late to emerge, don't move once established (tap root).
Calamagrostis x acutiflora 'Karl Foerster'	Feather reed grass	Medium to tall	The vertical form of stems and plumes makes exclamation points throughout the garden. Does not spread. Early summer blooms.	Non-native. Cut back in early spring for a fresh flush of growth.
Echinacea species and hybrids	Purple cone flower	Medium	Some of the older *E. purpurea* and *E. tennesseensis* cultivars are tougher and longer-lived than the fancy new hybrids.	Native. Tolerates most soils. Attracts bees and butterflies.
Eutrochium purpureum, E. maculatum, and *E. dubium* (previously *Eupatorium* genus)	Joe-Pye weed	Tall	Large umbels of silvery-pink to pale purple flower heads, interesting foliage on tall, strong stems. Try compact cultivars such as 'Little Joe' and 'Phantom' for the smaller garden.	Native. Brings bees and butterflies. Tolerant of wet soils.
Sporobolis heterolepis	Prairie dropseed	Low to medium	The fine foliage forms graceful mounds, accented by sprays of flowers in late summer. Drought and clay tolerant.	Native. Deer-resistant.
Symphyotrichum oblongifolium	Aromatic aster	Medium	Shrubby habit, smothered with lavender flowers throughout fall; often last option for bees and other pollinators	Native. Deer-resistant.

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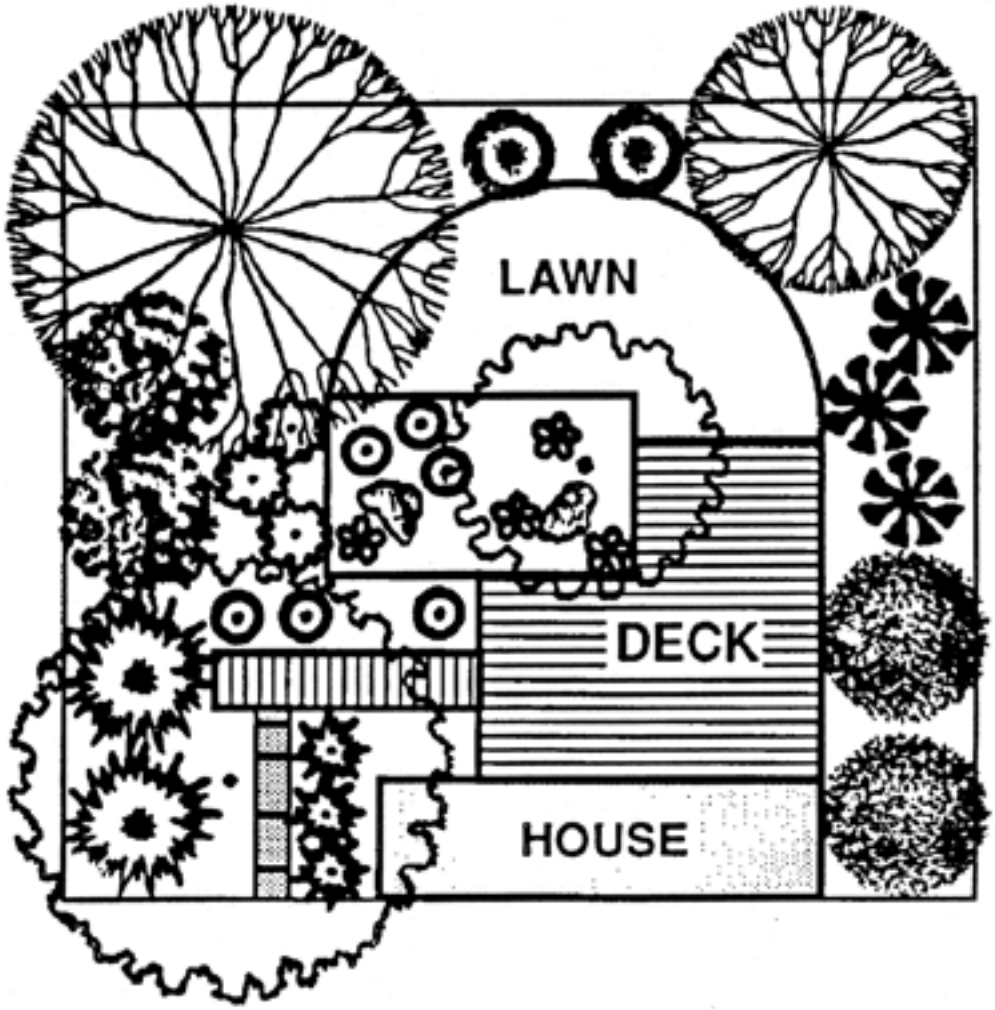
Chapter 18
Landscape
Design

Landscape Design

Chapter 18



Landscape Design

Chapter 18

Revised by *Laurie J. Fox, Horticulture Associate, Horticulture Department, Hampton Road AREC (2015)*

What is landscape design? It is the process of planning and organizing the natural and man-made parts of the landscape into an aesthetic, functional, and environmentally sustainable space. This can apply to the whole landscape or an area within the landscape.

Why is it important? People's wants and needs must be balanced with the environment and natural resource protection and preservation. Landscape design can affect site aesthetics, use and functionality, property value, water quality, wildlife, and long term management. Informed, thoughtful and creative planning and design can integrate the human and environmental factors for a positive impact at the individual residence level; which collectively impacts the larger community and watershed levels.

- What does a successful landscape design involve
- Gathering information and creating a plan to make the best use of the space
- The most of a site's natural features and advantages
- Balancing human impact, the environment and long term sustainability of the design
- Utilizing materials and plants that best fit the site and the design

Contents

Plans and Maps

The planning process is the most important part of landscape design, but unfortunately it is often neglected. An overall plan should be developed so that when any landscape work is done, it will be part of the whole picture. Usually it takes several years to implement a landscape plan. Construction and plantings are completed as weather and finances and other resources allow. Many plantings also need time to mature to create the desired effect. The overall landscape plan should include goals, timeline, budget, a list of resources and contacts, and various site maps and information. The smaller the house, site, and budget, the greater the need for an overall plan, because every square foot of space and every dollar must produce maximum results.

Prepare a scale base map of the site using one of the following techniques.

* Use landscape design software or use graph paper and let one square equal so many feet
* Have a friend help hold and read a tape measure or use a measuring wheel
* Record all measurements clearly on the map

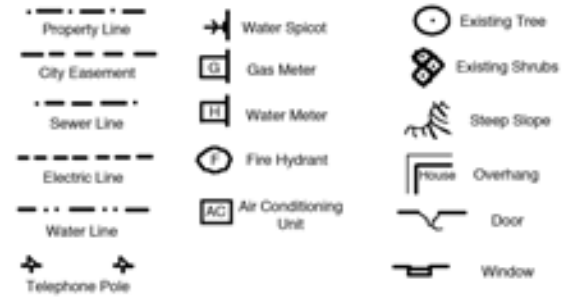
Draw the site to scale:

* Using a ruler, let one inch equal 8 feet for a small site, and 16 feet for a large site
* Using an engineer's or architect's scale, let 1 inch equal 10 feet for a small site, or 20 feet for a large site

A base map should include the following: (make 5-6 copies of this map & don't write on the original)

* Property lines, easements or setbacks
* North point
* House, garage, other buildings or structures
* Scale used
* Location of septic tank or sewer lines
* Walks and driveways
* Doors, windows, porches, and location of specific rooms
* Fire hydrants, meters, utility lines, water spigots, HVAC unit, telephone poles & lines

Suggested Symbols for Plans and Maps

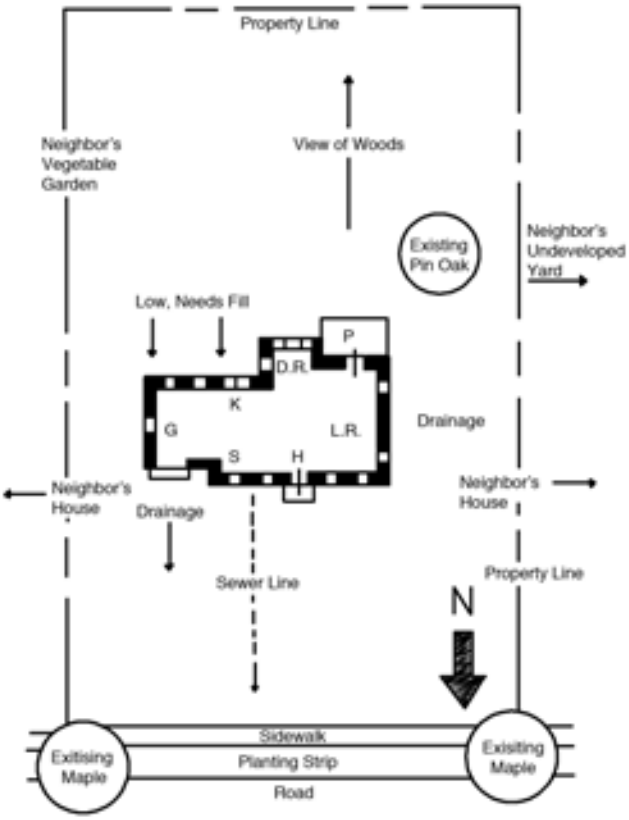


Suggested Symbols for Plan Drawings

Site Analysis

This involves gathering additional information about the site that could impact the design. Spend time (10-15 minutes) in different parts of the site at different times of the day just observing. Use one copy of the base map to add items from the list below. These are reminders of unique site features to incorporate into the design or challenges that need to be addressed in the design.

* Rock outcroppings, slopes, erosion, compacted or poor soil areas
* Path of stormwater runoff. Use arrows to show the direction of surface water flow onto the site, across the site, off the site and any low or constantly wet areas
* Setbacks, easements or streams (shorelines) that might have special restrictions/limitations
* Desirable and undesirable features of the site and adjoining property (noise, smells, traffic)
* Views - good and bad views from windows, porches, decks and different parts of the site
* Prevailing wind direction
* Light coming from security lights, street lights, neighbors
* Areas that need privacy screening



On another copy of the base map add the plant information. Existing healthy plants are a valuable resource that can be incorporated into the design. Make extra copies of this map as the plant information will change as the design develops.

* The cold hardiness and heat tolerance zones for the site
* The location of existing trees, shrubs, turf and other plants
* Microclimates (i.e. dry shade, wet soils, tree root competition, etc.)
* Locations for specific plants (i.e. 8' privacy hedge, small flowering tree, wildlife habitat, etc.)

* Create a companion list to this map identifying the plants on this map, noting their condition, and thoughts on keeping or removing them and any maintenance needed
* Create a list of favorite or desired plants that might be included in the design
* If you can't identify the existing plants or need suggestions for new plants, create a list of resources to help like the Extension office, nearby botanical gardens or arboretums, and websites

An understanding of the water, soil and climate conditions of a site is essential for plant selection and establishment and a successful design.

Water Factors

(See Water Quality chapter for more information.)

Water is critical to a successful landscape design. How much water is available will determine:

* The plants used in the design
* Whether an irrigation system is needed and what type to establish and maintain plants
* Whether to include natural or man- made water features in the design
* Whether there are drainage or erosion issues that need to be addressed in the design

During and after a rain, observe how water moves onto, across and off the site. Look for soil splashed on windows or outside walls, water pathways, erosion, tree roots or rocks becoming exposed, small rills or gullies beginning to show, locations where water collects or where water stands. These areas may need to be addressed in the design through plantings or drainage techniques.

Soil Factors

(See Soils chapter for more information.)

Drainage

Drainage can vary a great deal from one area to another, even if the site is relatively flat. During and after a rain, note any locations where water collects, is slow to drain, or stands for more than 24 hours. These areas may need to be addressed in the design through plantings or drainage techniques. A percolation or "perk" test may be needed in any location where water stands to determine the infiltration or percolation rate. More information on perk tests can be found on-line.

Soil Texture

To determine texture, send a soil sample to a lab and request a textural analysis. Traditional soil survey maps can only be used on undisturbed sites. This disqualifies most urban and suburban sites, as they are significantly disturbed during development. Soil (sometimes called fill) is often hauled away from or onto a developed site and can be very different from the existing site soil. Soil texture can affect many site design and maintenance decisions including: plant selection, stormwater management, choice of irrigation method, and amount of irrigation, and stability for structures.

Soil pH and Fertility

Send soil samples to a lab for analysis. A soil sample should be collected from each different area (i.e. front lawn, back lawn, wooded area, flower bed, vegetable garden, or any problem area). Soil pH and fertility can vary over short distances and can be influenced by paved areas and foundations (these often raise pH), past gardening practices, fill hauled onto a site, and drainage issues. Soil tests provide a base line of information that could impact the design decisions like plant selection, plant location, and any site preparation including soil amendments like organic matter, lime or fertilizer. Soil tests should be done every 3 years.

Topography

Changes in elevation can add interest and variety to a landscape. Natural variations should be considered an asset, and artificial ones should be minimized. For example, a hilly wooded site lends itself to an informal or natural design, with large areas left in a natural state. And, while grading of terraces or retaining walls might be necessary to facilitate construction or control water drainage, they should be kept to a minimum and designed to detract as little as possible from the natural terrain while accommodating vehicle and pedestrian traffic on the site. A particular challenge is creating topography for a water feature (i.e. a waterfall to a pond) in generally flat areas. If the feature isn't integrated into the overall site design and topography, it looks like it landed from outer space!

Compaction

Areas with heavy foot traffic, where cars are or have been parked, or where there has been any construction activity, are likely to be compacted. Test soil compaction

by forcing a shovel or other tool into the ground when soil is moderately moist. In healthy soil it should be fairly easy to push the tool into the ground, provided you do not hit any stones or large roots. Soil may be uniformly compacted, or there may be a hard layer, known as a hardpan, 6-18 inches under the topsoil that can restrict root growth and drainage. Because few plants will thrive in heavily compacted soil, aeration and/or amendments may be needed. Compacted areas should be noted on the site analysis map and addressed as part of the site preparation plan before implementing the design.

Climate & Microclimate

Climate includes sun, shade, all forms of precipitation, wind, and temperature. All these affect the way a house should be placed on a site, how the land is used, and what is planted. In planning the landscape, utilize the advantages of climate and microclimates. In protected microclimates, grow plants that might not normally survive or thrive in that growing zone, or use the microclimate to extend the growing season. Microclimates also create opportunities for diversity and adding unique plants to the landscape. In warm climates, enlarge the outdoor living area. In cold climates, plant so that the winter scene is enjoyed from the inside.

Cold Hardiness and Heat Tolerance

Cold hardiness and heat tolerance zone numbers help determine if a plant species will tolerate the temperature averages and extremes of a site. Refer to a USDA Hardiness Zone Map or an American Horticultural Society Heat Zone Map to determine the zones for a specific site. Other climate factors, such as rainfall, snow cover, soil types, winds, elevation and pollution should also be considered, as these may affect plant survival.

Sun and Shade Patterns

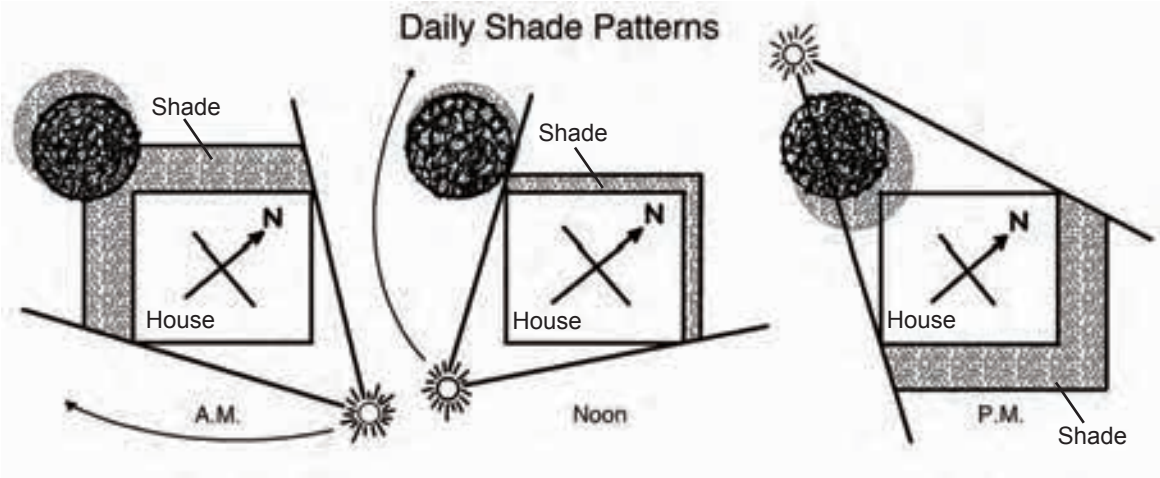
People respond differently to sun and shade, so it's important to study the amount and location of each at a site. Note daily and seasonal patterns and those areas that are heavily shaded or are exposed to late afternoon sun. The sun is highest and shadows are shortest in the summer. Take into account planned and existing structures and plantings. Sun for a minimum of 6 hours a day during the growing season is generally adequate for vegetables and other plants requiring "full sun," although 8 to 10 hours will result in significantly better growth and yield.

As the sun moves from east to west, it travels in the southern sky casting shadows to the north side of houses, structures and trees.

Plan future shade from tree plantings carefully in order to keep sunny areas for lawns and gardens, and summer shade for the house and patio/deck. Place trees off the corners (rather than the sides) of the house where they will accent the house but not block views and air circulation. Remember to plan and plant for the mature size of the tree(s). Consider possible shade from trees and houses on neighbors' property also.

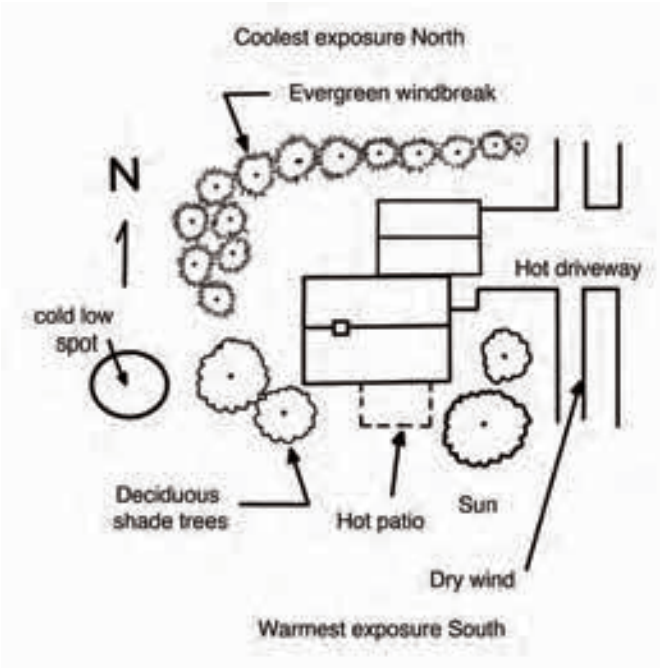
Site Specific Temperature:

Note exposed surfaces that reflect or give off heat, such as patios and driveways. These can greatly increase air temperatures around them making the area hotter during the day and radiating back heat overnight. Identify wind patterns and areas protected from or exposed to cold winter winds or drying summer winds. Note any low areas where cold air might settle and injure marginally hardy plants. Northern exposures receive the least light, and therefore are the coolest. The east and west receive more light; western exposures are warmer than eastern because they receive afternoon light. The southern



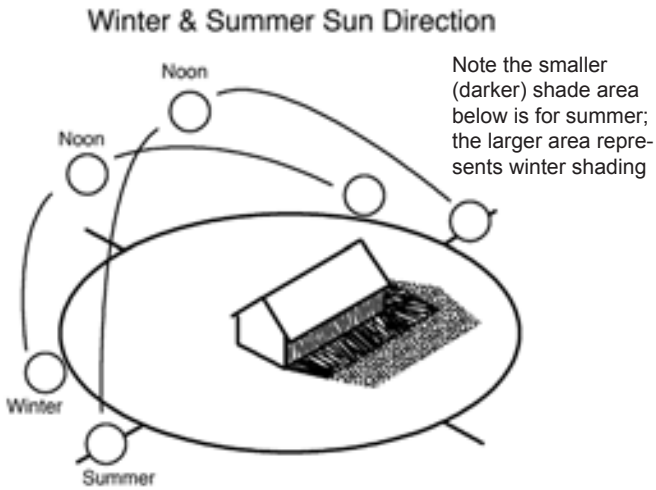
Landscape User Analysis Checklist	
Access to House	
	Walks - width, stability (i.e. gravel vs. pavers), appearance, lighting, ramps instead of steps
	Driveways - type of surface, width, turning radius, # of cars
	Security - fences, gates, flood lights
User Activities	
	Outdoor living - cooking, seating, patio, pool, hot tub, gazebo, deck, meditation, exercise
	Play area – bocce, croquet, volleyball, basketball, soccer, horse shoes, sand box, pets, etc.
	Extra parking - for user, guests, a camper, boat, ATV or bicycles
	Gardening - composting, tool & supply storage, water access or rain barrels, greenhouse
	Landscape maintenance – what level, storage for lawn mower & other tools & equipment
Other	
	Space for garbage and recycling cans, clothesline, yard art, sculpture, plant collections, dog house or pen, bees, chickens
	Storage for other equipment & supplies - ladders, power tools, chemicals
	User economic ability (budget)
	User time line – may need to do the landscape in phases
A user re-evaluation should occur when:	
	New users are added (children, parents or a blended family) Users leave (children move out, divorce)
	Users leave (children move out, divorce)
	Health issues arise (need to convert steps to ramps for wheelchair access)
	The house is put up for sale (staging the landscape to attract buyers)
	The house becomes rental property (simplifying the landscape to reduce maintenance)
	An environmental event (i.e. flood, hurricane, tornado, drought, severe winter, pest) significantly impacts the landscape

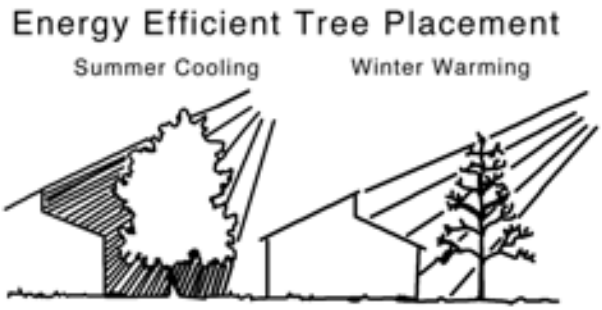
exposure receives the most light and tends to be the warmest. These factors can create microclimates that will affect plant selection and survival.



User Analysis

A landscape design should balance people's wants and needs with the environment and natural resource protection and preservation. A user analysis is essential to creating a design that will keep the balance while changing over time as the user's needs and lifestyle changes or as the users change. A user analysis should include: the people who will use it, their habits, actions, needs, desires, and economic abilities. A re-evaluation should occur when the user or situation changes. A successful landscape should change and mature with the user. For example: a plan for a young family would include inexpensive plantings and open areas in which children and pets can play. As a family reaches its middle years, more extensive and expensive plantings can be incorporated. The children's play area can transition into other functions. For example, the sand box can become a water garden. With the approach of retirement years, the landscape should become lower maintenance. Mature trees and shrubs will carry the landscape theme, high-labor areas such as flower beds can be minimized. Ramps may replace steps.





Use Areas

Public, private, and service areas can usually be easily defined in residential landscapes. The final design of these areas should reflect the user's priorities, aesthetics and functional requirements.

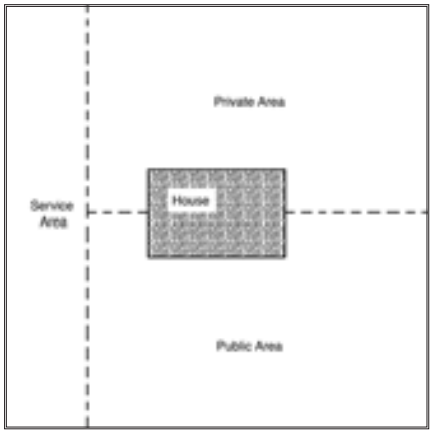
Public - is the part of the site that passersby and visitors view and that the user sees every time they come or go from the site. It is generally in front of the house and is attractively maintained to compliment the house and give a welcoming appearance.

Private - is generally behind the house and is for the user's activities such as entertaining, family activities, and pets. It is usually screened from public and/or neighbors views and has easy access from the house.

Service - is usually to the side of the house. It is the utility, work or production area and it often connects the public and private areas. This area can be screened off and is for storage, work, garbage and recycling, oil tank, air conditioning unit, sheds, vehicle parking, wood storage, compost pile, etc.

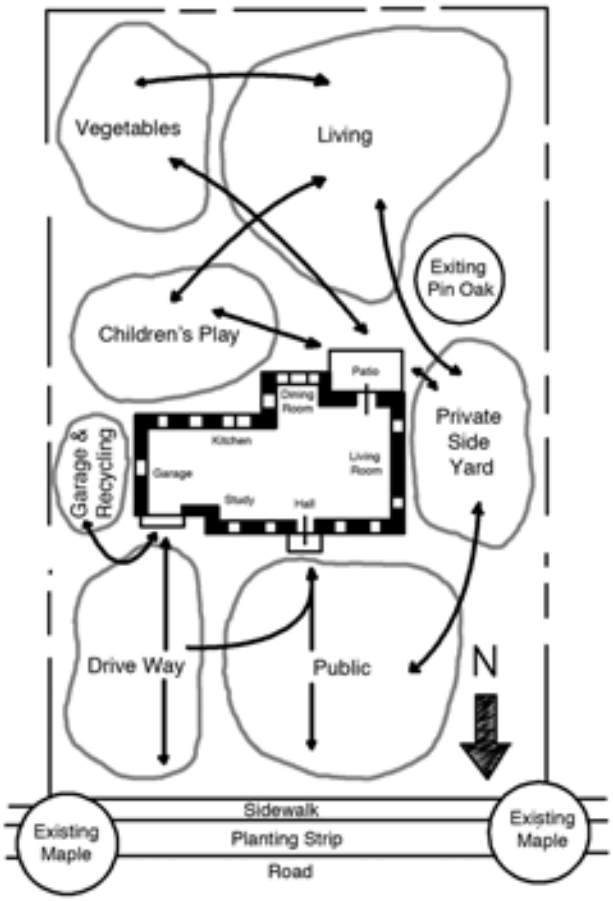
Traffic Flow

Think about different arrangements of these areas in relation to rooms in the house, user activities, views and traffic flow. Draw the three general areas on one copy of the site map. Then within these large areas, draw smaller areas for specific functions or activities. Consider what is happening in each of the areas, time of day the area is being used, the frequency of use of each area and the traffic flow to, from and through each area.



Add lines to show vehicle and foot traffic patterns from area to area and from the house to each area. Different colors or line thicknesses can denote more frequently used walkways or vehicle routes. Don't forget to create a legend to show what each color or line means. Consider whether the walkways should be formal or informal to fit into the overall design. Also note which walkways need to be wider, need lighting, or need heavy duty surfacing materials. For example, a wider walkway with an even surface is more formal and better for a front entrance, where garbage and recycling cans need to be wheeled, or for children, the elderly, high heels and wheel chairs. A narrower walkway with mulch or stepping stones is informal and can be used to meander through a garden area or across a turf area that is frequently mowed, or where there is infrequent activity or access. Heavy duty surfacing materials are needed for driveways, especially if there are turns for side parking areas or to pull into a garage. Consider using permeable paving materials for walkways and driveways for better water infiltration and reduced runoff. Also consider that driveways can serve

additional functions such as a basketball court, tricycle riding area or chalk art canvas.



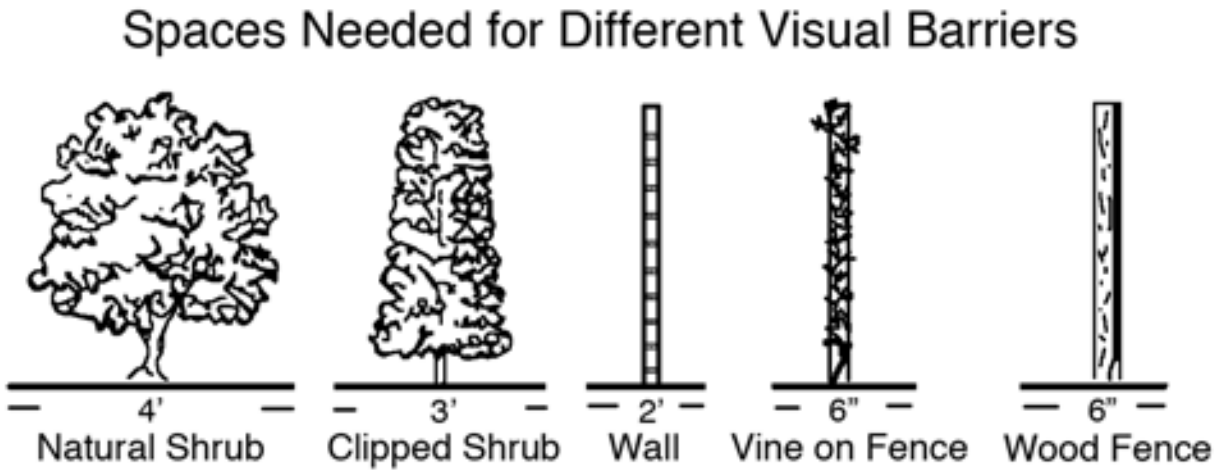
Space Transitions and Dividers

Different areas of the landscape need to flow into each other and sometimes they need to be delineated, separated or protected by fencing or screening.

* Transitions are the connecting links between spaces. For example: between the house and the landscape, between the front yard and backyard, between the service and private areas. Transitions should be composed of characteristics that are found in both of like common colors, textures, forms, plants, paving, or other materials.
* Dividers define or give privacy to spaces, create the background for outdoor activities, protect the landscape and house from prevailing winds or sun, and provide security. Dividers can be made up of fences, walls, plants as hedges, or plants as borders.

Study Questions

1. A baseline landscape design map should include: a) property lines; b) scale; c) existing buildings; d) all of the above
2. Signs of _____ include soil splashed on windows or outside walls and small rills or gullies.
3. To protect a house from cold winter winds, _____ trees should be planted on the____ side of the house: a) evergreen, north; b) deciduous, south; c)evergreens, west; d)



deciduous, east

4. The _____ orientation receives the most light and tends to be the warmest.

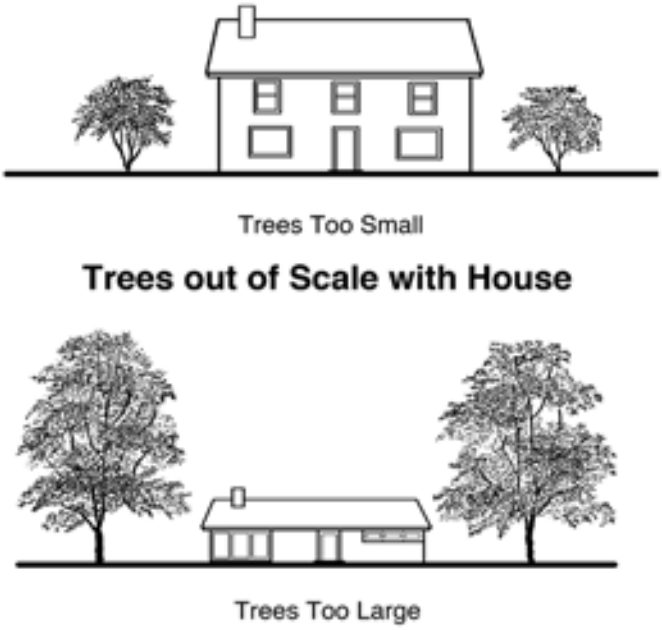
5. The three main landscape use areas are _____, _____, and _____.

6. The main consideration when fitting together use areas on a map is _____.

7. A user analysis should include: a) house access; b) user activities; c) storage needs; d) all of the above

8. A walkway depends on: a) user; b) amount of use; c) topography; d) overall design; e) all of the above

Answers:
1 - d; 2 - erosion; 3 - a; 4 - south; 5 - private, public, service; 6 - traffic flow; 7 - d; 8 - e



Elements and Principles of Design

The site and user analyses gather essential information that is incorporated into the landscape design. Each design is a unique creation. While there are no set rules, landscape designs are based on certain elements and principles. Keep the horizontal and vertical aspects of the site in mind when developing a design as landscapes are 3 dimensional.

Scale

Scale refers to the size relationship or proportion between different parts of a landscape. This could be between buildings and plants, plants and plants, or plants and people. Scale can change over time as plants grow, so design using the mature size (height and spread) of the plants. This is especially important when locating trees and shrubs near a building. Plants that grow large may overwhelm a small building or small plants around a large building can be similarly out of scale. When a landscape is out of scale, it appears uninviting and awkward like something is missing or not in the right place.

Balance

Balance in landscaping refers to an aesthetically pleasing integration of elements. It is a sense of one part being of equal visual weight or mass to another. There are two types of balance — symmetrical and asymmetrical. Symmetrical balance is formal. It has an obvious axis with everything on one side duplicated or mirrored on the other side. Asymmetrical balance is more informal, and is achieved by using different objects on both sides of a less obvious axis. For example, when there is a large existing tree or shrub, a grouping or cluster of smaller plants is used to counterbalance it. Balance may also be achieved through the use of color and texture. Whichever type of balance is used in the design, the result is the same; there is equal visual weight or mass on each side of the axis.

Unity (Harmony or Simplicity)

Unity is grouping or arranging different parts of the design to appear as a single unit. Repetition of shapes, lines or colors creates unity. The design should look like everything belongs together and be aesthetically pleasing from every view. Groundcover covers and turf unify a landscape by connecting different spaces. Repetition of the same plants in sweeps or groupings creates unity. A landscape with too many different plants, accessories (sculpture, yard ornaments, etc.), colors, shapes or textures in a limited area lacks unity. The landscape is chaotic, confusing and disordered. The viewer doesn't

know where to look or go. A landscape with unity complements the house, draws the eye and the traffic flow in a specific direction and presents an overall theme, tone and order to the space.

Symmetrical

Landscape Balance

Asymmetrical

Rhythm

Rhythm is even repetition, and it directs the eye in the landscape through continuity and flow. Rhythm is repetition of color, line, shape, or texture in regular measures and in a definite direction. Some examples are: several of the same plant planted exactly the same distance apart in a bed, the same curves repeated along a walkway or bed edges, the same paver pattern repeated every 3 steps in the walkway.

Accent (Focal Point)

An accent or focal point is something that deliberately stands out from the overall landscape. It gives the eye a place to rest. Without them, landscapes can appear monotonous or dull. Both the public and private areas of a landscape should have an accent. If those areas are divided into smaller areas, then each space should have one. Usually there is only one accent per space. Accents can be: sculpture, specimen plants, garden accessories, a water feature, boulders, the front door or the house itself.

Sustainability

Sustainable landscaping can also be called low maintenance, green, environmentally friendly, or conservation landscaping. The following sustainable concepts and practices should be kept in mind as a landscape design is developed. All the practices can't be used in every landscape, but even incorporating a few will make the landscape healthier, more resilient, and less maintenance intensive.

Sustainable Concepts

* Biological diversity – using many different plant species promotes beneficial insects, provides food & habitat for animals, & reduces pest & weather impacts
* Resource conservation – using existing topography, water, plants, & views in the design reduces costs & disturbance to the environment, using locally sourced plants, construction & other materials saves transportation costs & supports the local economy
* Long term planning – planning for mature plant sizes & the long-term look & use of the landscape reduces labor & costs by minimizing plant crowding & maintenance
* Low impact / input – disturbing the site as little as possible & using healthy, site appropriate plants reduce maintenance & pesticide & fertilizer use
* Water conservation – grouping plants with similar water needs, using rain sensors, rain chains, rain barrels, & rain gardens/swales to collect & manage runoff, help to conserve valuable water resources

Sustainable Practices Include:

* Rain chains & barrels
* Rain sensors
* Landscaped swales
* Permeable paving
* Ground covers & mulches
* Compost
* Canopy layering
* Passive solar heating/cooling
* Plant diversity
* Plant selection & spacing

* Plant grouping based on water
* Drip irrigation & watering bags
* Aeration
* Long term planning
* Correct planting
* Minimal site disturbance
* Grasscycling
* Recycled products
* Low input lawn
* Reduced or no fertilizers
* Zero or as needed pesticides
* Solar lights
* Soil testing
* Storm drain protection
* Use native plants
* Minimal deadheading

Construction Materials

Landscape design is not synonymous with plants. Often there are structures (pergolas, gazebos, fences, sheds, decks, arbors, benches, etc.) and hardscape (walls, walkways, steps, terraces, patios, outdoor kitchens, fire pits, lighting, etc.) included in a design. Careful consideration should be given to the construction materials and their use in order to create the desired design aesthetic. A wide variety of products are available, and many factors influence the choices.

Considerations:

* The specific look or effect being created
* Budget – may need to do it in phases
* Do it yourself or hire someone
* Time line for the project(s) and best time of year to do it
* Natural, synthetic or recycled products
* Source location – local, non-local, on-line
* Availability of the product
* Shipping/hauling/delivery expenses
* Durability and weather resistance
* Space to store materials and supplies (i.e. piles of stone or pallets of pavers)
* Security of stored materials (from vandalism or theft)
* Access for delivery or transportation of materials to specific construction site (i.e. delivered in the front driveway, but need to transport to the back yard for use)
* Any property restrictions (i.e. colors, fence height/ style, historic, easements, etc.)

Study Questions

9. _____ refers to the proportion between two sets of dimensions.
10. An axis with everything on one side duplicated or mirrored on the other side is called: a) rhythm; b) symmetrical balance; c) asymmetrical balance; d) unity
11. A sustainable landscape: a) reduces costs; b) is more resilient; c) includes many different practices like promoting beneficial insects; d) all of the above
12. _____ form the connecting link between spaces.
13. A _____ analysis and a _____ analysis provide essential information for the landscape design.
14. Construction materials: a) can be natural, synthetic or recycled; b) are important in creating a specific look or effect; c) might need storage space & security; d) all of the above
15. In addition to plants, a landscape design often includes _____ & _____.

Answers:
9 - scale; 10 - b; 11 - d; 12 - transitions; 13 - site, user; 14 - d; 15 - structure & hardscape

Planting Design (Plan)

On a fresh copy of the site base map, mark where plants are needed for:

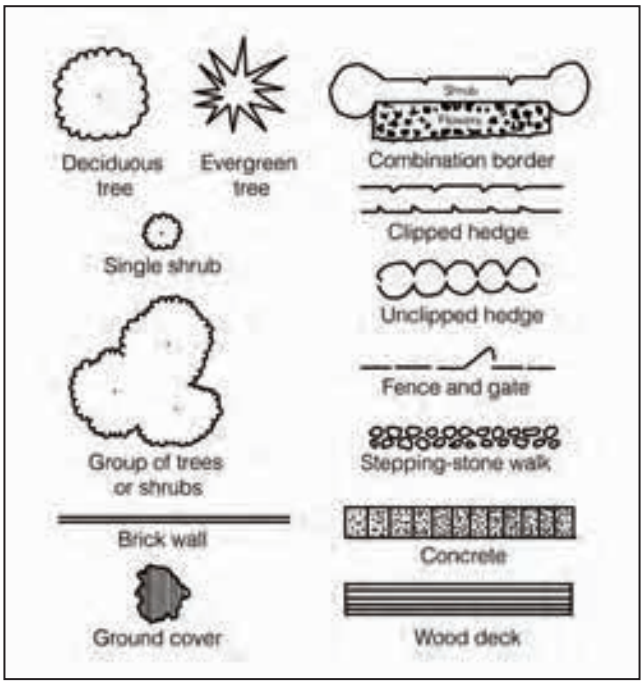
* Separating areas
* Screening undesirable views or privacy
* Providing shade or windbreaks
* Accent (i.e. specimen plant or to complement the house)

* User activities (i.e. turf for play, herbs & vegetables, plant collections, butterfly, cutting or rain garden, erosion control, pet area, seasonal interest, etc.)
* Specific conditions (i.e. dry shade, hot & dry southwest exposure)

Review the site analysis maps and information and the user analysis information to determine what plants are needed where on the site. Think about individual plants and groups of plants that will meet the desires of the user(s), serve a purpose (functionality), tie the various areas together into a unified plan (aesthetics), and be environmentally sustainable. Keep in mind that landscapes are dynamic. Plants grow and change over time. Consider successional planting. For example, planting annuals or perennials between the shrubs until they mature or planting a sun loving groundcover under the newly planted small tree, to be changed to a shade loving groundcover in several years when the tree canopy wider)

Different symbols should be used to indicate the different types of trees, shrubs, groups and groundcover covers. Create a legend and label each symbol or use these examples. Add symbols for the hardscape later. A first draft of a planting design might just be different sizes of circles in the general locations. As the design comes together, the next drafts should use the different symbols for specific types of plants. The symbols should be drawn to scale (plant or group width) in order to see how many of a plant are needed or will fit into the actual space. Examples of common symbols are below. More complicated symbols can be found on-line. All of this can be done without knowing the exact plants. For example, an evergreen hedge is needed for privacy on the east side of the site or a deciduous tree is needed on the southwest corner of the house, or a butterfly garden is located off the patio in a sunny area.

As the planting design becomes more detailed, exact plants can be specified. Sometimes there may only be a certain amount of space available at a site location and that will determine which exact plant is used (i.e. only 6' width for a hedge). Sometimes the user already knows exactly which plant(s) they want and that is incorporated into the design (i.e. a 15' wide weeping Japanese maple accent plant or a 60' wide chestnut oak for shade). Sometimes research to find the exact plant for a location or purpose is needed. In that case, make a list of the specifications to help narrow down the plant choices.



Plant Choice Specifications
Height - low, medium, tall
Form - spreading, upright, arching, globe
Purpose - shade, background, hedge, screen, accent, mass
Seasonal Interest - fruit, flowers, foliage, bark, fragrance
Type – annual, perennial, woody, herbaceous, evergreen, deciduous, tree, shrub, bulb
Maintenance – pests, pruning, debris (leaves, berries, cones)
Cultural Needs - shade, sunlight, moisture requirements, hardiness zone

Add a planting key to the planting design to list the exact plants as they are selected. Keep a "backup" list of second and third choices in case the first plant choice isn't available. The planting design may need to be implemented in phases if there are time, availability, or budget constraints. For example, bed areas can be defined, prepared, and mulched during the summer but planted in the fall; large trees, which are expensive, can be planted first and the other plants when the budget allows; or the area around the patio can be planted but the back of the yard can wait until later. Numerous resources are easily available to help with plant selection. A good place to start is at the local Extension office, nearby botanical or public gardens, or with local garden groups, clubs or societies.

Using native plants is becoming the norm rather than the exception. While there are many reasons and benefits to

using native plants, the design rule should always be put the right plant in the right place. The Virginia Department of Conservation and Recreation and the Virginia Native Plant Society are good resources for more information on native plants.

Benefits of Using Native Plants
Increase landscape biodiversity, sustainability and resilience
Reduce maintenance and chemical (fertilizer and pesticide) inputs
Provide food and habitat for beneficial insects and wildlife
Support the local ecology
Provide a sense of place (i.e. palm tree in Florida, cactus in Arizona)
Manage erosion and stormwater
Prevent invasive plants
Provide beauty
Improve soil, water, and air quality

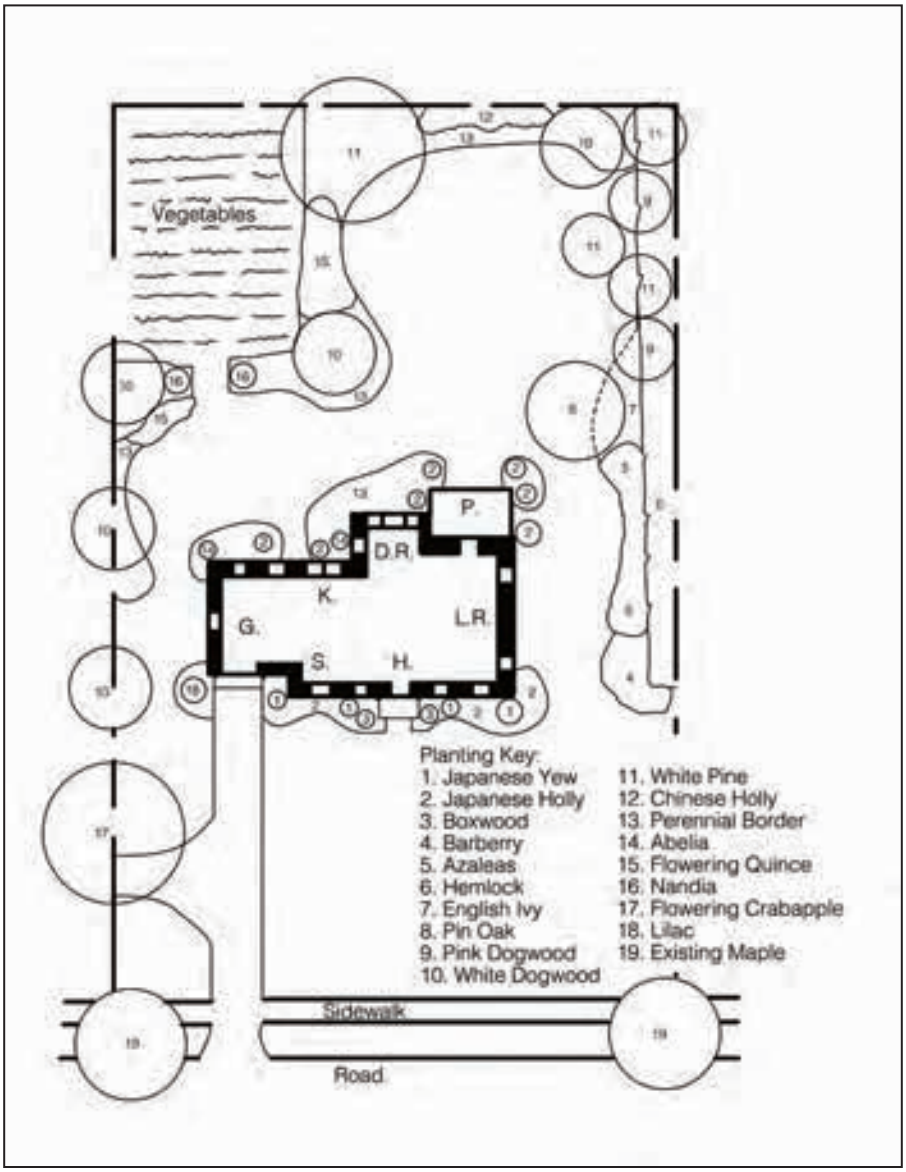
Considerations for using native plants:

* Make sure the plant is native to the area (plants native to other parts of the United States may not do well in Virginia)
* Do not dig native plants from the wild and transplant into a landscape (unless they are being rescued)
* Urban/developed sites often don't have the specific growing conditions needed (soil, water, sun/shade exposure)
* A native plant just may not be the best choice for a particular location or design need
* Native plants can sometimes be difficult to find, transplant, and establish
* Native plants may not be as "ornamental" or aesthetically pleasing as non-natives
* Many native species are too large in size for smaller landscapes
* Some native species are aggressive spreaders or seeders and can be a maintenance headache or invasive
* There is often controversy about what exactly is native (i.e. before a certain historical time, are cultivars or varieties of a native species truly "native")

Energy Conservation through Landscaping

A well designed landscape can significantly reduce home heating and cooling cost; making the home and budget more comfortable while conserving energy and helping the environment.

* Deciduous trees (those that shed their leaves) planted on the west sides of a house cast shade on the house keeping it cooler which reduces air conditioning costs. In the winter when the leaves fall off, the sun warms the house reducing heating costs. This is especially effective on houses with brick, concrete, or dark colored walls. Remember to account for the mature size of the tree canopy and don't plant it too close to the house. Branches that extend over the roof can drop debris that can stain shingle and clog gutters. Also don't plant a tree if it will block any solar panels on the house.
* Collectively, tree and shrub canopies cool the air through transpiration; thus conserving energy.
* If trees can't be used to shade the house, then partial shading can be accomplished with shrubs. Plant them far enough away from the foundation so that the mature canopy edge reaches 1' from the house. This creates shade and an insulation space, but keeps the branches from rubbing the house or causing mold or mildew problems and provides access space.
* Using trees, shrubs or a trellis or fence to shade the air conditioning unit reduces the air temperature around the unit which make it more efficient. Again, this reduces costs and energy use, and can also increase the life expectancy of the unit.
* Evergreen trees planted on the north side of the house block cold winter winds which reduces the amount of heating required in the winter.
* Trees can also be planted to influence wind movement around and through a house. The idea isn't to reduce winds (as they can help cool the house), but to influence the wind's circulation patterns. This is appropriate for times of the year when temperatures are mild and air conditioning is not needed or when there is no air conditioning. Determine the prevailing wind direction, then plant trees along that pathway to act as a funnel for breezes into the windows, thereby maximizing natural cooling. If there are existing trees, then prune up the low branches to allow the breezes to pass through to the house. If air conditioning is used frequently, then directing winds with tree position can actually increase air conditioning use and thus cost.
* Light-colored construction materials in the landscape (for roofs, fences, decks, and patios) reflect light and don't absorb as much heat; keeping the house and



surrounding living areas cooler. Planting a green roof on the house acts as insulation. Inside temperatures are more even and heating and cooling costs are reduced. Green roofs also significantly lengthen the life expectancy of a roof and reduce stormwater runoff. For more information on conserving energy with the landscape see VCE Publication 426-712.

Maintenance

Landscape maintenance should be assessed in the user analysis and accounted for in the design process. The level of maintenance (low, moderate, high) is subjective and totally dependent on the user. Someone who enjoys working in the yard, may consider pruning, raking leaves, mowing or pulling weeds low or moderate maintenance. Someone who wants a well maintained landscape but can't or doesn't like to do those tasks would probably consider a landscape requiring them high maintenance. Realize that all landscapes need maintenance. New landscapes or recently renovated areas in a landscape will need more as plants get established. Mature or more naturalized landscapes should require less maintenance unless renovation or invasive species control is needed. Landscapes that have more spaces, are more elaborate, are large, are formal, or are heavily used often need more maintenance. A low-maintenance plan is the goal of most homeowners, and that can be achieved through thoughtful design, careful planning, and smart plant choices.

Practices for cost efficiency and lower maintenance:

* Keep the overall design simple.
* Decide which tasks the user can/will do and which

will be hired out.

* Have a small lawn area or none at all.
* Avoid sharp angles, tight corners, and irregular areas that are hard to mow.
* Layer plant canopies (tree, shrub, groundcover) for habitat for beneficial insects and birds.
* Use groundcover covers or natural mulches to reduce weeds and conserve water.
* Use permeable paving in heavily traveled areas to reduce compaction and runoff.
* Provide mowing strips of brick or concrete to edge flower beds and shrub borders.
* Use fences or walls instead of clipped formal hedges for screening.
* Use fewer annuals and more trees, shrubs, perennials and bulbs for color.
* Use annuals in small amounts for accent in highly visible areas.
* Select plants well adapted to the site conditions, with pest resistance (including any turf).
* Do not have an irrigation system.
* Group plants with similar water requirements.
* Use plants that have low debris (pine cones, leaves, fruit, sap, etc.)
* Avoid aggressive plants (spread quickly or seed prolifically)
* Scout frequently to catch any problems early.

Themes

A theme is an idea or concept. There are as many themes for landscapes as there are gardeners and designers. An entire landscape can be designed around one theme, or the design can incorporate several themes. Theme can be based on particular historic periods, location, plant species, colors, architectural or gardening styles, hobbies, etc.

Examples of Garden Themes	
Rose or bulb	Butterfly or pollinator
Water or bog	Topiary
Rain garden	Medicinal
Herb or vegetable	Seaside
Tropical	Fragrance or texture

Examples of Garden Themes	
English cottage	Winter interest
Victorian or Colonial	Native plant
Meditation	Evening or night
Cut flower	Edible landscape
Rock or xeriscape	Japanese
Wildlife habitat	Sculpture

Study Questions

16. Specifications for plants in a planting design do NOT include: a) a specific cultivar or variety; b) height; c) seasonal interest; d) maintenance required

17. A planting design: a) can be done without knowing the exact plants; b) can be done in phases; c) should incorporate site and user information; d) all of the above

18. Which is NOT a low- maintenance landscape practice: a) permeable paving; b) pest resistant plants; c) large turf/lawn area; d) mulch & groundcovers

19. Rose, meditation, butterfly, and Victorian are types of _____ gardens.

20. Landscapes can help conserve energy by: a) using tree canopies to shade the house; b) using light colored surfaces to reflect light; c) using green roofs for insulation; d) all of the above

Answers:
16 - a; 17 - d; 18 - c; 19 - theme; 20 - d

References

Virginia Cooperative Extension Publications: www.ext.vt.edu

430-019 Selection and Use of Mulches and Landscape Fabrics

430-024 Trees for Problem Landscape Sites — Trees for Hot Sites

430-025 Trees for Problem Landscape Sites — Screening

References

430-026 Trees for Problem Landscape Sites — Wet and Dry Sites

430-027 Trees and Shrubs for Acid Soils

430-031 Trees and Shrubs that Tolerate Saline Soils and Salt Spray Drift

426-043 Rain Garden Plants

426-070 Backyard Wildlife Habitats

426-087 The Effect of Landscape Plants on Perceived Home Value

426-202 Planning the Flower Border

426-220 Patriotic Gardens: Bulbs for a Red, White, and Blue Spring Garden

426-223 Patriotic Gardens: Red, White, and Blue Native Plants

426-312 Planning the Vegetable Garden

426-604 Selecting Landscape Plants: Rare and Unusual Trees

426-605 Selecting Landscape Plants: Conifers

426-607 Selecting Landscape Plants: Broad-leaved Evergreens

426-609 Selecting Landscape Plants: Ground Covers

426-610 Selecting Landscape Plants: Shade Trees

426-611 Selecting Landscape Plants: Flowering Trees

426-616 Guide to Water-wise Landscaping

426-617 Planting on Your Septic Drain Field

426-712 Conserving Energy with Landscaping

BSE-145NP ENERGY SERIES: What about Landscaping and Energy Efficiency?

426-713 Creating a Water-wise Landscape

426-716 Landscaping for Less in the Landfill

426-719 Selecting Turfgrass

426-721 The Value of Landscaping

426-724 Mulching for a Healthy Landscape

426-840 Small Fruit in the Home Garden

426-841 Tree Fruit in the Home Garden

430-300 Virginia Firescapes: Firewise Landscaping for Woodland Homes

450-236 Problem-free Shrubs for Virginia Landscapes

450-237 Problem-free Trees for Virginia Landscapes

3005-1446 Introduction to Cold-Hardy Tropicals for Virginia Landscapes

CSES-17NP Virginia Turfgrass Variety Recommendations

CSES-41NP A Lawn To Dye For - How to Create a Perfect Lawn: Choosing The Right Grass

HORT-59NP For the Birds, Butterflies & Hummingbirds: Creating Inviting Habitats

HORT-84P Selecting Plants for Virginia Landscapes: Showy Flowering Shrubs

Other Resources:

Books

The Plant Growth Planner, Caroline Boisset, ISBN 0-13-681230-9

The Principles of Gardening, Hugh Johnson, ISBN 0-671-50805-9

Taylor's Guide to Gardening in the South, ISBN 0-395-59681-5

The New York/Mid Atlantic Gardener's Book of Lists, ISBN 0-87833-261-8

Best Plants for Hampton Roads A Landscape & Garden Companion, ISBN 0-9726455-0-0

Bringing Nature Home, ISBN 978-0-88192-992-8

The Living Landscape, ISBN 978-1-60469-408-6

Sustainable Landscaping for Dummies, ISBN 978-0-470-41149-0

Conservation Landscaping Guidelines, ISBN 978-1-49362-497-3

The Essential Garden Design Workbook: Second Edition, ISBN 978-0-88192-975-1

Web

Landscape for Life - http://landscapeforlife.org/

USDA Hardiness Zones - http://planthardiness.ars.usda.gov/PHZMWeb/Default.aspx

US National Arboretum - http://www.usna.usda.gov/

VA Dept. of Conservation & Recreation (native plants) – http://www.dcr.virginia.gov/natural_heritage/nativeplants.shtml

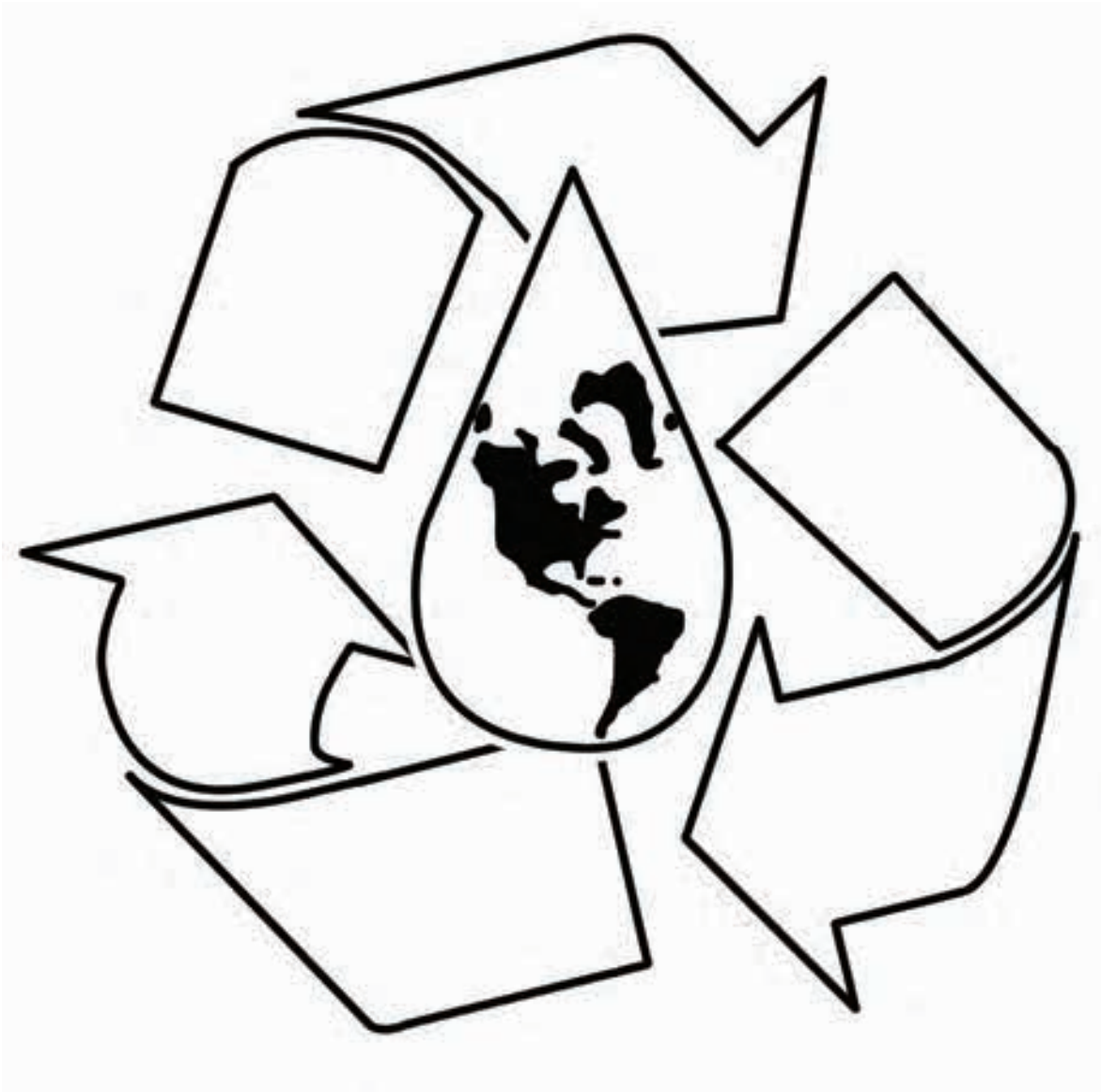
Virginia Native Plant Society - http://vnps.org/

State Arboretum of Virginia - http://blandy.virginia.edu/arboretum

Chapter 19
Water Quality
& Conservation

Water Quality & Conservation

Chapter 19



Water Quality & Conservation

Chapter 19

Revised by *Laurie J. Fox, Horticulture Associate, Horticulture Department, Hampton Road AREC (2015) Original Chapter Water Quality and Conservation, Chapter 16, prepared by Susan D. Day, Research Associate, Horticulture*

"When the well's dry, we know the worth of water." Benjamin Franklin

Water is essential. People cannot live without it, but they also cannot continue to view and use water the way that they currently do. Water is a priceless limited resource and should be treated as such. The earth's population continues to grow rapidly, and weather patterns and climate continue to change; increasing the demand for and stress on water supplies. Water shortages are becoming more frequent and severe, and water use restrictions are now permanent in many parts of the world and across the United States. Regulations governing water quality protection and water quantity conservation are more numerous and stringent than ever before. For these reasons, it is everyone's responsibility to be a good steward of this essential, invaluable and finite resource.

Contents

Water Quality History & Laws

Federal

1970
The U.S. Environmental Protection Agency (EPA) was created in order to control pollution and enforce laws regarding water, air and land.

1972
Congress passes the Clean Water Act (CWA). The act is the cornerstone of surface water quality protection in the United States. (The Act does not deal directly with groundwater or with water quantity issues.) The act includes regulatory and non-regulatory tools to reduce direct pollutant discharges into waterways, finance municipal wastewater treatment facilities, and manage polluted runoff with the goal of restoring and maintaining the chemical, physical, and biological integrity of the nation's waters so that they can support "the protection and propagation of fish, shellfish, and wildlife and recreation in and on the water".

1974
The Safe Drinking Water Act is passed, requiring the EPA to establish national standards for contaminants in drinking water systems.

1990
The Coastal Zone Act Reauthorization Amendments (CZARA) Section 6217 requires states and territories with approved Coastal Zone Management Programs to develop Coastal Nonpoint Pollution Control Programs.

1998
President Clinton announces a Clean Water Action Plan to restore and protect America's waters. The EPA creates an internet web site that allows citizens to obtain environmental information about their communities by entering a zip code.

2000
The Beaches Environmental Assessment and Coastal Health (BEACH) Act amendment to the Clean Water Act authorizes EPA to award grants to eligible states, territories and tribes to develop and implement beach water quality monitoring and notification programs for coastal and Great Lakes recreational beach waters and programs to inform the public about the risk of exposure to disease-causing microorganisms in the water at the nation's beaches.

2002
Public Health Security and Bioterrorism Preparedness and Response Act (Bioterrorism Act) addresses drinking water security and safety. Title IV requires drinking water systems serving more than 3,300 persons to conduct assessments of their vulnerabilities to terrorist attacks or other intentional acts.

2009
The EPA revamps and re-enforces the rules and regulations of the Clean Water Act. The new goals are to improve the protection of our nation's water quality, raise the bar in federal and state performance, and enhance public transparency.

State

Virginia is in EPA Region 3 (Mid-Atlantic) which also includes Delaware, District of Columbia, Maryland, Pennsylvania, and West Virginia.

Chesapeake Bay Total Maximum Daily Load (TMDL)
TMDL is a historic and comprehensive "pollution diet" that involves all the states in EPA Region 3 plus a part of New York state. A TMDL is used to determine the maximum amount of pollution a water body can assimilate without violating water quality standards. The Bay TMDL includes pollution from permitted point sources (waste water), and nonpoint and natural sources

(landscapes, wildlife, etc.). The TMDL, the largest ever developed by EPA (encompassing a 64,000-square-mile watershed), identifies the necessary pollution reductions from major sources of nitrogen, phosphorus and sediment. The TMDL was established in 2010 with rigorous accountability measures to initiate sweeping actions to restore clean water in the Chesapeake Bay and the region's streams, creeks and rivers. It is based on watershed implementation plans (WIPs) for reducing pollution going into the bay prepared by the 6 states and the District of Columbia; submitted to and approved by EPA. Specifically, the TMDL sets Bay watershed limits of 185.9 million pounds of nitrogen, 12.5 million pounds of phosphorus and 6.45 billion pounds of sediment per year – a 25 percent reduction in nitrogen, 24 percent reduction in phosphorus and 20 percent reduction in sediment. In 2012, the jurisdictions submitted Phase II implementation plans designed to strengthen the initial cleanup strategies and reflect the involvement of local partners. They also submitted a set of two-year milestones outlining near-term restoration commitments. The Bay TMDL is a key part of an accountability framework to ensure that all pollution control measures needed to fully restore the Bay and its tidal rivers are in place by 2025, with practices in place by 2017 to meet 60 percent of the necessary pollution reductions. For more information go to http://www.epa.gov/reg3wapd/pdf/pdf_chesbay/BayTMDLFactSheet8_26_13.pdf

State Water Control Board

The board is one of three regulatory boards (Air Pollution Control Board, State Water Control Board and Waste Management Board) that is composed of Virginia citizens appointed by the Governor. The board is responsible for adopting many of Virginia's environmental regulations including state mandates on water quality in the Clean Water Act and the Code of Virginia. The board reports to the Virginia General Assembly.

The State Water Control Law (Code of Virginia)

The law requires the Board to establish standards of water quality and to modify, amend or cancel any such standards or policies every three years. It also requires the Board to hold public hearings periodically for the purpose of reviewing the water quality standards. The Virginia State Water Control Law incorporates the Chesapeake Bay Preservation Act, Erosion and Sediment Control Law, Virginia Stormwater Management Act, and General Permit for Discharges of Stormwater from Construction Activities.

Virginia Antidegradation Policy

Virginia's antidegradation policy protects water quality at three levels or "tiers." Tier 1 specifies that existing instream water uses and the level of water quality to protect the existing uses shall be maintained and protected. This means that, as a minimum, all waters should meet adopted water quality standards. Tier 2 protects water that is better than specified water quality standards. Only in limited circumstances may water quality be lowered in these waters. Tier 3 are exceptional waters where no new, additional or increased discharge of sewage, industrial wastes or other pollution are allowed. These waters must be specifically listed in the regulation.

Virginia Water Quality Standards

These standards are part of the State Water Control Law. They consist of statements that describe water quality requirements. They also contain numeric limits for specific physical, chemical, biological or radiological characteristics of water. These statements and numeric limits describe water quality necessary to meet and maintain uses such as swimming and other water-based recreation, public water supply, and the propagation and growth of aquatic life. Standards include general and specific descriptions, because not all requirements for water quality protection can be quantified or numerically defined. The standards are adjusted constantly to reflect changes in law, technology and information available to the Water Board and DEQ.

Virginia Department of Environmental Quality (DEQ)

DEQ administers Virginia's laws and the regulations approved by the State Water Control Board through two Divisions (Water Permitting and Water Planning) with the goals of improving and protecting Virginia's streams, rivers, bays, wetlands and ground water for aquatic life, human health and other beneficial water uses.

Watersheds

What Is a Watershed?

Image courtesy VCE publication 426-041

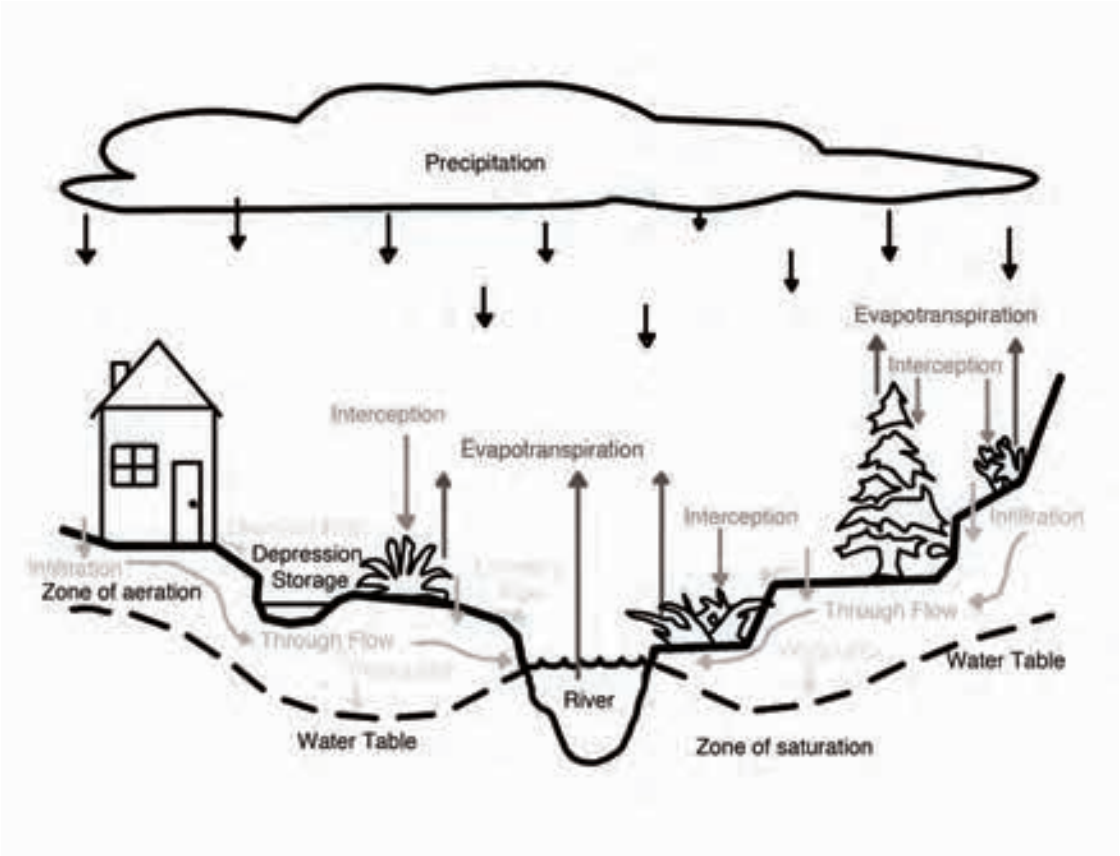
A watershed is an area of land that drains to a lake, river, wetland, or other waterway. When precipitation occurs, water travels over forest, agricultural, or urban/suburban land areas before entering a waterway. Water can also travel into underground aquifers on its way to larger bodies of water. Together, land and water make up a watershed system. Watersheds can be any size. For example, the Chesapeake Bay Watershed drains upstream land from a 64,000 square mile area in six states. Local watersheds drain much smaller areas, perhaps only a few acres in size.

Virginia Watersheds

Everyone lives in a watershed, and Virginia has nine major watersheds with numerous sub-watersheds. Virginia's watersheds ultimately drain into three main bodies of water. Nearly two-thirds of Virginia drains into the Chesapeake Bay. Southeastern and south-central Virginia drain into the Albemarle Sound in North Carolina. Rivers in Southwest Virginia flow to the Mississippi River and then to the Gulf of Mexico.

Why Are Watersheds Important?

Healthy watersheds are a vital component of a healthy environment. Watersheds act as a filter for runoff that occurs from precipitation and snowmelt, providing clean water for drinking, irrigation, and industry. Recreation and leisure are important components of watersheds, with many possibilities in Virginia for boating, fishing, and swimming. Watersheds also support a variety of plant and



wildlife communities. Scientists and community leaders recognize the best way to protect our water resources is to understand and manage them on a watershed basis. Human activities as well as natural events that occur in a watershed can significantly affect water quality and quantity.

There are nine major watersheds in Virginia. Some flow to the Chesapeake Bay. Some go directly into the Atlantic Ocean. Others flow to the Ablemarle Sound in North Carolina. Some rivers in Virginia even flow to the Mississippi River and then to the Gulf of Mexico.

1. Shenandoah-Potomac
2. Rappahannock
3. York
4. James
5. Eastern Shore of the Chesapeake Bay and coastal rivers
6. Chowan
7. Roanoke
8. New
9. Tennessee-Big Sandy

Water Cycle

Earth's water is always cycling; constantly moving and changing states between liquid, vapor, and ice. The water cycle, also known as the hydrologic cycle, describes the continuous movement of water on, above, and below the surface of the Earth. Development negatively impacts the water cycle by 1) stripping plant cover, and 2) replacing it with impervious surfaces (roofs, roads and parking lots) that prevent infiltration of precipitation. The result is the generation of high volumes of runoff from urban development that causes erosion and flooding downstream.

Study Questions

1. The Clean Water Act deals with: a) surface water; b) aquifers; c) ground water; d) wells

2. The three pollutants covered under the Chesapeake Bay TMDL are: a) bacteria, nitrogen & sediment; b) nitrogen, sediment & phosphorus; c) heavy metals, bacteria & sediment; d) pathogens, nutrients, & heavy metals

3. Who administers Virginia's water regulations: a) the Virginia Water Control Board; b) DEQ; c) Virginia Soil & Water Conservation Districts; d) EPA

4. Watersheds: a) filter water; b) drain to a body of water; c) are made up of land and water; d) all of the above.

5. The water cycle: a) is also called the hydrologic cycle; b) is negatively impacted by development; c) is constantly changing; d) all of the above

Answers: 1 - a; 2 - b; 3 - b; 4 - d; 5 - d

Surface, Ground, & Storm Waters

Surface water

Surface water is water on the earth's surface or that has not penetrated much below the ground such as in a stream, river, lake, wetland, reservoir, stormwater pond, or ocean.

Surface water is replenished by precipitation, and is lost through evaporation, infiltration into the ground where it becomes ground water, and use by plants or by man.

Groundwater

Groundwater is water located beneath earth's surface, held underground in the soil and in pores and crevices in rock (aquifer)

Stormwater

Stormwater is water that originates during precipitation events and snow/ice melt; stormwater can soak into the soil (infiltrate), be held on the surface and evaporate, or run off into surface water bodies

Surface, ground, and storm waters are often viewed and treated as separate entities, but they are part of an interconnected system where each impacts the other and humans impact them all. Depletion of surface and ground water sources is caused by over-use. Flooding, erosion and reduced groundwater recharge are caused by development (impervious surfaces). Water pollution is caused by carelessness, irresponsible behavior, and a lack

of understanding that water is a finite resource critical to our survival.

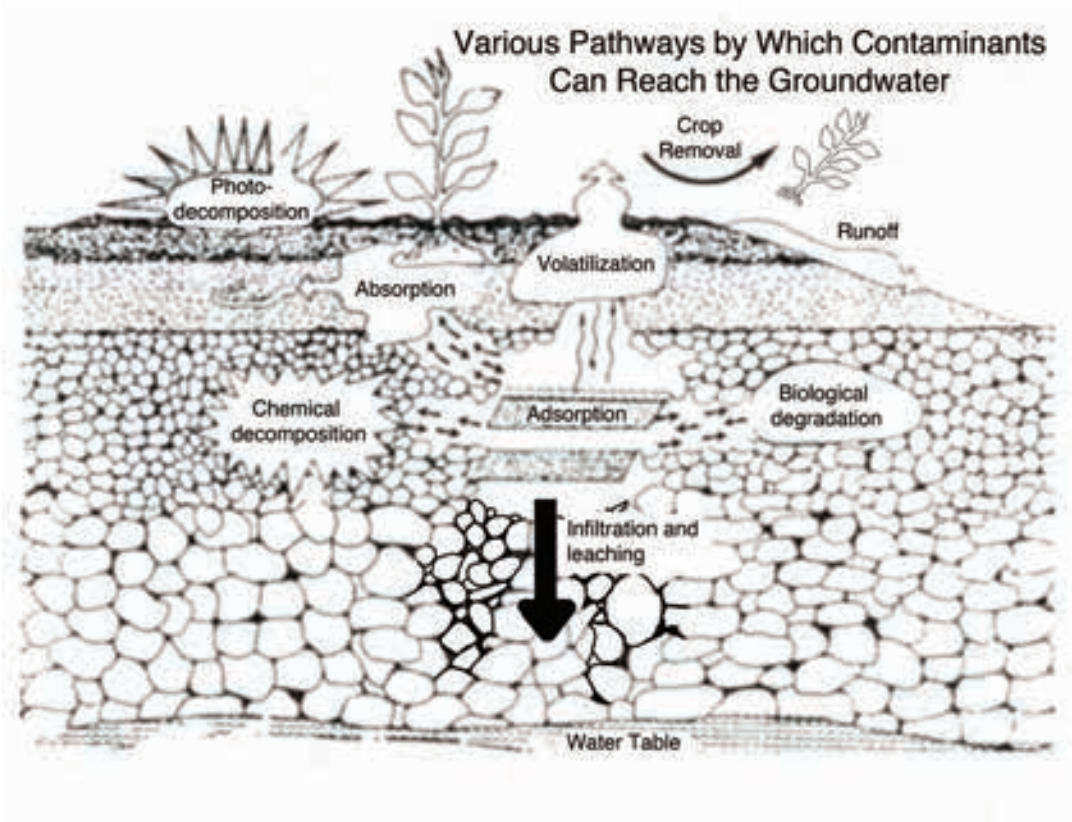
Wells are holes or shafts sunk into the earth to obtain water. One in five Virginians, or nearly 1.7 million people, rely on private water supplies such as wells, springs, and cisterns for their household water (VT/0715/BSE-187NP). In the U.S., all water systems (with the exception of a few private wells) are regulated under the Safe Drinking Water Act, which requires routine water testing and treatment. However, people with private water supplies are responsible for all aspects of system management, including water testing, interpreting test results, and addressing problems. Through the Virginia Household Water Quality Program, Virginia Cooperative Extension provides access to affordable and confidential water testing, interpretation of results, and education about system care and dealing with problems. Testing includes total coliform and E. coli bacteria, nitrate, lead, copper, arsenic, pH, hardness, sulfate, fluoride, iron, manganese, sodium, and total dissolved solids. The cost for analysis is $50 per sample kit. For more information about the Virginia Household Water Quality Program and wells and springs in Virginia, visit www.wellwater.bse.vt.edu.

Water Pollution

Pollution can refer to either contaminants themselves or to the act of contaminating water bodies (surface and ground) when pollutants are discharged (directly or indirectly) into them without treatment to remove harmful compounds.

Pollutants include:

* Nutrients (primarily nitrogen & phosphorus)
* Sediment
* Pathogens (disease causing microorganisms)
* Petroleum products & fuel
* Detergents & solvents
* Pharmaceuticals
* Heavy metals
* Pesticides
* Manufacturing & industrial waste
* Sewage & fecal matter
* Leaves, trash and other debris



Water pollution affects the entire ecosystem. The effect can be acute (one time immediate effect) or cumulative (building up over time). Sometimes the pollution can be cleaned up or inactivated quickly, but most of the time the recovery process is lengthy.

Groundwater and surface water are interconnected parts of the water cycle and both can be contaminated through a variety of mechanisms. When precipitation falls, part of that water is absorbed by plant canopies, part evaporates, part runs off into surface water bodies, and part soaks into the ground. Water that soaks into the ground is held in the soil, taken up by plants or it infiltrates deeper into the soil. The water that reaches the saturated zone (water table) is known as recharge water, and it is needed to resupply groundwater that is continually being brought to the surface through natural springs, wells, plant use, and other means. Pollutants flow with the water either horizontally on the surface or vertically into the ground. When water infiltrates the soil and carries a pollutant with it, it's called leaching.

Water Contamination Mechanisms

* Pollutants in the air fall to the ground with precipitation (atmospheric deposition)
* A pollutant is deliberately discharged into the water
* A pollutant is accidentally discharged into the water
* A pollutant is moved by runoff
* A pollutant attaches to sediment which is then moved by runoff
* Surface water leaches a pollutant into the groundwater
* Contaminated groundwater is pumped into a surface water body

Water pollution categories:

Point source pollution - comes from a single source, typically a spill, a discharge pipe, or an illegal dump of chemicals

Nonpoint source pollution - comes from a large land area, not from one specific location or source; typically from daily and land use activities, collected and concentrated through runoff

Water quality programs, which include both regulatory, voluntary and grant programs, have significantly reduced point source pollution in the United States. Because non-point source pollution is wide spread and is the result of many different activities, it is much more difficult to regulate and reduce.

Examples of pollution include:

* Accumulation of sediment from erosion flowing into the Chesapeake Bay, destroying submerged aquatic vegetation and associated habitat, which then can lead to "dead zones" from lack of oxygen in the water.
* Excess fertilizer in runoff from landscapes creating algae blooms in stormwater retention ponds.
* Raking or blowing leaves or dumping chemicals into a storm drain.
* A pesticide gets into a surface water body and kills fish as a result of not following label directions.
* A pesticide tank accidentally overturns and pesticides leach through the soil and contaminate groundwater.
* Dog waste that is not "scooped" up washes into the water and swimming areas are closed because of high levels of pathogens

Persistence and solubility determine the contamination potential of a chemical.

Persistence

Persistence is the amount of time a chemical remains active before it is degraded or broken down into harmless components. Persistence is measured in a "half-life" which is the amount of time it takes for one-half the original amount of a chemical to be degraded. Chemicals that have a long half-life remain active for a longer periods of time.

Solubility

The ease with which a chemical dissolves and mixes with water is called solubility.

A chemical with a long half-life and high solubility would have the greatest potential for water contamination. Conversely, a chemical with a short half-life and low solubility would not be chemically active as long and would have a reduced risk of water contamination.

Contaminants are inactivated in many ways. They can be diluted by surface water until they are below a harmful level. They can be broken down into harmless components by sunlight (photodecomposition) or by microorganisms (biological degradation) or through

chemical reactions (natural or manmade). Contaminants can change form through volatilization and move into the atmosphere. Finally, they can be absorbed into the plant where they are used, broken down or stored, or they can attach to soil particles or organic matter (adsorption).

Study Questions

6. Water pollutants include: a) pharmaceuticals; b) fuel; c) fecal matter; d) all of the above

7. A chemical with: a) a long half-life & high solubility; b) a short half-life & high solubility; c) a long half-life & low solubility; d) a short half-life & low solubility has the greatest potential for water contamination.

8. Contaminants are inactivated by: a) absorption & adsorption; b) photodecomposition & volatilization; c) crop removal & biological degradation; d) all of the above

9. Ground water is contaminated through: a) runoff; b) evapotranspiration; c) leaching; d) discharge.

10. In the U.S., water systems are regulated under the Safe Drinking Water Act: a) true: b) false.

Answers: 6 - d; 7 - a; 8 - d; 9 - c; 10 - a

Water Quality Standards

Water quality can be evaluated using many standards, including: color, odor, dissolved oxygen content, nutrient levels, aquatic life, pathogens, turbidity, salinity, pH, chlorophyll, sediment, and many more. Standards are used to assess water quality for purposes such as drinking, swimming, irrigation, wildlife and aquatic life health, and food safety (fish and shellfish). Water quality in undisturbed healthy ecosystems is measured and documented using different standards, then water quality in disturbed ecosystems is measured and compared. Standards provide the basis for the regulations governing water quality and the measure of water quality improvement or decline over time.

The Virginia Department of Environmental Quality (DEQ) extensively tests Virginia's rivers, lakes and tidal waters for pollutants. More than 130 pollutants are monitored annually to determine whether the waters can be used for swimming, fishing and drinking. Waters that do not meet standards are reported to the citizens of Virginia and the U.S. Environmental Protection Agency in the Virginia Water Quality Assessment 305(b)/303(d) Integrated Report.

DEQ has developed a list of impaired waters since 1992 that includes segments of streams, lakes and estuaries that exhibit violations of water quality standards. The report details the pollutant responsible for the violations, and the suspected cause and source of the pollutant. Since 1998, DEQ has developed plans, with public input, to restore and maintain the water quality for the impaired waters. Within these plans are "total maximum daily loads," or TMDLs. TMDL is a term that represents the total pollutant a water body can assimilate and still meet standards. For example, the Chesapeake Bay TMDL is based on nutrient (nitrogen and phosphorus) and sediment standards.

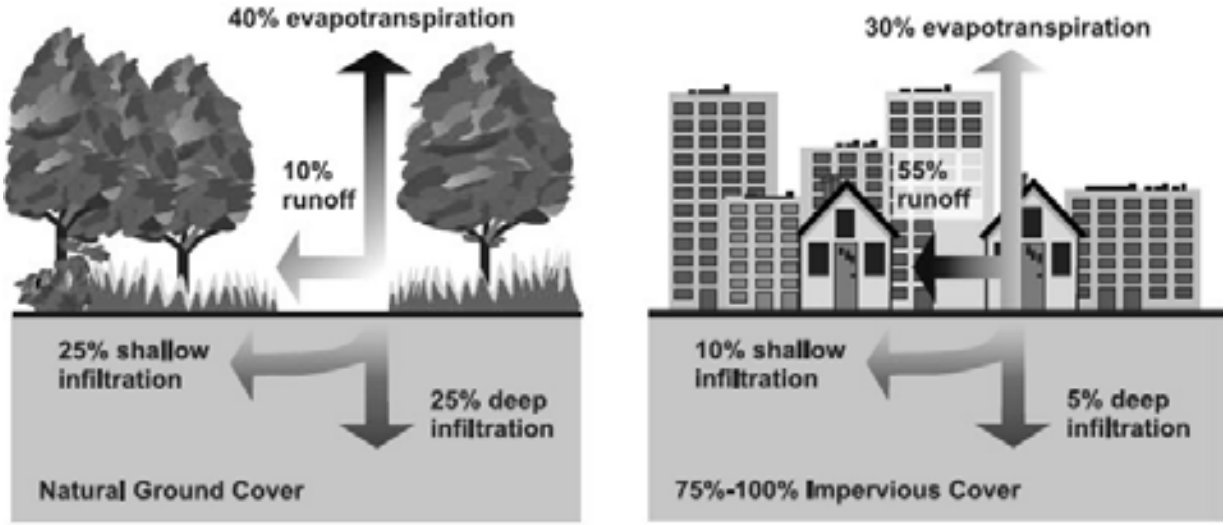
Water Conservation & Protection

How can residential landscapes be smartly designed and used for water conservation and protection? How can small simple practices by individuals have a significant and positive impact on water quality? How can we ensure the state's surface and ground water resources are high quality and plentiful and still have attractive lawns and landscapes? The answer is balance between awareness and action. First there has to be an understanding of the value of water, how the water cycle works, and that water is everyone's business. Then everyone has to do something. Collectively, many small actions by individuals lead to powerful results. There are really only two main water quality issues to focus on:

* Water misuse and waste
* Stormwater management

Statistics

Virginia's average annual rainfall is 38-49 inches depending on the city and region (coastal, piedmont or mountain) of the state (1981 to 2010 data from the NOAA National Climatic Data Center). While the rainfall is generally distributed fairly evenly throughout the year, distinct wet and dry periods do occur.



Increasing impervious surface in a watershed increases runoff and decreases infiltration and evaporation.

Image courtesy epa.gov

- The average American family uses 320 gallons of water per day
- About 30% of those 320 gallons is devoted to outdoor uses
- More than 50% of that outdoor water is used for watering lawns and gardens
- As much as 50% of water used for irrigation is wasted due to evaporation, wind, or runoff caused by inefficient irrigation methods and systems

WaterSense program http://www.epa.gov/watersense *(EPA 2015)*

Storm events are increasing in magnitude and dry periods are becoming longer, possibly due to climate change. With human population comes development and associated impervious surfaces, which replaces the natural vegetation and soil filtering system of the watershed. More development generates more runoff. When water runs across impervious surfaces, pollutants (see the list under "Water Pollution") are collected and carried into storm drains. Runoff water does not go to a treatment facility; instead, storm drains deliver the polluted water directly into waterways and water bodies. Runoff is the biggest contributor to non-point source pollution. The three important runoff components to manage are: volume, velocity or flow rate, and pollutants.

Water-Wise Landscaping

Start with a site analysis. Then use that information to develop a management plan which incorporates water conserving and protection best management practices (BMPs) that meet the site and user goals and that conserve and protect water resources. The plan can be set up as a one year monthly check or reminder list. It can also include long term planning. For example: researching and selecting trees is done in the spring or summer and purchasing and planting in the fall when they are dormant and do not need as much irrigation to get established; the driveway is badly cracked, so it will be replaced with permeable pavers in 2 years.

Calculate the size of the property. Multiply the length x width to get the total square feet. Then add up the square feet of all the impervious surfaces (roofs of the house and outbuildings, driveway, sidewalks, patio, etc.). Rainfall runs off of these surfaces. Divide the impervious surface number by the property size to get the percent (%) of the

property that generates runoff. This calculation assumes that there is 100 % runoff from the impervious surfaces. There is no right or wrong answer, but the higher the %, the more important water management is for the property.

Example			
Property size: 80' x 136' = 10,880 ft^2 (about 1/4 acre)			
Impervious surfaces	House roof	60' x 80'	= 4,800 ft^2
	Driveway	12' x 50'	= 600 ft^2
	Patio	15' x 20'	= 300 ft^2
	Sidewalks	3' x 50'	= 150 ft^2
	Total		= 5,850 ft^2
5,850 ft^2 / 10,880 ft^2 = 54% impervious			

In this example, rainfall runs off of over half of the property. If 45 inches of rain fell in one year, that would be 84,997 thousand gallons of runoff; enough to fill 1,214 standard bathtubs! (rainfall calculation tool http://www.calctool.org/CALC/other/default/rainfall)

Conduct a water quality site analysis. Use the chart on the site analysis form at the end of the chapter to evaluate the landscape practices that impact water quality. This information might come from landscape design documents or a walk around the property. Put a check in the plus column if the practice is existing or being done and a check in the minus column if it is not. Use the comments section to note whether a practice in the plus column could be improved. As with the % impervious number, there is no right or wrong answer. This chart is simply a tool to evaluate what practices could be done better or added to the landscape to improve water management.

Runoff calculation tool

The James River Association is a non-profit organization working to protect and enhance the James River and the 15,000 miles of tributaries that flow through its watershed. They have a runoff calculation tool on their website that can be used to estimate the amount of runoff flowing off a property and how certain practices can reduce it. http://www.esf.edu/ere/endreny/GICalculator/RunoffHome.html

Study Questions

11. Water quality can be evaluated using standards such as: a) dissolved oxygen content; b) sediment; c) nutrient levels; d) all of the above

12. The total amount of pollutant a water body can assimilate and still meet standards is called: a) turbidity; b) TMDL; c) persistence; d) half-life

13. Increasing the amount of impervious surface: a) decreases runoff; b) increases infiltration; c) reduces ground water recharge; d) reduces erosion

14. As much as 50% of the water used for landscape irrigation is wasted due to: a) evaporation; b) system leaks; c), inefficient irrigation methods and systems; d) all of the above

15. A water quality site analysis involves: a) calculating % impervious area; b) planting flowers; c) digging ditches; d) watering by hand.

Answers: 11 - d; 12 - b; 13 - c; 14 - d; 15 - a

Stormwater Best Management Practices (BMPs)

Stormwater BMPs can be used individually or connected together to manage runoff. For example, a downspout can be disconnected from the storm drain so that it runs into a rain barrel or into swale which then connects to a rain garden. A combination of BMPs is frequently used to manage water quality on a site. They can be designed as part of the site development or retrofitted into the site over time.

Remember, the three important runoff components to manage are: volume, velocity, and pollutants. Reduce the volume, slow the velocity, and remove the pollutants.

Healthy soil

A healthy soil acts like a sponge and filter; soaking up stormwater and filtering it as it infiltrates and percolates through the layers into the ground water. Soil texture, organic matter content and pH all affect the movement of pollutants through the soil. Water infiltrates sandy soils quickly and clay soils more slowly. Water should not stand for more than 4 days after a storm; ideally 2 days or less as mosquitos can go from egg to adult in standing water at 7 days. Aeration and incorporation or spreading organic matter on top of the soil (especially in lawn areas) will improve drainage. Soils with a higher organic matter content filter pollutants more effectively. Organic matter promotes healthy microbial populations, which break down pollutants, and many pollutants will adsorb to organic matter particles and become inactivated. Organic matter also provides nutrients to plants which means less

fertilizer is needed. A soil test should be done every 3 years to make sure there are adequate nutrients available for plants and to prevent over fertilization. Soil pH can affect the movement of chemicals, especially fertilizers, through the soil by influencing their availability to plants. In very acidic or very alkaline soils, some nutrients can become unavailable to plants and then may be leached into the ground water. Bare areas should be covered with mulch or vegetation to prevent erosion. Steep slopes should be planted or terraced to prevent erosion. A healthy soil grows healthy plants, which require fewer nutrients and less pest management thus reducing the potential for pollution from fertilizers and pesticides.

Healthy plants

Select plants that are adapted to the site and environmental conditions and plant them correctly, so the roots establish quickly and they require less or no irrigation (after establishment). Use pest resistant plants and scout regularly to catch any pest problems early. Use cultural, biological or mechanical control methods and the least toxic insecticides and fungicides to treat when necessary. This is integrated pest management (IPM), and it significantly reduces the amount of chemicals used and thus the potential for water pollution from them. When pesticides (insecticides, fungicides, herbicides) are necessary, use the product least toxic to the applicator and environment. Read the entire label and follow application instructions carefully. Do not apply pesticides right before an irrigation cycle or rain event as they usually need time to dry. If they wash off, they could have off-target effects on other parts of the landscape or the aquatic ecosystem. Plants should be grouped by their water needs (hydrozones) so that irrigation is used only where necessary and efficiently. For example, impatiens should not be planted next to cactus. Use large trees, understory trees, shrubs and lower growing plants to create canopy layers. Canopies intercept rainfall, absorbing some of it (as much as 80%) and slowing the rest down so it is more likely to soak in than run off when it reaches the ground. Use a mulching mower and leave the grass clippings on the lawn. This is a free and natural source of nutrients and organic matter which keeps the grass healthier and reduces the need for fertilizer. Mowing the lawn at the correct height keeps the grass from thinning, which prevents weeds and reduces the need for herbicides. A healthy dense lawn reduces runoff and erosion.

Irrigation

Irrigation is the application of water to land. Irrigation systems can be expensive to install and require maintenance. Remember to call MISS UTILITY at 811 before digging to install a system. Take the time to design an efficient adaptable system based on the landscape design, user lifestyle and vegetation.

* Overhead irrigation
* Also called high flow, spray or sprinkler irrigation
* Can include rigid pipe, fixed risers, irrigation heads (spray, rotor, and impact)
* Applies water over top of plants simulating rainfall
* Uses a higher volume of water than drip irrigation
* Has a higher potential than drip irrigation for waste from runoff and evaporation
* Problems include: broken line or heads, uneven coverage,
* Can be operated by a controller
* Needs to be checked periodically for problems
* Drip irrigation
* Also called low flow or volume, micro, and trickle irrigation
* Can include soaker hoses, flexible tubing, drip lines or emitters, micro spray
* Applies water to the plant root zone with less volume, evaporation, and runoff
* Problems include: clogged emitters, lines chewed by wildlife, may require a pressure reducer and filter, tripping hazard
* Can be operated by a controller
* Needs to be checked regularly for problems

Trees and shrubs really only need irrigation long enough to get established. Watering bags or a temporary drip system is suitable for those areas. Annuals, perennials, vegetables, and lawns require more and consistent water. Consider reducing the amount of annuals and lawn in the landscape to conserve water as they require the most. Use irrigation heads that spray the exact amount of water exactly where it needs to go and not on impervious surfaces like sidewalks or driveways. Parts of the landscape may need to be re-designed to eliminate unusual shaped spaces that are difficult to irrigate. Sprayer heads or heights may need to be adjusted as plants grow. Set the irrigation timer for watering early in the morning and only 1-2 times a week. The general

recommendation is for 1 inch of water per week during the growing season. Early and infrequent deep watering grows a healthier plant. The foliage is not wet frequently or for long periods of time which reduces diseases. Roots grow strong and deep, and there is very little runoff or loss from evaporation with the hotter temperatures later in the day. Perennials and vegetables often do better with a drip system. Water is used more efficiently than with an overhead spray system, and again, disease problems are reduced. Irrigation systems should have a connected rain sensor so that they don't come on when it is raining. The system timer should be set in the fall for less or no irrigation because plants are dormant and natural rainfall is usually adequate. The system should also be inspected annually for leaks, breaks, broken heads or heads that aren't spraying the correct pattern or amount of water. All these maintenance chores insure the system runs efficiently, reducing waste and especially cost if city water is being used. There are many internet sites with information on designing irrigation systems and on efficient sprayer heads.

Nutrient Management

Nutrient management in the landscape is an important BMP. When fertilizer is spread on impervious surfaces or too much is applied, plants can't utilize it and it becomes a pollutant that either runs off or leaches into the ground water. A soil test is recommended every three years and is the only way to tell what is already there and what is needed. Fertilizer should be applied when: plants are young or newly planted, plants are stressed (from insects, disease, drought, storm or construction damage), or plants are actively growing. Fertilizers vary tremendously in solubility and persistence. A water soluble fertilizer dissolves quickly so all the nutrients are available at one time. Slow release fertilizers are formulated so that the nutrients are inside a capsule. The capsule wall degrades over time releasing the nutrients at a slow steady rate. Slow release fertilizers can last from 3 to 18 months. Synthetic fertilizers generally have higher nutrient values than organic fertilizers, so it takes more organic product to get the same application rate. Incorporating fertilizer into a planting bed or hole and using slow release or organic fertilizers reduces the potential for pollution by putting the nutrients at the root zone where they are easily accessible and less likely to run off or leach. Pet waste is a pollutant source that is frequently overlooked. Excrement contains not only nutrients, but pathogens as well. If it is not collected and disposed of properly, runoff carries it into waters used for drinking and swimming where it can cause health problems.

Runoff

Runoff can collect a wide variety of pollutants and carry them long distances and into natural water bodies. Runoff volume and velocity can cause water levels to rise quickly and forcefully, resulting in erosion of stream and pond banks and sediment transport. In addition to the above practices, runoff volume, velocity and pollutants can be addressed by harvesting or by using other BMPs that

spread out and slow down the water; giving it a chance to infiltrate, evaporate or have pollutants removed before moving into natural water bodies. (Reference VCE pubs in resources list for more detailed information on these practices)

How to Calibrate an Overhead Irrigation System

- Use 4-6 rain gauges or straight-sided cans (soup, coffee). If using cans, make sure all are the same shape and size.
- Place the rain gauges or cans in a scattered pattern in the area being irrigated
- Run the irrigation system for 15 minutes
- Measure the amount of water in each gauge or can to the nearest 1/8-inch
- If the amounts in each container are NOT close to the same amount, check for leaks and adjust the spray heads for more even coverage. Repeat steps above.
- If the amounts in each container are close to the same amount, then add the amounts together and divide by the number of containers to get the average depth of water collected.
- Multiple the average depth of water times four to determine the irrigation rate in inches per hour.
- Use the chart to determine the amount of time to run the irrigation system to apply the desired amount of water

Time required to apply water for a given irrigation rate

	Irrigation Rate (inches of water applied/hour)			
	0.5”	1”	1.5”	2”
Water to Apply	Minutes to Run			
1/2”	60	30	20	15
3/4”	90	45	30	23
1”	120	60	40	30

If runoff occurs before the irrigation cycle is finished, then the timer should be reset for a split application: irrigate for half the time, wait 2-4 hours then irrigate the rest of the time remaining. Do this in the morning before daytime temperatures and sunlight cause evaporation.

Rain barrels

Rain barrels or cisterns are an old practice used to collect/harvest rainwater from roofs for later use. Roofs are used because the water running off a roof generally has fewer pollutants than water running off roads, parking lots and landscapes. One inch of rain falling on a 1000 square foot roof generates 623 gallons of runoff. Be sure to calculate the runoff volume when sizing a cistern or deciding how many rain barrels are needed. Rain barrels can be connected to each other in order to store more water, but always have an overflow plan. Remember that roofs are often slanted or sectioned to run into different downspouts. Stored water should be used or treated before 7 days to prevent mosquitos. The systems should be inspected regularly for debris or sediment buildup and cracked or leaky parts or connections. Water from rain barrels can be used for irrigating plants, washing cars and pets, and filling bird baths and water gardens. Many cities and environmental groups sell or offer make-your-own rain barrel workshops. Rain barrels vary in size, shape and color but generally hold 40-50 gallons and cost $70-$150. Larger more complex systems can cost hundreds to thousands of dollars. Rebates, water bill credits or other incentives are often available for people who install rain harvesting systems in an effort to reduce the volume of stormwater going into aging and over-burdened drainage systems.

Swales

A swale is a shallow and wide channel that moves water slowly from point A to point B allowing it to infiltrate or evaporate along the way, unlike a ditch; which is narrow and deep and moves water quickly from point A to point B. Swales are generally less than 12 inches deep and have vegetation growing in them. They require permeable soil, little space, grading for water flow, and maintenance to keep the vegetative cover dense and trash and debris cleaned out. Swales act like shock absorbers by reducing the initial volume and velocity of runoff flow.

Rain gardens

A rain garden (bioretention) is a shallow landscaped depression that filters polluted stormwater before it evaporates, evapo-transpires through the plants, or percolates through the soil into the groundwater. Basically, imagine a landscaped puddle. A rain garden has three planting zones (high, middle, & low), with low being wettest the longest. Runoff should move out of the rain garden within four days. If drainage is poor, then aeration or an underdrain or dry well can be used to improve water infiltration. At least five percent of the impervious area should drain into the rain garden to make it worth doing cost and labor wise. The depth of a rain garden is approximately six inches. Usually they are dug and graded deeper, 12-24 inches, because organic matter is added, plant root balls displace soil, and mulch is added to the top; which all raise the level. The gardens can be placed at any point along the runoff pathway. One large rain garden or several small ones connected together can be used depending on the available space and landscape design. Always plan for an overflow event. Many rain garden plant lists recommend using natives. Plants should be spaced so that the canopies touch and provide a solid cover to prevent weeds. They generally establish quickly and need to be divided about every 3 years. Mulch should be added sparingly after the

establishment period, because adding it every year will raise the level and the garden will not hold enough water to be effective. After establishment, maintenance is minimal and mainly involves removing invasive weeds, tree seedlings, trash, and debris. The most comprehensive resource for residential or small-scale rain gardens in Virginia is the Rain Gardens Technical Guide from the Virginia Department of Forestry www.dof.virginia.gov. Larger rain gardens that are used for commercial sites are typically engineered and often include underdrains if underlying soils have low infiltration rates. These larger rain gardens are known as "bioretention systems".

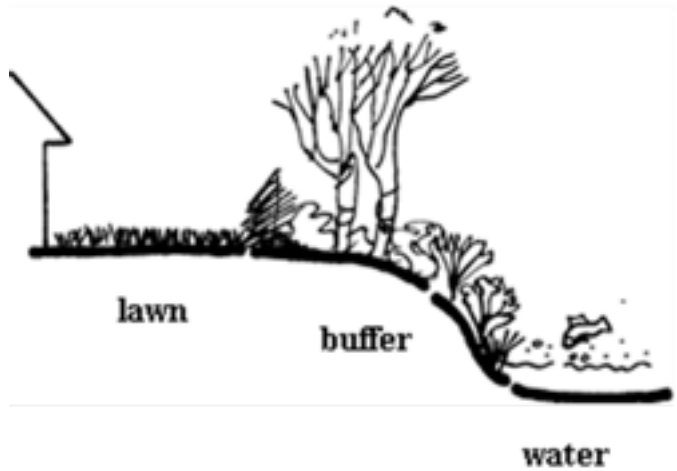
What size should the rain garden be?
To calculate the area needed for a rain garden, divide the number of square feet of impervious surface draining into it by 20. (This calculation assumes all surfaces are 100% impervious)

$$\frac{600\ ft^2\ (driveway) + 2000\ ft^2\ (half\ the\ roof)}{20} = 130\ ft^2\ (size\ of\ rain\ garden)$$

Buffer Zones
A buffer zone (riparian buffer) is an area of vegetation adjacent to a body of water. It functions similar to a rain garden with high, medium, and low planting zones.

Buffers:

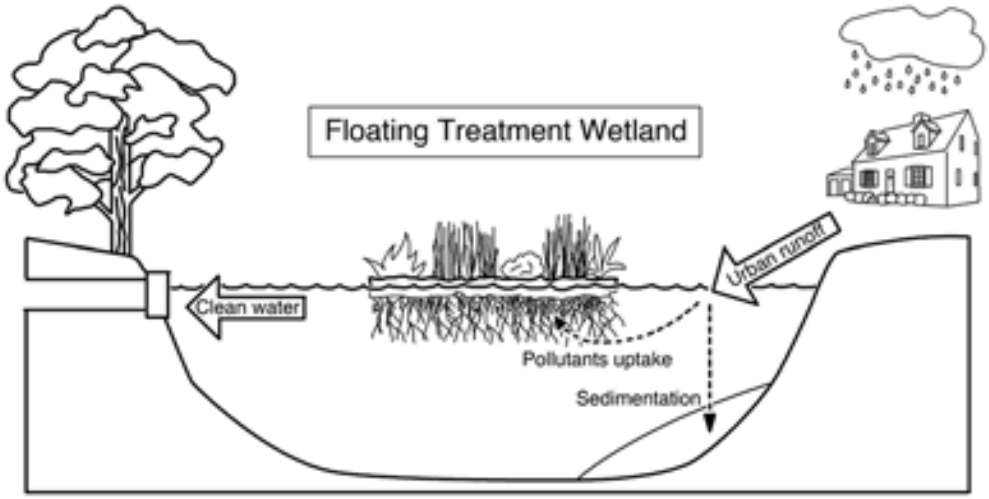
* Slow down & spread out runoff
* Filter sediment, nutrients, & pollutants
* Stabilize the shoreline & prevent erosion
* Provide food & habitat for wildlife
* Add visual & species diversity
* Help moderate flooding



Buffer zones are unique for each location, and can be formally landscaped, naturalized, or anywhere in between. Buffer width can range from as little as 5' to over 100'. No formal design is required. They can be easily created in residential or commercial landscapes along fresh or brackish/salt water. A combination of woody and herbaceous plants is recommended. Most buffer zones are low maintenance. Buffer zones have the biggest impact on improving water quality for the least amount of money, effort, and long term maintenance.

Rooftop or downspout disconnect
Rooftop or downspout disconnect and rain chains are practices that slow runoff velocity. Sometimes downspouts connect directly into a pipe that runs into the storm drain. Disconnecting the downspout from the pipe and redirecting the runoff into a swale, a rain garden or into the landscape treats pollutants at the beginning of the runoff pathway and prevents erosion and stream blow out from high volumes and velocities of runoff. Rain chains take the place of downspouts. They also slow the velocity of the runoff and can be connected from the gutter to a swale, a rain barrel or a rain garden. These practices can be used on any residential or small commercial building as long as the site can handle the volume of runoff and it is directed away from the building foundation. Rain chains and extension pipes for downspouts are inexpensive. Maintenance involves keeping the gutters clear of debris to prevent clogging the downspout or rain chain.

Permeable paving
Permeable paving includes pervious concrete, porous asphalt and interlocking concrete pavers. Stormwater infiltrates into pores in the concrete and asphalt or into joints between the pavers instead of running off. These products are most suited for low-traffic-load and



parking areas, and for pedestrian traffic areas. They are also used on certain highways to prevent hydroplaning. These pavements consist of several layers, including the pervious top layer and underlying layers of gravel or stone that create a stormwater storage reservoir. The pavement depth and materials are determined by the amount of runoff storage needed and by amount of traffic. Permeable pavements provide stormwater management through temporary storage of runoff which then infiltrates or through an underdrain, discharges to a stormwater drain. Permeable paving can remove sediments, nutrients, and some metals; however, sediment clogs the pores of these systems. Periodic vacuuming of the surface is necessary to remove sediments and keep the system functioning. These systems can be expensive.

Stormwater ponds

Stormwater ponds can be either wet (retention) or dry (detention). Runoff comes into the pond through storm drains and culverts. This interrupts the runoff pathway which slows the velocity and reduces the volume of runoff from impervious surfaces flowing into natural waterways. The water is stored temporarily while pollutants are removed through settling and biological uptake. Sediments settle to the bottom and vegetation and aquatic organisms filter or break down pollutants over time. A wet pond holds water all the time. When a storm happens, polluted runoff comes into the pond and pushes the clean water out of the pond through an outflow or overflow pipe into natural waterways. Because they retain water for a longer time, wet ponds typically are able to remove more pollutants. Wet ponds should have buffers around the perimeter to stabilize the bank, prevent erosion, and filter runoff coming over land instead of through pipes. The average life expectancy for a wet pond is 15-20 years before it needs to be dredged out so it will continue to hold the desired volume of runoff and not cause flooding. Dredging is very expensive (approximately $100,000 per quarter acre based on the amount of sediment removed, disposal costs, and permits/fees). Maintaining a buffer around the pond to prevent bank erosion and keeping trash and debris out of the storm drains and the pond extend the life of the pond. A dry pond is designed to hold water for a short period of time before allowing the water to discharge to a nearby stream. Between rain events, a dry pond looks like a large, grassy low area. When it rains, the pond fills with water and holds it for 48-72 hours to allow sediment and pollutants to settle out. Because they detain water for a brief time before allowing it to flow out, dry ponds are also called detention ponds. Dry ponds are generally more common, less expensive to install, require less maintenance and may involve less liability for the communities around them. However, they are also the least efficient pond for removal of pollutants. Most stormwater ponds are on commercial or municipal property or are in community "common areas" that are maintained by homeowner associations, civic leagues or property management companies.

Green Roofs

Green roofs (living or vegetated roofs) slow and filter stormwater on top of buildings at the very beginning of the runoff pathway. The system components include plants, a light weight growing media, drainage layer, and a waterproof liner to cover the roof structure. It is much easier to design a green roof for a new building than to retrofit an existing building because of the weight load. In addition to stormwater management, green roofs

insulate the building and extend the roof life and lower urban air temperatures. Green roofs are either intensive; thicker, support a wider variety of plants, heavier, and require more maintenance or extensive; shallow, lighter, and require minimal maintenance. There are many green roof designs and systems available. Periodic irrigation and invasive plant removal is required.

Floating treatment wetlands

Floating treatment wetlands (FTWs) are man-made ecosystems that mimic natural wetlands. FTWs are created using floating rafts that support plants grown hydroponically. The rafts float on a wet pond water surface and are either anchored to the bottom or the shore. They improve water quality by filtering, consuming, or breaking down pollutants from the water. FTWs should be located adjacent to the shoreline or where inflow pipes deliver polluted runoff into the pond so they will intercept the most polluted runoff. FTWs located near the shoreline also attenuate wave action and reduce undercutting and bank/shoreline erosion. Advantages of FTWs include: can be sized to fit into almost any pond or lake, enhances the pollutant-removal effectiveness of existing stormwater wet ponds, provides a sustainable pollutant-removal system and wildlife habitat, can tolerate water-level fluctuations, and improves aesthetics. FTW maintenance includes: removing invasive plants, keeping the anchoring system secure, and harvesting the vegetation for maximum nutrient removal rates. Designs are available for making FTWs or manufactured ones can be purchased. Cost ranges from $1-$24 per square foot.

Storm drain protection

Storm drain protection/cleaning is a simple but effective runoff management practice. A storm drain is a system to carry runoff from impervious surfaces such as streets, parking lots, sidewalks, and roofs to a stormwater pond or natural water body. Do not rake or blow grass clippings or leaves into a storm drain or dump oil or any other chemicals down it. Keep branches, trash and other debris out of it. If the drain gets clogged, it will cause flooding. When a drain is in the landscape, plant low growing evergreen plants around it to slow and filter runoff before it goes into the drain. The plants also keep trash, grass clippings and mulch from washing into the drain.

Subsurface drainage

Subsurface drainage might be needed if runoff does not drain through soils in a timely manner. This type of drainage is sometimes used underneath rain gardens. The two most common types of subsurface drainage are French drains (under drain, drain tile) and dry wells. A French drain is a trench filled with gravel or containing a perforated pipe that redirects surface water and groundwater away from an area. French drains are primarily used to prevent ground and surface water from penetrating or damaging building foundations. They can also be used to distribute water, such as a septic drain field or behind retaining walls to relieve ground water pressure. A dry well (infiltration basin) is an underground structure that collects runoff and allows it to seep into the ground to recharge groundwater. Water flows into a dry well either through gravity or pipes. Dry wells can be manufactured devices with perforated sides and bottom or a pit filled with gravel or rock covered by landscape fabric to prevent sediment from clogging the pores. Dry wells are usually buried completely, so that they do not take up any land area. For example, the dry wells for a parking lot's storm drains are usually buried below the same parking lot.

Study Questions

16. FTWs provide benefits other than pollution removal like: a) wildlife habitat; b) wave attenuation; c) beauty; d) all of the above

17. Rain gardens are designed to store runoff for long periods of time: a) true; b) false

18. Rain barrels and cisterns: a) are ugly; b) are new technologies; c) temporarily store water; d) are bad because they are breeding places for mosquitos

19. Permeable paving: a) includes pervious concrete, porous asphalt & interlocking concrete paver; b) is expensive; c) often has water storage capacity underneath; d) all of the above.

20. Stormwater wet ponds: a) last forever; b) need dredging about every 20 years; c) remove all pollutants; d) have less maintenance than dry ponds.

21. Buffers: a) filter sediment, nutrients, & pollutants; b) stabilize the shoreline & prevent erosion; c) a & b; d) are weedy & shelter rats & snakes.

22. A water-wise landscape design utilizes water effectively by the following methods EXCEPT: a) grouping plants with similar water needs; b) removing unusually shaped areas; c) increasing lawn areas; d) covering bare ground with mulch or

plants.

23. Water movement and retention are influenced by factors such as: a) soil organic matter content; b) vegetation or mulch; c) grading and drainage; d) all of the above

24. Clippings left on the lawn do NOT: a) aid in water retention; b) contribute to nutrients in runoff; c) provide nutrients as they decompose; d) provide organic matter to soil

25. Stormwater wet ponds: a) should have buffers around them; b) need to be dredged about every 20 years; c) provide storage for runoff; d) all of the above

Answers: 16- d; 17 - b; 18 - c; 19 - d; 20 - b; 21 - c; 22 - c; 23 - d; 24 - b; 25 - d

Resources

Websites

Buffers

Chesapeake Bay Program www.chesapeakebay.net/
Virginia Dept. Conservation & Recreation http://www.dcr.virginia.gov
Virginia Institute of Marine Science (salt tolerant plants & living shorelines) www.vims.edu/

Rain Gardens

Virginia Department of Forestry Rain Gardens Technical Guide www.dof.virginia.gov
Low Impact Design Center Rain Garden Design Templates http://www.lowimpactdevelopment.org/
Chesapeake Bay Trust http://www.cbtrust.org/
Chesapeake Bay Foundation http://www.cbf.org/

Rainfall calculation tool

http://www.calctool.org/CALC/other/default/rainfall

Weather information

University of Virginia http://climate.virginia.edu/online_data.htm
NOAA (National Oceanic & Atmospheric Administration) http://www.ncdc.noaa.gov/

VCE Publications

A Glossary of Water-Related Terms 442-758
A Lawn to Dye for - How to Create a Perfect Lawn: Watering the Lawn (video) CSES-35NP
Best Management Practice Fact Sheet 1: Rooftop Disconnect 426-120
Best Management Practice Fact Sheet 5: Vegetated Roofs 426-124
Best Management Practice Fact Sheet 6: Rainwater Harvesting 426-125
Best Management Practice Fact Sheet 7: Permeable Paving 426-126
Best Management Practice Fact Sheet 10: Dry Swales 426-129
Best Management Practice Fact Sheet 14: Wet Ponds 426-133
Creating a Water-Wise Landscape 426-713
Groundwater Quality and the Use of Lawn and Garden Chemicals by Homeowners 426-059
Home Landscape Practices to Protect Water Quality 426-723
How to Plan for and Plant Streamside Conservation Buffers with Native Fruit and Nut Trees and Woody Floral Shrubs ANR-69P
Innovative Best Management Fact Sheet No. 1: Floating Treatment Wetlands BSE-76P
Irrigating the Home Garden 426-322
Pest Management for Water Quality 426-615
Pest Management Guide: Home Grounds & Animals 456-018
Pest Management Guide: Horticultural and Forest Crops (Aquatic Weed Control in Ponds & Lakes Chapter 7) 456-017
Reducing Erosion and Runoff 426-722
Residential Stormwater: Put It in Its Place Decreasing Runoff and Increasing Stormwater Infiltration 426-046
Urban Stormwater Terms and Definitions 426-119
Urban Water-Quality Management: What Is a Watershed? 426-041
Urban Water-Quality Management: Rain Garden Plants 426-043
Understanding the Science Behind Riparian Forest Buffers 420-151

Water Terms & Definitions

Absorption – a process by which pollutants are removed by moving into minute pores or spaces, for example, a plant takes up nutrients or a sponge absorbs water.

Adsorption - the attachment of dissolved or gaseous pollutants to the surface of solids. For example, odors from freezers and refrigerators are adsorbed to baking soda.

Algal bloom - large, visible masses of algae that develop in bodies of water during warm weather. Algal blooms are the result of excessive levels of nutrients (generally phosphorus or nitrogen) in water.

Aquifer - a geologic formation that holds and yields usable amounts of water. The water in an aquifer is called groundwater. Aquifers may be categorized into confined aquifers and unconfined aquifers.

Contaminant - an undesirable substance not normally present, or an usually high concentration of a naturally-occurring substance, in water, soil, or other environmental medium. In more restricted usage, a substance in water that may be harmful to human health.

Drainage - (1) the natural movement of surface water over a land area to a river, lake or ocean (surface drainage), (2) removal of water from a soil using buried pipelines that are spaced regularly and perforated (subsurface drainage).

Erosion - the detachment and transport of soil particles by water and wind. Sediment resulting from soil erosion represents the single largest source of nonpoint source

pollution in the United States.

Eutrophication - the process of nutrient enrichment causing a water body to fill with aquatic plants and algae. Eutrophic lakes often are undesirable for recreation and may not support healthy fish populations. The end result of eutrophication is the death of the lake, as it fills in.

Evaporation - the process by which a liquid is transformed to the gaseous state.

Evapotranspiration (ET) - the process of transforming soil water into water vapor through the combination of evaporation from the soil surface and plant water use (transpiration).

Flood - a temporary condition of partial or complete inundation of normally dry land areas from the overflow of inland or tidal waters or from the unusual and rapid accumulation of runoff.

Groundwater - water that fills voids, cracks, or other spaces between particles of clay, silt, sand, gravel or rock within a saturated zone or formation (aquifer) below the soil surface.

Groundwater recharge - the process where water enters the soil surface and eventually reaches the saturated zone. Recharge varies from place to place due to the amount of rainfall, infiltration rate, and surface vegetation.

Infiltration (percolation) - the process by which water (surface water, rainfall, or runoff) enters the soil.

Infiltration rate - the quantity of water that enters the soil surface in a specified time interval. Often expressed as a volume per unit of soil surface per unit of time (in^3 per in^2 per hour). Soil surface wetness, soil texture, residue cover, precipitation rate, irrigation application, topography, and other factors control the infiltration rate.

Irrigation - the controlled application of water to land to supply plant water requirements not satisfied by rainfall.

Leaching - the removal of dissolved chemicals from soil caused by the movement of a liquid (like water) through the soil.

Nonpoint source pollution (NPS) - pollution originating from diffuse sources on the landscape. Examples include runoff from fields receiving manure applications, runoff from urban landscapes, or roadbed erosion in forestry. It has been estimated that NPS pollution accounts for more than one-half of the water pollution in the United States today.

Nutrient - (1) an element or compound essential to life, including carbon, oxygen, nitrogen, phosphorus, and many others; (2) as a pollutant, any element or compound, such as phosphorus or nitrogen that when present in excessive amounts contributes to abnormally high organic growth in aquatic ecosystems.

Permeability - a measure of the ease with which liquids or gases will move through soil or other porous material. Permeability is a characteristic of the soil media and does not depend on the type of fluid being transmitted.

Point source pollution - pollutant loads discharged at a specific location from pipes, outfalls, and conveyance channels. Point source discharges are generally regulated through the National Pollution Discharge Elimination System (NPDES) permitting procedures established by the EPA. Point sources can also include pollutant loads contributed by tributaries to the main receiving stream or river.

Pollutant - any substance of such character and in such quantities that when it reaches a body of water the effect is to degrade the receiving water perhaps to a point rendering it unfit for some specified designated use.

Pollution - alteration of the physical, biological, chemical, and radiological integrity of water due to human activities, any unwanted contaminating property that renders a water supply unfit for its designated use.

Potable water supply - a source of water that is of adequate quality to be used for human consumption.

Precipitation - rain, sleet, snow, or hail that falls to the earth as the result of water vapor condensing in the atmosphere.

Riparian - pertaining to the banks of a river, stream, or other typically, flowing body of water as well as to plant and animal communities along such bodies of water. This term is also commonly used for other bodies of water, e.g., ponds, lakes.

Runoff - that part of rainfall or snowmelt that does not infiltrate the soil but flows over the land surface toward a

surface drain, eventually making its way to a stream, river, lake or an ocean. It can carry pollutants into receiving waters. Also known as stormwater.

Sediment - in the context of water quality, soil particles, sand, and minerals dislodged from the land and deposited into aquatic systems as a result of erosion.

Transpiration - the physiological process by which water vapor escapes from a living plant, principally through the leaves, and enters the atmosphere.

Turbidity - a measure of the cloudiness or opaqueness of the water expressed in nephelometric turbidity units (ntu). The turbidity is influenced by the amount and nature of suspended organic and inorganic material in water. Typically, higher concentrations of the suspended material equal greater turbidity. The source of turbidity could be sediment (fine sand, silt, and clay), organic material, particles of iron and manganese or other metal oxides, rust from corroding piping, algae, carbonate precipitates, etc.

Watershed - area that drains or contributes water to a particular point, stream, river, lake or ocean. Watersheds are also referred to as basins. Watersheds range in size from a few acres for a small stream basin, to large areas of the country like the Chesapeake Bay Basin that includes parts of six states.

Water table - the depth at which soils are fully saturated with water, the upper surface of an unconfined aquifer.

Water quality standards - a group of statements that constitute a regulation describing specific water quality requirements. In Virginia, water quality standards must have at least the following three components: designated uses, water quality criteria to protect designated uses, and an antidegredation policy. Every state is required to develop water quality standards and revise them periodically.

Well - a deep hole or shaft sunk into the earth to obtain water groundwater

Wetlands - transitional lands between terrestrial and aquatic systems where the water table is usually at or near the surface, or the land is covered by shallow water. Wetlands are those areas where water saturation is the dominant factor determining the nature of soil development and the types of plant and animal communities living in the surrounding environment.

For more complete glossaries go to VCE pub 442-758 or 442-119 at http://pubs.ext.vt.edu

Water Quality Landscape Analysis

Site Date

Total area of site

Total area impervious (roof, driveway, patio, sidewalks)

% Impervious (total impervious / total area)

	PLUS	MINUS	Comments
Soil			
Good drainage			
Aeration of lawn areas			
Soil test every three years			
Organic matter added or adequate			
Bare ground			
Vegetation			
Grouped by water needs			
Layered canopy			
Healthy trees, shrubs, perennials			
Healthy turf (dense with no bare areas)			
IPM practiced			
Recycle/compost grass clippings			
Low maintenance/native plants			
Irrigation			
Drip=plus, Overhead=minus			
Rain sensor on irrigation system			
Zoned system			
Annual system inspection			
Timer reset seasonally			
Runoff			
Rain garden/swale			
Buffer zone			
Rain barrel/storage			
Downspout disconnected			
Erosion			
Permeable paving			
Rain chains			
Storm drain protection/clean			
Fertilizer			
Slow release=plus water soluble=minus			
Based on soil test			
In planting hole/incorporated			
Organic=plus synthetic=minus			
Other			
Pet waste collected			
TOTAL			

Habitat Gardening for Wildlife

Chapter 20

Habitat Gardening for Wildlife

Chapter 20

Prepared by *Carol A. Heiser, Education Section Manager and Habitat Education Coordinator, VA Department of Game and Inland Fisheries (2015)*

Landscaping for wildlife is both an art and a science. Whether we use plants creatively as a form of artistic expression or we design the landscape as merely a utilitarian space, we can sustain the biodiversity around us by planning our gardens with an ecological function in mind. When we plan our surroundings in a way that supports complex interactions between plants and animals, we become more fully connected to nature ourselves.

Habitat gardening is an enjoyable way to more fully appreciate nature while improving the available food, water and cover for birds, amphibians, mammals and other wild creatures in our landscape. Applying the principles of good vegetative structure and horizontal layering as we add plants to the landscape will provide wildlife with beneficial food sources as well as much needed cover from predators, winter winds and summer sun. Nest boxes, water features, brush piles and other amenities will enhance the habitat's value and can be planned as attractive focal points in the garden.

However, as one assesses the existing habitat and makes choices about what plants and amenities to add, care must be taken in the placement of those enhancements, in order to minimize the possibility of attracting "unwelcome" wildlife species. There are no "nuisance wildlife" species; rather, we create the conditions in our landscape that attract wildlife, and sometimes our unwitting choices set the stage for certain wildlife species to become a problem. Therefore, we must plan the habitat garden in a way that balances our need for aesthetics and beauty with the reality of how wildlife will likely use the space as we've designed it.

Contents

Introduction

Habitat Loss and Declining Wildlife Populations

The **decline of wildlife species** is occurring at an alarming, accelerated rate. In 2005, the Virginia Department of Game and Inland Fisheries published a Wildlife Action Plan which identified 925 species of greatest concern, classified into four groups or 'tiers' that describe varying degrees of population declines attributed to habitat loss. Of these, 290 species or 31% are insects, which are an essential part of aquatic and terrestrial food webs.

Wildlife Groups in Virginia (Total Species in Parentheses)	*Number of Species of Greatest Conservation Need*
Mammals (96)	24
Birds (390)	96
Fishes (210)	97
Reptiles (62)	28
Amphibians (82)	32
Mussels	61
Aquatic Crustaceans	61
Aquatic Insects	148
Terrestrial Insects	142
Other Aquatic Invertebrates	34
Other Terrestrial Invertebrates	202
[List does not include marine wildlife, except 1 regularly nesting sea turtle species]	**TOTAL 925 Species of Greatest Concern**

Habitat loss is caused by many factors. The most obvious is development and fragmentation of forest, meadow and wetland habitats, as we continue to grow the economy by building commercial and residential sites. This development brings with it a host of factors that adversely impact the remaining or surrounding habitats, and these

factors include but are not limited to a prevalence of impervious surfaces that contribute to increased erosion and runoff, which carries chemicals and sediments with it, and the extensive use of lawn and other non-native plants in the landscape for ornamentation. There are adverse impacts occurring in the more rural or agricultural areas, too, including the routine use of herbicides and pesticides and 'clean' farming practices that remove hedgerows and large expanses of vegetation, in order to maximize production. In addition, as more land disturbance occurs across all these areas—urban, suburban and rural—we've seen a concomitant proliferation of invasive exotic plant species that compete with native plant communities.

The additive effect of all these factors or pressures on the environment is an overall reduction in the quantity and quality of aquatic and terrestrial habitats, which is the single most important reason that wildlife populations are in decline, across multiple genera and species. The 2015 revised edition of the Wildlife Action Plan therefore places even greater emphasis on habitat conservation by providing summaries of priority actions that local Planning District Commissions can apply on a regional scale.

What can Master Gardeners do at the local level to support the Wildlife Action Plan? Master Gardeners are in a unique position to influence the trajectory of habitat loss by increasing public understanding of this issue. Oftentimes, homeowners and landowners are either completely unaware of or only vaguely familiar with the connection between their landscape practices and the effects of those practices on habitat quality. Continued emphasis in our education outreach programs about good conservation landscaping practices is essential for raising awareness. If we provide consistent, clear messages and simple guidance about how to improve or restore habitat in our communities, then the resulting actions by the public should help to slow—and ultimately, one hopes, to reverse—the trend of declining wildlife species. Conservation begins at home and in the neighborhood, and habitat gardening is a good first step to restoring and sustaining biodiversity.

Habitat Principles

What Wildlife Needs: Vegetative (Biotic) Components

In order to fully understand what wildlife needs, we must begin with plants. Each plant species in a given geographic area has a total number of individual plants that make up a **population**, and the collection of plant populations found in that area form an assemblage known as the **plant community**. A diverse, healthy plant community provides multiple ecological services, such as interception of rainfall, which helps to recharge the groundwater and reduce flooding and erosion. Plant communities also contribute to nutrient cycling, oxygen exchange and carbon sequestration processes. Perhaps one of the most crucial functions of a plant community, in addition to these many benefits, is the life-sustaining support it provides to an associated community of wildlife species. The plant community provides organic matter for a variety of organisms, such as bacteria and fungi, and the plants also provide food and cover for wildlife, including birds, mammals, reptiles, amphibians and insects.

Plant and animal communities live and interact together in varying compositions and in distinct, often complementary relationships to each other. These biologically diverse communities, when combined together with the other non-living (abiotic) elements of the surrounding environment, such as soil, water and sunlight, form a functional system of continuous energy exchange called an **ecosystem**. Forests, wetlands and prairies are examples of ecosystems that contain thousands of plant and animal populations that interact with each other in the context of other landscape components.

Together, these interdependent populations of plants and animals make up countless communities within ecosystems, which give an area its species richness and genetic diversity. **Biodiversity** refers to the variety of genes, species and ecosystems in the aggregate, across the larger landscape.

A habitat is the area within an ecosystem where an animal is able to secure the food, water, cover and space it needs to survive and reproduce. Every wildlife species has specific habitat requirements; but because there are often overlaps of habitat features within a system, there are usually multiple wildlife species that can live in a given habitat. Salamanders, for example, require moist soil and rich organic matter that can be found in forest, riverine and wetland ecosystems. Each of those ecosystems contain multiple habitat components—the tree canopy, boggy low areas, rocky outcrops, etc.—and other wildlife species like frogs and birds will be found in association with the habitats in those ecosystems, too. This means that if we want to restore and sustain biodiversity in the landscape around our home or on our property, we simply

need to "put back" an assemblage of many of the plant species and other elements that would naturally have occurred there, and arrange the plants and those elements in such a way that many wildlife species will be able to take advantage of them and meet their needs for survival.

Habitat gardens are therefore most successful when they support a broad diversity of wildlife species, and the easiest way to achieve wildlife diversity is to choose a variety of plant species that most closely mimic the vegetative structure of a natural system. Plants are the living or biotic component of the landscape, and vegetative or **vertical structure** refers to layers of plants that provide a level of complexity and functionality in their arrangement such that they sustain a broad array of wildlife species.

For example, on the ground plane of an eastern deciduous forest, the first component is the mulch layer, which forms a humus blanket that maintains soil temperature and can protect the ground from erosion. The mulch layer is critical for the decomposition process and supports many insects such as sow bugs, beetles and millipedes. These insects then become food for predatory insects such as centipedes and also serve to feed other wildlife, such as spiders, salamanders, toads, lizards, turtles, small mammals and birds. As the leaf litter and woody debris are broken down through the chewing and shredding of insects, along with the associated decay that's wrought by fungi and bacteria, nutrients are released back into the soil, where plants can take them up again. This continuous recycling of organic matter and replenishment of soil is a most valuable aspect of the mulch layer. Therefore, one of the very first steps in establishing a habitat garden is to retain the leaf litter in the landscape, so as to support a rich assortment of organisms that will form the foundation for a complex food web.

The next layer in our forest example is the **herbaceous layer.** These are plants with green, mostly non-woody stems, and they include species that form the groundcover layer. Groundcovers are plants that creep along the mulch or grow in clumps or masses and provide a protective covering for the soil below. Foamflower, wild ginger, striped wintergreen, sundrops, woodland phlox, columbine and bluebells are some wildflowers or "**forbs**" we might see in the forest setting. In addition to these groundcover plants, the herbaceous layer may also contain a variety of ferns as well as vines, such as crossvine, pipevine, trumpet vine and Virginia creeper. Of special note is that groundcovers in nature are typically much taller than the two to three inches in height we're accustomed to seeing in a conventional lawn. Hence, the herbaceous layer in a productive habitat garden is not likely to be a short carpet but rather a diverse composition of plants of varying heights that simply cover the ground.

Standing above the herbaceous layer but below the taller trees is the **shrub layer** or "sub-canopy" layer. This layer is comprised of flowering shrubs that grow in a wide range of sizes, from as small as two feet for huckleberry or lowbush blueberry; to medium heights of six to 12 feet for deerberry, spicebush, and viburnums; and as tall as 15 or 20 feet for American hazelnut, witch hazel, and rhododendrons.

Overhead is the canopy formed by the tallest plants, the **tree layer**. Some trees are small, only 20 to 35 feet in height, such as pagoda dogwood, paw paw, and redbud. Others grow within a range of 30 to 60 feet in height, such as serviceberry, flowering dogwood, and American holly. The largest trees, such as oaks and hickories, can attain heights of 80 to 100 feet.

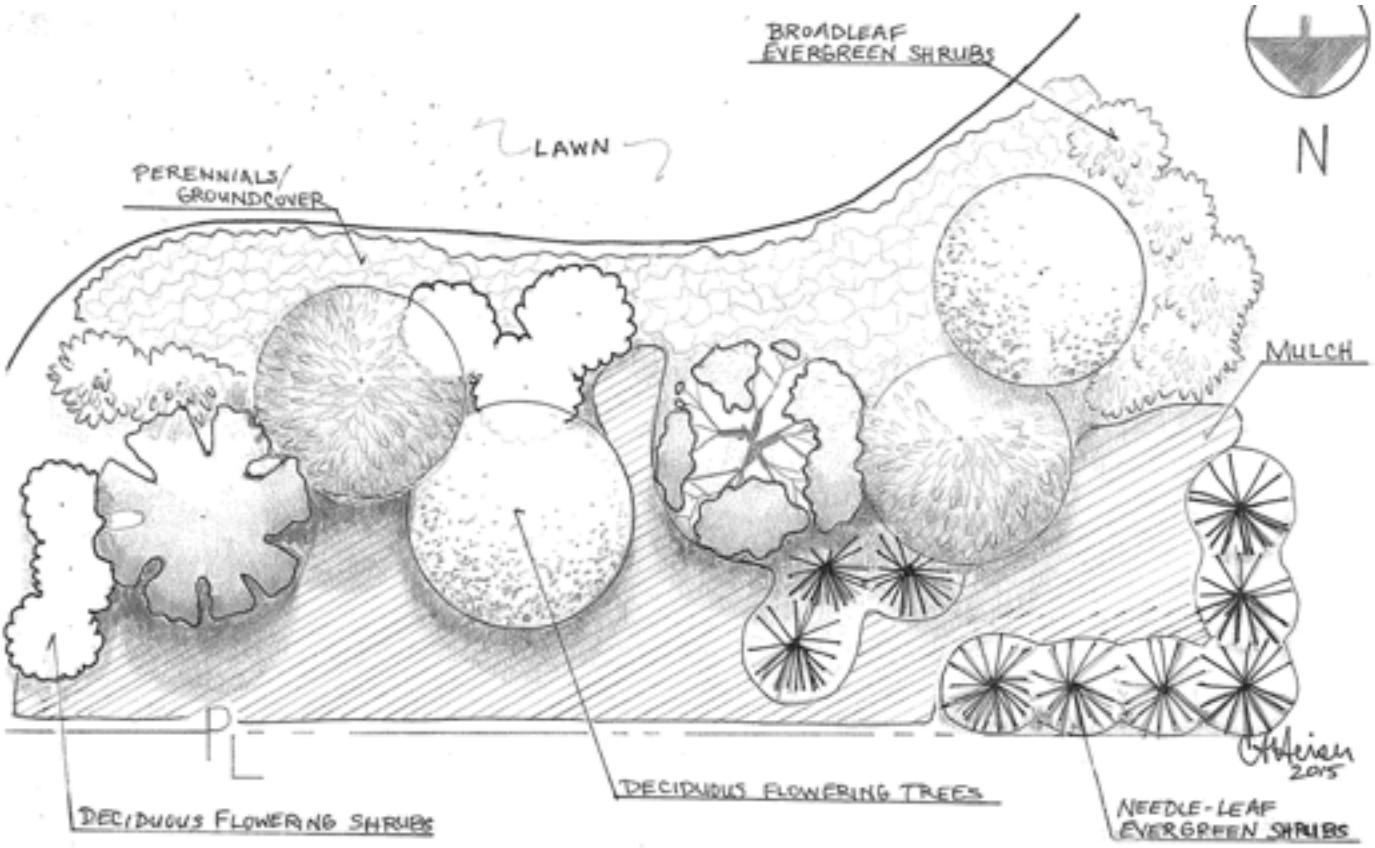
Since most of our built landscapes are typically missing one or more vegetative layers, we can easily support more wildlife species by taking our cues from nature and choosing a palette of plants appropriate for our particular site conditions. For example, if the landscape is primarily wide open lawn, which is devoid of vegetative layers and diversity, we could bring life back to the scene by emulating a meadow habitat made up of sun-loving native grasses and flowers. If our landscape has some tree cover but little else, we could add a shrub layer and herbaceous ground covers. A very wet, boggy area in the yard that's difficult to mow and maintain could be transformed into a mini-wetland with the addition of common elderberry and buttonbush to make up the shrub layer; moisture-loving plants like Joe pyeweed, cardinal flower, and swamp milkweed would form an herbaceous layer.

Another habitat principle we can apply in our landscape planning is **horizontal structure**. Over the course of time, plant species within a given community will naturally change, if there are no interventions such as mowing, grazing or burning. Each stage of change occurs in succession after the one before it, and this process of succession is why a plant community that starts out as a meadow will gradually be replaced with woody species and eventually become a forest in the final stage. The arrangement and interspersion of these different

successional stages in proximity to each other is what provides horizontal structure. We can use basic gardening and maintenance methods to improve horizontal structure by encouraging the growth of particular vegetative types that will mimic different successional stages, which in turn will support different wildlife species. For example, if we stop mowing an area, we can allow woody shrubs and trees to gradually take over and provide a forest-type habitat. If, on the other hand, we already have a woodland and want to attract wildlife species that require grasses and other flowering herbaceous plants, we can create an opening in the canopy and plant perennials and grasses, then keep the successional changes in check by mowing every two to three years, which will prevent woody vegetation from becoming re-established there.

We can also enhance the places where two habitat types come together, referred to as an **edge**. This transition zone is made up of plants from each of the habitats juxtaposed to each other and therefore contains wildlife species from both habitats as well. The greater the number and variety of plant species along an edge, the higher the abundance of wildlife found there. In a landscape setting, we can maximize this edge effect by increasing the number of plant species in the space between where two different vegetative types occur. For example, where a lawn abuts a stand of trees, we can add a shrub layer alongside the trees, to soften the edge. We could even take the edge one step further by adding a layer of herbaceous flowering plants next to the shrub layer. Hence, even a very small space like a townhouse yard can greatly increase its habitat potential by simply adding layers that improve both vertical and horizontal structure.

Similarly, the edges of small creeks and streams that run through the landscape can be enhanced or protected with vegetation. An edge of shrubs and trees planted along a waterway will provide a sheltering buffer for wildlife



HABITAT STRUCTURE: Adding layers of plants to the landscape is a very effective way of increasing available food and cover for wildlife. Flowering perennials form an herbaceous groundcover next to shrubs and small trees of varying heights and texture. Placement of a shrub border is ideal along an edge where the grouping will be adjacent to taller trees. Look for places throughout the property to increase vertical structure, such as along fences, property lines, walkways and driveways. Shrub beds can also be situated in the middle of a lawn to create a habitat island. Arrange the plants in large clusters or groupings, which will maximize the depth of the bed and the interior structure for greater cover, rather than installing a single row of plants.

from human activity, and the roots of the plants will hold the soil and filter runoff that enters the stream – thus improving the aquatic habitat within the stream, too.

Choosing Plants for Wildlife: Interrelationships and Biodiversity

Now that we know how to put a habitat together—arrange it in layers, with lots of structure and diversity—the next step is deciding which plants to use. There's an important case to be made for selecting native plants for wildlife whenever possible.

What's a native plant? According to the Plant Conservation Alliance, a native plant is "…one that occurs naturally in a particular habitat, ecosystem, or region of the U.S. and its territories or possessions, without direct or indirect human actions." The U.S. Fish and Wildlife Service defines native plants this way: "With respect to a particular ecosystem, a species that, other than as a result of an introduction, historically occurred or currently occurs in that ecosystem."

Mounting scientific evidence indicates a strong correlation between the use of native plants in the landscape and insect biodiversity. Dr. Doug Tallamy of the University of Delaware has conducted research that illustrates this correlation. In his landmark book Bringing Nature Home: How You Can Sustain Wildlife with Native Plants [2009 edition, Timber Press], Tallamy cites the following research results:

"In a survey of insect herbivores found eating woody native and alien species in Oxford, Pennsylvania, native plants produced over four times more insect biomass than alien plants produced. This difference resulted entirely from the inability of insects with chewing mouthparts to eat alien plants. (p. 328)

"In a comparison of the diversity of herbivorous insects on native and alien woody plants in Oxford, Pennsylvania, more than three times as many insect species were associated with native plants as with alien plants. (p. 329)

Tallamy also explains that because 96% of songbirds feed their young insects, and 37% of all animals on earth are herbivorous insects (pp. 21-24), the choice of plants we make in our landscape not only impacts the biodiversity of insect populations but also multiple bird populations as well.

Further, Tallamy and other scientists have found that not all native plants are equally productive. Some plant species support far greater biomass or numbers of organisms than others. For example, native plants in the Lobelia genus (such as cardinal flower) only support four species of Lepidoptera (butterflies, moths, and skippers), while plants in the Carex genus (the sedges) support 36 species of Lepidoptera [http://udel.edu/~dtallamy/host/index.html].

As gardeners, then, we have a wide range of choices before us when selecting plants for habitat improvement. The initial decisions we make for habitat gardening will likely be the same as for any other project, based on three primary factors: 1) how we plan to use the site; 2) the current site conditions; and 3) what plant species are most appropriate for those site conditions and the geographic region we live in. (Budget is typically a fourth factor, but will not be addressed here.) Although it's true that the more native plant species we use, the better the wildlife diversity will be, it's important to find the right balance to suit our specific site, which is an individual choice that will depend on our own particular needs. Ultimately, the degree to which one is able to improve habitat and sustain wildlife will be unique to each situation and dependent on individual preference.

In addition, there are many other reasons to use native plants besides the benefit of providing food and cover for wildlife. Whenever we choose "the right plant for the right place," we ensure a more successful outcome, especially if we select those best adapted for drought- or water-tolerance. And although native plants are not maintenance free—contrary to popular opinion—they can substantially decrease long-term maintenance requirements over time, once established. In general, native plant landscapes use less water, help reduce energy costs, and can increase property value because of their intrinsic aesthetic appeal.

Conservation Landscaping and Habitat Gardening

Conservation landscaping refers to landscape principles that apply best practices for conserving water, soil, and existing native plant communities. The Chesapeake Conservation Landscaping Council [www.chesapeakelandscape.org] has developed simple guidelines that can help homeowners, landowners, landscape professionals and municipal decision-makers take action to improve the health of the Chesapeake Bay watershed. However, these guidelines can certainly be

applied to other areas of the state that are outside the Bay watershed, because conservation practices help improve environmental quality no matter where we live. The "Eight Essential Elements" listed below are useful for making informed landscape choices.

A conservation landscape:

1. Is designed to benefit the environment and function efficiently and aesthetically for human use and well-being;

2. Uses locally native plants that are appropriate for site conditions;

3. Institutes a management plan for the removal of existing invasive plants and the prevention of future nonnative plant invasions;

4. Provides habitat for wildlife;

5. Promotes healthy air quality and minimizes air pollution;

6. Conserves and cleans water;

7. Promotes healthy soils;

8. Is managed to conserve energy, reduce waste, and eliminate or minimize the use of pesticides and fertilizers.

Conservation landscaping is therefore a systematic approach that integrates the use of native plants and wildlife habitat into our built environment while simultaneously reducing the need for mowing or for using fertilizers, pesticides, herbicides, water and fossil fuels. With this approach, plants are selected not just for their ornamental appeal but for their function in providing the highest habitat value for the site, in order to sustain multiple wildlife species. There's much less emphasis on using turfgrass as the predominant cover type, because turfgrass supports very little biodiversity. Instead, the principles apply greater emphasis on replacing lawn with assemblages of native plants that would be found locally in the natural environment. In essence, a conservation landscape sustains life and conserves resources in a way that traditional landscaping often does not. Yet, conservation landscapes can provide as much—and many would say they provide more—beauty and aesthetic appeal to the human eye.

Other Habitat Amenities: Structural (Abiotic) Components

After the vegetative components have been chosen and the various layers of plants have become established, it's time to look around the landscape and strategically fill in any remaining spaces with additional structural components that will augment the available habitat for wildlife. These are the non-living or abiotic elements of the landscape. The most commonly used structural components include brush piles and rock piles, snags (dead trees), nest boxes, areas with bare soil, and water features.

Brush Piles and Rock Piles

Brush piles and rock piles provide places for wildlife to seek shelter from the elements of rain, wind and snow over the course of a year. The "nooks and crannies" afford cool, dark areas to hide from the summer sun, or a protected spot to nestle down and retain warmth against the winter's chill. Temperature extremes aside, these simple constructed piles of easily found materials also provide valuable escape cover from predators, as well as places for wildlife to raise young. Rabbits, raccoons, mice, chipmunks, box turtles, lizards, snakes, insect-eating birds are just some of the many other animals that seek out these protected areas from time to time, either to rest, find food, overwinter, or lay their eggs. Depending on how big the pile is, some species may create a burrow or nest underneath the pile to live on a more permanent basis.

The limiting factor for brush piles and rock piles, of course, will be the size of the yard, as these piles are best suited to fairly large size lots (at least an acre), with plenty of space. It's also important to locate the pile well away from buildings and vegetable gardens, in order to minimize the likelihood of attracting wildlife such as groundhogs or skunks, which might decide to seek alternative shelter under the foundation of a nearby house or shed. Very small yards, such as a courtyard or a town house lot, are not conducive to making a pile at all.

Rock piles can be placed on the edges of the property near existing vegetation, or behind a shrub bed or adjacent to a stand of trees—wherever the rocks will blend in with the surrounding landscape to look natural and not too contrived. A rock pile can also benefit frogs and other aquatic organisms when stacked loosely among the vegetation next to a creek or a pond, or partially submerged at the water's edge, at least a foot below the water's surface.

Examples of Conventional Landscaping Practices that Reduce Habitat Value	Examples of Conservation Landscaping Practices that Increase Habitat Value
Select plants primarily for their perceived decorative value, unusual physical characteristics, or rapid growth habits that will quickly and easily fill in a site, regardless of where the plant species originated.	Select plants primarily for their utility to wildlife, water quality and ecosystem processes, in order to emulate native plant habitats that would be found naturally in the local region and are most appropriate for the given site conditions. Avoid selecting non-native "alien" or "exotic" invasive plant species known to be problematic in the environment, and control these plants if they enter the landscape, in order to reduce the likelihood of their competition with native plant communities.
Maximize lawn as a predominant feature of the landscape.	Minimize lawn by using it artistically where needed, for its specific functional value, such as for a pathway, or for certain recreational activities, or to frame a view or provide an intentional edge around a planted bed.
Routinely apply fertilizer and pesticides to optimize plant growth.	Use native plant species that are well-adapted to local soils, climate, and insect predation, thereby reducing or eliminating the need for fertilizers or pesticides, which can run off the site during a rain event and have harmful effects on water quality and aquatic wildlife species.
Rake-up and bag-up leaves in autumn, and dispose of in the landfill. Remove and dispose of all downed twigs, branches and other woody debris.	Keep leaves on site by shredding and/or composting them, and use the material for mulch and/or as an organic amendment to ornamental planting beds, which will enrich the soil and provide a sustainable food source for insects and other wildlife. Keep downed twigs and branches on site by chipping them and composting the material or using it for mulch, or cut the larger branches into manageable sizes that can be used to create brush piles for wildlife cover.
Remove all dead vegetation from flowering plants in the fall.	Allow dead vegetation to remain on site throughout winter (until late February/early March), which will provide cover for dormant insects or their eggs, and places for birds to feed and seek protection from harsh weather. Design the landscape such that plant species are strategically chosen and placed to provide interesting structural elements in winter dormancy, and therefore greater visual and aesthetic interest throughout the season.
Mow all the vegetation along a creek or stream, down to the water's edge.	Maintain at least a 35-foot buffer of plants such as shrubs and trees along waterways, which will filter runoff from the surrounding land, will shade the water, and will keep the soil from eroding the banks, thereby protecting aquatic wildlife species that cannot tolerate extremes of water temperature and that need clean water to thrive.

To build the pile, choose rocks or old bricks and blocks of various sizes and shapes, ranging from potato size to soccer ball size for the home landscape setting, or larger sizes in the more rural, spacious setting. Arrange the rocks unevenly, with open spaces between them, to fill an area at least five or six feet wide and one or two feet deep. Don't worry about being too artistic with rock placement. Wildlife doesn't care how pretty it looks; they just want a place to hide when the time comes. Consider planting a ground cover around the edges of the rock, or a vine that will grow over it, to provide additional protection. No need to mow there anymore!

Similarly, a brush pile is loosely constructed with lots of open spaces between the branches, which will make it easier for a wren to fly in or a rabbit to run under when threatened. Although a brush pile can be messy and built as big and wide as you like, avoid dumping a big pile of debris on the ground, which is a practice more suited to starting a compost heap. Rather, build the foundation of the brush pile in the manner of a miniature log cabin, starting with stumps or small logs, depending on what you have on hand, and criss-cross these in a couple of stacks until you have a firm base, preferably on level ground. Then stand large tree limbs up against the base, stacked against it, tipi style, with the butt ends of the branches on the ground, and the thinner, lighter tips pointing up above. This will form a somewhat pyramidal-looking structure that you can continue to add smaller branches to, until most of the interior is no longer visible, but with plenty of empty voids remaining throughout the stack. Place the greatest number of branches on the side of the pile that faces the prevailing winds, to ensure additional protection from summer thunderstorms and winter winds.

Effective brush piles are quite large. In a rural landscape or on a very large lot, they should be at least 12 to 15 feet in diameter and at least five or six feet tall. However, this may not be practical for a smaller suburban lot. A smaller pile, such as six to eight feet wide and four to five feet

tall, may be more appropriate for a residential setting and should still be adequate for many wildlife species to use.

Snags

Another structural component that some would say is "worth its weight in gold" for wildlife is a dead tree or snag. Dead trees provide a cornucopia of benefits, because the decaying material is host to innumerable insects and their larvae that chew their way through the wood or otherwise feed beneath the bark. Approximately 30 percent of native bee species use abandoned beetle tunnels in dead trees as a nesting site to lay their eggs. This abundance of burrowing insects, grubs, and eggs provide an invaluable protein source for dozens of bird and mammal species. Woodpeckers make their homes in dead trees, too, and the holes they leave behind in the trunk and the branches provide places for bluebirds, chickadees, nuthatches, tree swallows, screech owls, titmice, opossums, tree squirrels, bats, raccoons, and other cavity-seekers to raise their young. Snags provide open perches for hawks to hunt from, and when dead trees are located near a water body, kingfishers, flycatchers, and herons can hunt from these perches as well. Other birds use snags as a convenient post to sing from when proclaiming their territory. Dead trees also provide a refuge for birds and hibernating mammals in winter, when fewer resources for cover may be available in other parts of the landscape. In a pond environment, a fallen tree in the water can provide excellent habitat structure for fish and other aquatic species.

The astonishing array of wildlife species that rely on dead trees—and on decomposing logs and branches on the ground—cannot be overstated. Therefore, whenever possible, leave dead trees standing. If a dying or dead tree poses a threat to a walkway, driveway, or building, the tree can be taken down and left on the ground to decompose naturally and become an interesting if not unusual focal point, especially if it's used as a backdrop for planting flowers and ferns around it. Or, sections of the tree can be cut up and used to make a brush pile, as described earlier. Either way, retaining dead trees and woody material on site will greatly enhance the habitat value for wildlife and also recycle nutrients back into the soil.

Nest Boxes

Where no dead or dying trees are present, the next best thing is to put up nest boxes for cavity-seekers. Nest boxes provide vital homes for birds and small mammals such as flying squirrels to bear and raise their young, and each species that uses them has different requirements for the box dimensions, including the overall size of the box, the diameter of its opening, and the depth of the cavity within.

There are several considerations for constructing a bird house. Use untreated wood and select rough-cut lumber that's a minimum of ¾- inch thick (one inch is better). Cedar is a good choice, if available, because of its durability. The box should provide for adequate ventilation near the top, for heat to escape, and holes in the bottom for drainage, if water gets in. The roof of the

Examples of Common Nest Box Dimensions

Bird Species	*Diameter of Entrance Hole (inches)*	*Depth of Cavity (inches) - from bottom of hole to the floor of the box*	*Floor of Cavity (inches x inches)*	*Height of Box Above the Ground (feet)*	*Comments*
Eastern Bluebird	1 1/2	6 1/2	5 x 5	5-15	Place in open areas away from buildings and spaced 100 feet apart
Carolina Chickadee	1 1/8	8	4 x 4	5-15	Place in area with mature hardwoods
Northern Flicker	2 1/2	16-18	7 x 7	8-10	Fill box with sawdust
House Wren	1	6-8	4-6	5-10	This species will fill the nest box with sticks

Various sources may recommend different dimensions. More detailed specifications for constructing nest boxes are available in Woodworking for Wildlife and on the Cornell Lab of Ornithology web site, listed in the "Resources for Further Reference" section below.

box should overhang the front, to keep rain from entering, and the box should also have a provision for opening up the side or the top to clean out the contents at the end of the breeding season. Roughen the inside of the front part of the box, or attach a small piece of hardware cloth to it, to make it easier for young birds to climb out when it's time for them to fledge; do not paint the inside of the box. Also, do not attach a perch to the outside of the box, which merely provides an easier foothold for predators and encourages other non-native birds like starlings and house sparrows to attempt to enter.

To install a bird house, place it on a free-standing post or pole, well away from trees, which are the domain of the black rat snake. Secure a conical or stovepipe-type baffle to the post or pole beneath the box, in order to discourage raccoons, snakes and other predators. Do not use grease on the pole, as this is an unreliable method for deterrence and may sicken animals which ingest it. Be sure the front of the box is directed away from the prevailing winds, but face the box towards a distant tree where young birds can land when they leave the nest.

Bat houses are constructed very differently than bird houses. A bat house has no floor on the bottom, because bats fly in and out from below, and the interior of the box is made up of several narrow partitions, conducive to the bats hanging between the baffles. The species that most commonly use bat houses in the mid-Atlantic region are the little brown bat and the big brown bat; females of these species congregate in nursery colonies in the summertime and may use boxes to raise their young. However, success with bat houses is mixed and seems to depend on many variables, such as the numbers of partitions within the box and the width between them; or how much sun the box receives (it should be painted a dark color to absorb sunlight, because bats need warm temperatures); or how far above the ground the box is mounted (typically 12 to 20 feet). Boxes placed in proximity to a natural water source, such as a pond, lake, stream or river, are often said to have the greatest success of use, because bats frequent aquatic areas where insect numbers are typically high. Place bat houses on the side of a building away from nighttime lights, and orient the box towards the southeast for maximum exposure to sunlight in the early morning. [More detailed specifications for constructing bat houses are available at Bat Conservation International; see "Resources for Further Reference" section below.]

Another type of nesting house is one that can be made for orchard mason bees, which seek out holes or tunnels in plant stems to build brood cells in which to lay their eggs. Make the bee nest house from plants that have hollow stems, such as reed grass or teasel. If there happens to be a stand of invasive bamboo available, select narrow stems approximately half inch or less in diameter and cut them into five or six inch lengths. Then hollow out about three and a half inches on the end of each stem, leaving part of the tube closed. Gather about 10 to 15 of these pieces, tie them into a bundle with the closed ends together, and hang the bundle horizontally from a tree or building about three to six feet off the ground, in a sunny area with the holes facing east or southeast, and sheltered from the elements.

Or, make a "bee block" by drilling a series of holes between 3/32 and 3/8 inch in diameter, about ¾ inch apart on center, into an untreated (preservative free) block of wood, or into an old log or stump. Do not drill all the way through but rather only three to four inches deep, for holes less than ¼ inch diameter, or five to six inches deep for holes larger than ¼ inch.

Areas with Bare Soil

Bare soil is an often an overlooked element in the landscape that can be useful for some wildlife species. Songbirds will appreciate an occasional dust bath where bare soil is available, in order to control mites and other external parasites on their skin or in their feathers. Birds also ingest bits of grit and coarse sand, which help to grind up food such as hard seeds in the bird's gizzard. A simple way of providing the dust they need is to scrape away the vegetation from a two to three foot diameter patch of ground and allow it to dry out.

Areas of bare ground are also extremely important to bees, because almost 70 percent of North America's 4,000 native bee species nest in the ground [USDA/NRCS-Xerces]. These are solitary-nesting bees, which means that individual females seek out their own nest site to tunnel into the ground. Since the soil surface should be bare in order to provide bees the access they need to dig, a good rule of thumb is to clear small patches of bare ground in a sunny, open space, up to a few feet across, and pat the areas firmly to compact the surface. Different locations will attract different bee species; therefore try clearing patches on both flat ground and on slopes, particularly those that are facing south.

Bare ground can also be supplemented with sand pits for bees. Find a sunny spot, dig a hole in the ground about two-feet deep, and fill it with a mix of sand and loam that

will provide good drainage.

Water Features

Another structural element that's essential to any habitat garden is the presence of water, which can be provided in many ways. Bird baths are perhaps the easiest and can be purchased in a variety of shapes and sizes. Choose a bird bath with a shallow basin that has gradually sloping sides and is no more than two or three inches deep. Put one or two fist-sized stones into the water where birds can land, and place the bird bath several feet away from a shrub or tree, so that birds can easily seek cover if needed. To extend the season for year-round bird use, install a small heating element that will keep the water from freezing in winter.

An even simpler way of creating a bird bath is to turn the lid of an old trash can upside-down and nestle it within a plant border, or use a large, plastic plant dish the same way. Regardless of size or type, completely empty, clean, and replenish all bird baths with fresh water every few days throughout the summer to keep mosquitoes from breeding there.

Creating small mud puddles for insects is another method of providing water. Butterflies in particular use wet patches of soil (or wet manure) to obtain minerals, and this "puddling" behavior is commonly seen along the muddy edges of roads after a rain storm. To replicate a small mud puddle, fill a shallow cake pan with a mixture of sand and soil, fill it with water, and place it in a sunny area near a flower bed.

There may also be opportunities in the landscape to capture and divert a portion of the rainwater that falls and to collect it in a shallow depression to create a mini-wetland. Unlike a true rain garden, which is constructed several feet deep with permeable soil and is designed to hold water for no more than four days, the mini-wetland is only about 12 to 15 inches deep and is lined with a layer of clay at the bottom to hold the water for a longer time. The depression is filled with a soil mixture that contains mostly loamy organic matter and a bit of clay, then it's planted with species that are adapted for periodic inundation—hence the habitat. Locate this water feature in a low-lying area where water already naturally collects.

Or, construct the mini-wetland approximately 10 feet away from a building where it will receive some of the water from a downspout, with the aid of a shallow, planted swale that directs the water from the downspout to the area below. One can also connect a flexible plastic pipe to the downspout and bury it in the ground, with the end of the pipe daylighting directly into the clay-lined depression. However, be sure there's enough slope between the building and the water feature, so that the pipe doesn't back up during a heavy downpour.

The above examples are simple ways of providing water for terrestrial wildlife species to drink from or bathe in. A water garden or frog pond provides a larger habitat for aquatic species to live and breed in and is discussed in the section below, "Water Garden for Frogs, Salamanders and Other Aquatic Species."

Study Questions

1. The Department of Game and Inland Fisheries Wildlife Action Plan has identified ____ (how many) species of "Greatest Conservation Need."
2. There are many factors that cause habitat loss and declining populations of wildlife species. List 3 of these.
3. What is a plant community?
4. What's the difference between an ecosystem and a habitat?
5. T/F: Vegetative or vertical structure refers to layers of plants that provide a level of complexity and functionality in their arrangement, such that they sustain a broad array of wildlife species.
6. Which of the following best describes the layers that make up vertical structure in a forest ecosystem: a) Brushy cover; short plants; tall plants; rocky outcrops; b) Soil layer; animal layer; bird layer; air layer; c) Mulch layer; herbaceous layer; shrub layer; tree layer
7. Which of the following terms best describes the process of change in a plant community over time? Choose one: Horizontal structure; interspersion; succession; decomposition; edge effect
8. Which of the following statements best completes this sentence: "Habitat structure refers to how plants are arranged in relation to each other…. a) and whether or not they're well-adapted to the site conditions. b) and how long it takes for the plants to decompose. c) in both the horizontal and

the vertical plane. d) and their management with mowing, grazing and burning.

9. In just a few sentences, explain the statement: "There is a strong correlation between the use of native plants in the landscape and insect biodiversity."

10. T/F: It doesn't matter which native plant species you pick to improve a habitat, because all native plant species support the same number of wildlife species and are therefore equally productive.

11. Which of the following is not an example of Conservation Landscaping that increases habitat value: a) Control non-native invasive plant species known to be problematic in the environment. b) Keep leaves on site by shredding and/or composting them. c) Maximize lawn as a predominant feature of the landscape. d) Select plants primarily for their utility to wildlife, water quality and ecosystem processes. e) Maintain at least a 35 foot buffer of plants such as shrubs and trees along waterways.

12. Which of the following statements are correct: a) Snags are hosts to innumerable insects that provide an invaluable protein source for many bird and mammal species. b) Brush piles and rock piles provide valuable escape cover from predators, as well as places for wildlife to raise their young. c) A bird house should not be installed directly on a tree, because black rat snakes are an arboreal species and can easily prey on the birds. d) Areas of bare ground are extremely important to bees, because almost 70 percent of North America's 4,000 native bee species nest in the ground. e) Butterflies commonly gather in muddy patches of soil to obtain minerals, called "puddling" behavior. f) None of the above. g) All of the above.

Answers:
1 - 925; 2 - Development and fragmentation of forest; prevalence of impervious surfaces that contribute to erosion and runoff; extensive use of lawn and other non-native plants; routine use of herbicides and pesticides; "clean" farming practices that remove hedgerows and large expanses of vegetation; proliferation of invasive exotic plants; 3 - A plant community is an assemblage or collection of plant populations found in an area; 4 - An ecosystem is a complex, functional system made up of living (biotic) plant and animal communities and the non-living (abiotic) components in the environment. A habitat is the area within an ecosystem where an animal is able to secure the food, water, cover and space it needs to survive and reproduce; 5 - True; 6 - Mulch layer; herbaceous layer; shrub layer; tree layer. 7 - Succession; 8 - in both the horizontal and the vertical plane; 9 - Tallamy's study showed that native plants produced over four times more insect biomass than alien plants produced. 10 - False; 11 - Maximize lawn as a predominant feature of the landscape; 12 - All of the above.

Selected Habitat Gardens that Sustain Wildlife Diversity

Habitat Garden for Butterflies and Other Pollinators

One of the most popular, visually-rich landscaped habitats is a garden designed specifically to support pollinators. Pollinators are wildlife species that move pollen from the flowers of male plants to the flowers of female plants of the same species, when the pollinator travels from flower to flower in search of nectar, pollen or other insects to eat. Pollinators include hummingbirds, butterflies, moths, bees, wasps, beetles, flies and some species of bats. Their role is to help fertilize female plants and enable the plants to produce seeds, nuts or other fruit. These animals are therefore critical for ecological function. Without pollinator services, plants would not be able to survive reproductively, because over 85% of flowering plants require an animal—usually an insect—to move pollen [Ollerton, Winfree & Tarrant; 2011; How Many Flowering Plants are Pollinated by Animals? Oikos 120], and over 25% of the global diets of birds and mammals are comprised of pollinator-produced fruits and seeds [Xerces]. Our agricultural industry is also heavily reliant on pollinators to produce the high yielding crops we've come to expect in food production. "The economic value of pollinator-dependent crops in the United States was estimated to be between $18 and $27 billion in 2003." [Xerces] In Virginia, bees are attributed with supporting $33 million of the apple industry [2010 VA Apple Board] and $8 million of cucurbits [2006 VDACS].

Restoring a site by replacing lawn with pollinator habitat can transform the landscape, because as the new plants

become established and begin blooming, insects of all types very quickly descend on the flowers, seemingly from out of nowhere. To plan a pollinator garden, as with any other kind of habitat garden, it's helpful to remember that each group of organisms has different requirements. [Note: Hummingbirds are discussed in the "Bird Garden" Section below.] When we attempt to select plants for butterflies, we need to think of butterflies as if they're "two animals in one," because of their metamorphic life cycle. A butterfly starts out as an egg, develops into a caterpillar that must eat leaves, and then after several stages and successive molts, it forms a chrysalis and develops into an adult, which must get its energy from flower nectar. Hence, to be successful, a butterfly garden must include host plants for the larvae and nectar plants for the adults. For example, the larvae of monarchs need milkweed leaves, while the adults can forage among numerous nectar-producing plants. If the only plants we select for a garden are the ones that simply provide a colorful bed of blooms, then we will have missed half the equation, and the overall habitat value for butterflies will be lower as a result.

A tremendous number of butterfly species rely heavily on tree species as host plants. For example, black cherry trees support swallowtails, painted ladies and luna moths, and black locust trees support sulphurs and skippers. Elm is the host plant for mourning cloak butterflies, willow is the host for tiger swallowtail, and hackberry tree for question marks. Dr. Doug Tallamy's research assistant, Kimberly Shropshire, has developed a list of 20 woody plant genera, which includes trees and shrubs, ranked by their value for supporting Lepidoptera (the classification of butterflies, moths and skippers). The list is based on an exhaustive search of the scientific literature about host plant ecology. Below are the top 10 tree genera for supporting Lepidoptera:

Ten Most Valuable Woody Native Plant Genera for Supporting Lepidoptera
Quercus (oaks) support 534 species of Lepidoptera
Prunus (cherries) 456 species
Salix (willows) 456 species
Betula (birches) 413 species
Populus (poplars) 368 species
Malus (crabapples) 311 species
Vaccinium (blueberries) 288 species
Acer (maples) 285 species
Ulmus (elms) 213 species
[Tallamy, Bringing Nature Home, 2009]

Ten Most Valuable Woody Native Plant Genera for Supporting Lepidoptera
Pinus (pines) 203 species
[Tallamy, Bringing Nature Home, 2009]

In addition, Tallamy's project has also gathered rankings for 20 native perennial flowering plant genera. Below is a list of those top 11:

Most Valuable Ornamental Native Perennial Plant Genera for Supporting Lepidoptera
Solidago (goldenrods) support 115 species of Lepidoptera
Aster (asters) 112 species
Helianthus (sunflowers) 73 species
Eupatorium (pyeweeds, boneset) 42 species
Ipomoea (morning glories) 39 species
Carex (sedges) 36 species
Lonicera (honeysuckles) 36 species
Lupinus (lupines) 33 species
Viola (violets) 29 species
Geranium (geraniums) 23 species
Rudbeckia (coneflowers) 17 species
[Tallamy, Bringing Nature Home, 2009]

These data clearly indicate that butterfly species—indeed, whole populations of butterfly species—are dependent on hundreds of species of trees, shrubs and perennial flowers. We would therefore do well to select several trees, shrubs and flowering plants from the above groups when planning our pollinator garden, knowing that when we do, we'll have all our bases covered, because the myriad connections between all those groups will ensure a high likelihood of a biodiverse habitat.

In addition to Tallamy's work, other scientists are also conducting field research to further document the association between pollinators and specific plant species. In Pennsylvania, for example, Connie Schmotzer at Penn State Extension devised a series of "Pollinator Trials," in part to evaluate "the level of insect attractiveness of various perennial plant species or cultivars." The study monitored "88 pollinator-rewarding herbaceous perennial plants," to see how many and what type of insect pollinators would seek them out. Below is a synopsis of some of the study results:

Best Plants for Pollinator Visitor Diversity (ranked in order of preference, out of 88)
Clustered Mountain mint (*Pycnanthemum muticum*)
Coastal Plain Joe Pyeweed (*Eupatoriadephus dubius*)
Stiff Goldenrod (*Solidago rigida*)
Swamp Milkweed (*Asclepias incarnata*)
Gray Goldenrod (*Solidago nemoralis*)
Rattlesnake Master (*Eryngium yuccifolium*)
Flat Topped Aster (*Doellingeria umbellata*)
Spotted Joe Pyeweed (*Eupatoriadelphus maculatus* 'Bartered Bride')
[Schmotzer 2013]

Best Plants for Sheer Number of Bee and Syrphid [Fly] Visitors
Clustered Mountain mint (*Pycnanthemum muticum*): 19 bees/syrphids*
Gray Goldenrod (*Solidago nemoralis*): 14 bees/syrphids
Pink Tickseed (*Coreopsis rosea*): 14 bees/syrphids
Lance-Leaved Coreopsis (*Coreopsis lanceolata*): 13 bees/syrphids
Spotted Joe Pyeweed (*Eupatoriadelphus maculatus* 'Bartered Bride'): 12 bees/syrphids
Rattlesnake Master (*Eryngium yuccifolium*): 12 bees/syrphids
**Mean number of bees/syrphids observed per plot in 2 minutes*
[Schmotzer 2013]

Best Plants for Attracting Butterflies
Coastal Plain Joe Pyeweed (*Eupatoriadephus dubius*): 17 butterflies/skippers*
Blue Mistflower (*Conoclinium coelestinum*): 5 butterflies/skippers
Showy Aster (*Eurybia spectabilis*): 4 butterflies/skippers
Sweet Joe Pyeweed (*Eutrochium purpureum* subsp. *maculatum* 'Gateway'): 3 butterflies/skippers
Dwarf Blazing Star (*Liatris microcephala*): 3 butterflies/skippers
**Mean number of butterflies/skippers observed per plot in 2 minutes*
[Schmotzer 2013]

As one can see, certain plants are like powerhouses when it comes to supporting pollinators. Therefore, all one needs to do to have a highly productive pollinator habitat is to start with the above top genera [goldenrods (*Solidago*); milkweed (*Asclepias*); tickseed (*Coreopsis*); mountain mint (*Pycnanthemum*); pyeweed (*Eupatorium* or *Eutrochium*); asters (*Eurybia*); mistflower (*Conoclinium*); and blazing star (*Liatris*)], and then look at the Virginia regional native plant list for the garden area in question [Coastal Zone, Piedmont or Mountain—see "Resources for Further Reference" section], in order to determine the particular species of goldenrod, milkweed, tickseed, pyeweed, aster etc. that would be most suitable for the given site conditions.

Moreover, not only do these represent a broad spectrum of species and flowering types, they also bloom at different times throughout the season, which adds a temporal dimension to the association of insects that will frequent the plants. For example, peak bloom time for mountain mint is mid-June to mid-July; for swamp milkweed, mid-July to mid-August; and for pyeweed, mid-August to early September. This means if we select a variety of plants across flowering times, in addition to selecting across genera, we can magnify the habitat benefits even more. A good rule of thumb is to "provide blooming plants from early spring to fall, with at least three species of flower in bloom each season" [Xerces Pollinator Conservation Fact Sheet].

In addition to the genera listed above, other excellent pollinator plants include those in the coneflower (Rudbeckia), beardtongue (Penstemon), phlox (Phlox), bergamot (Monarda), and ironweed (Vernonia) genera. Flowering perennials such as these, combined with native warm-season grasses to form meadows in large open settings, will provide early successional habitat that benefits many bird species as well. Some native warm-season grasses suitable for dry, sunny meadows are the following: big bluestem (*Andropogon gerardii*); little bluestem (*Andropogon scoparius* or *Schizachyrium scoparium*); Indiangrass (*Sorghastrum nutans*); and switchgrass (*Panicum virgatum*). (For woody plant recommendations, see the Appendix for a table of native shrubs, which includes a column indicating their "Value to Pollinating Insects.")

Looked at another way, if landscape diversity is currently low in the built-environment around us, and if we add more forestal and meadow-like components (i.e. a diversity of shrubs, trees, grasses and flowering perennials), then we'll be supporting the butterfly species that are associated with each of those vegetation types (see table below).

An established pollinator habitat garden or meadow should be allowed to stand throughout the dormant months in fall and winter to provide winter cover. Mowing a pollinator garden is rarely necessary, and typically this practice is reserved for larger landscapes where the predominant vegetative type is native warm-season grasses, which are either burned or mowed only once every three years, to keep the thatch on the ground from becoming too thick. There's a fairly short window

of time for mowing or burning these rural fields, usually between mid-February to mid-March, which is at the end of winter, when insects have been dormant in the dead vegetation, but before birds begin nesting in the spring.

Here are some additional pollinator habitat tips from Xerces:

* "Avoid pollen-less cultivars and double-petaled varieties of ornamental flowers."
* Butterflies need warmth in order to fly; therefore plant pollinator habitats in open, sunny areas.
* Shelter pollinator habitats from the wind with some type of cover, such as groups of shrubs or hedgerows, trees, or a nearby wall or fence.
* Include some tall grasses in the habitat, allow the grass to remain overwinter, and conserve dead leaves and sticks in small piles. Caterpillars will use the grasses and brush piles to seek safety to build a chrysalis.
* Avoid cleaning out leaves and garden debris in the weeks leading up to the first severe cold spells of winter, because butterflies overwinter (hibernate) in the debris, either as eggs, larvae, pupae or even adults, depending on the species.
* Do not use insecticides in or near the garden, especially neonicotinoids, which "are systemic chemicals absorbed by plants and dispersed through plant tissues, including pollen and nectar."

Bird Garden

In earlier sections of this chapter we describe the importance of enhancing layers of vegetative structure within the landscape to support a biodiverse assemblage of plant and animal communities, and here we revisit that theme again in the context of providing good habitat for birds. The most effective way to design a garden space that will become a home for many bird species is to grow lush shrub borders and hedgerows replete with fruits and seeds; to plant trees for an overhead canopy; and to fill the landscape between those two layers with pollinator habitat that will attract the insects and spiders that birds feed on for protein. These vegetative elements—the herbaceous flowering layer, the shrub layer and the canopy layer—along with other structural elements like brush piles, nest boxes and water features already described above [in the section "Other Habitat Amenities: Structural (Abiotic) Components"], will ensure an abundance of bird species throughout the seasons.

Birds need plenty of space to establish a territory, engage in courtship, build a nest, raise and feed their young, and move about in the landscape to find food and escape cover. The choice of shrub species and how they're arranged in

Butterfly Species Associated with Forest, Field, and Forest/Field Intergrade

Forest	Field	Forest/Field Intergrade
Zebra Swallowtail	Black Swallowtail	Monarch
Easter Tiger Swallowtail	Cabbage White	Common Wood Nymph
Spicebush Swallowtail	Clouded Sulphur	Red-Banded Hairstreak
Pipevine Swallowtail	Orange Sulphur	
Common Blue	American Copper	
Question Mark	Eastern Tailed Blue	
Eastern Comma	Great Spangled Fritillary	
Mourning Cloak	Meadow Fritillary	
Red Spotted Purple	Pearl Crescent	
	Red Admiral	
	Common Buckeye	
	Hackberry Emperor	
	Tawny Emperor	
	Northern Pearly Eye	

[Source: Maria Van Dyke, Native Bee Research Lab, Dept. Entomology, Cornell University]

relation to the surrounding trees and other elements will provide varying degrees of food and cover depending on the time of year. During the growing season in spring and summer, deciduous plants are full of leaves that provide shade and protection, but in winter, birds will need the cover of evergreens such as eastern red cedar (*Juniperus virginiana*), bayberry (*Morella pennsylvanica*) , American holly (*Ilex opaca*) and Virginia pine (*Pinus virginiana*).

In spring, the new growth on trees like oaks, cherry and poplar are a magnet for insects, and migratory neotropical birds such as orioles, warblers, tanagers and vireos will utilize the canopy to glean insects from the leaves and branches. As late spring gives way to summer and birds begin breeding, they turn their attention to berry-producing shrubs and other mast (fruits and seeds), as more food becomes available.

Birds will also use hedgerows as a protective corridor to get from one area to another throughout the year. Shrubby thickets made up of species such as blackberries (*Rubus*), sumac (*Rhus*), chokeberry (*Aronia*), dogwood (*Cornus*) and viburnums (*Viburnum*) provide excellent cover and mast for catbirds, mockingbirds, thrashers, robins and many others.

The advancing progression of fruit ripening over the seasons ensures there's always plenty of food available from spring to fall, and many berries and seeds are persistent through the winter. Therefore, prune trees and shrubs in late winter, after the majority of fruits and seeds have been eaten, and before nesting season begins.

In large landscape settings, a good size shrub bed is a large circle of 15 to 30 feet in diameter, with a variety of species planted at least eight feet apart. This many plants results in a deep mass of leaves and branches, where birds can nest or easily dart in and out of when threatened. Alternatively, select one species to fill an entire plant bed, for example five inkberry (*Ilex glabra*) in one bed, or five American beautyberry (*Callicarpa americana*), or five New Jersey tea (*Ceanothus americanus*). In smaller landscapes with less room, plant clusters of just three shrubs instead. Mainly the goal is to group plants together as much as possible, rather than singly, here and there. (See the Appendix for a table of native shrubs suited for birds and other wildlife species.)

Every once in a while we hear folks complain that "all the quail and rabbits are gone," and they claim it's because "there's too many hawks." But the reality is that the decline of small mammals and birds is because too many landowners—in cities and in rural areas—are "cleaning out" fencerows, hedgerows and ditches. There's a definite need to educate the public about the value in letting hedgerows and fencerows stay a little more wild with blackberries, greenbrier, grape vine and Virginia creeper, in order to preserve habitat for the small mammals and birds that the hawks feed on, whether one lives on a tiny urban lot or on a large rural farm. "Gardening for birds" is so rewarding that it shouldn't be limited to foundation plantings but extended throughout the landscape.

One other special consideration is the ruby-throated hummingbird, which is a joy to see in any habitat setting, and a bird garden would seem incomplete without these jewels on the wing. As pollinators, they're especially keen on the nectar of tubular-shaped flowers, but they will also use a few other flower types selectively. If the landscape doesn't already include a pollinator patch with some of the following plant species in it, choose at least a few from the plant list below, based on the region of the state it's in, and the growing conditions of the site:

Plant List for Ruby-Throated Hummingbird
Wild Columbine (*Aquilegia canadensis*)
Oxeye Sunflower (*Heliopsis helianthoides*)
Coral Bells (*Heuchera americana*)
Jewelweed (*Impatiens capensis* or *I. biflora*)
Seashore Mallow (*Kosteletzkya virginica*)
Cardinal Flower (*Lobelia cardinalis*)
Great Blue Lobelia (*Lobelia siphilitica*)
Virginia Bluebells (*Mertensia virginica*)
Horsemint or Wild Bergamot (*Monarda bradburiana* or *M. fistulosa*)
Beebalm (*Monarda didyma*)
Sundrops (*Oenothera perennis*)
Narrow-Leaved Sundrops (*Oenothera fruticosa*)
Foxglove Beardtongue (*Penstemon digitalis*)
Lyre-Leaf Sage (*Salvia lyrata*)
Buttonbush (*Cephalanthus occidentalis*)—SHRUB
Yellow Poplar or Tuliptree (*Liriodendron tulipifera*)—TREE
Trumpetvine or Trumpet Creeper (*Campsis radicans*)—VINE
Crossvine (*Bignonia capreolata*)—VINE
Trumpet or Coral Honeysuckle (*Lonicera sempervirens*)—VINE
Carolina jasmine or jessamine (*Gelsemium sempervirens*)—VINE

Water Garden for Frogs, Salamanders and Other Aquatic Species

The most effective habitat for supporting frogs, salamanders and other aquatic species is an in-ground

wildlife pool that mimics a natural pond or wetland system. There are many options for providing ground-level water features, ranging from small and inexpensive to large and elaborate. Pre-fabricated liners are available at many garden centers and offer a convenient way to get a water source into the landscape quickly. These are often shaped like bathtubs and are available in different dimensions. Most are about three feet deep and made of thick, durable plastic or fiberglass, with built-in, shallow shelves for placement of potted aquatic plants. To install a pre-fabricated liner, dig a proportionate hole to accommodate its shape and size, and make sure the liner is level once it's in the ground. [Remember to call Miss Utility at 811 before digging.]

Alternatively, one can dig a water garden by hand and create a custom-made shape that's tailored to the specific site, as big or as small as practical. Locate the garden where it can be seen from a porch or window, and in a level area where there will be at least three to five hours of sunlight per day, with plants shading the water the rest of the day, because most aquatic organisms such as tadpoles need shade protection from temperature extremes.

Dig the deepest area 36 inches, then create shallower edges in concentric circles around this, to make ledges of different heights, such as 24 inches deep, 14 inches deep, and eight or 10 inches deep. The biggest challenge will be to level the sides with each other. Remove any rocks, roots, sticks or other sharp objects from the hole as it's being dug.

A hand-dug water garden will require two flexible plastic (PVC) liners and two geo-textile pads that are at least eight ounces in weight each. The size of the liners and pads should be larger than the total size of the pond (for example, a 30 foot diameter pond would need liners 40 x 40 feet). An ideal size is about 18 to 20 feet long by 12 to 15 feet wide, but do some research first to see what size pond liners are actually available on the market. Be sure to buy a liner specifically designed for aquatic gardens, and at least 30-45 mil thick, rather than an ordinary tarp or liner from a hardware store, because the typical home improvement products are usually too thin and are often pre-treated with a fungicide or algicide.

The installation is assembled like a giant sandwich: start with a two-inch layer of sand on the bottom, or use one geo-textile pad; next lay one of the PVC liners over the sand or pad; then lay another geo-textile pad down; and finish with the second PVC liner. The padded underlayment will help protect the water feature from tree roots and small burrowing animals that might tunnel underneath; some folks use old carpeting for this purpose.

Once the plastic layers are installed, use large rocks to hold the liner down in the middle, as well as along the ledges and around the upper edge. Small logs can also be used for edging around the top. If the pond is large, provide shallow, muddy areas, and also flat rocks in the open, where amphibians can bask in the sun. Fill the pond with non-chlorinated water (or wait several days for the chlorine in treated water to dissipate), and check the level during the driest part of the summer, to see if water may need to be added from time to time. To prevent a terrestrial animal like a bird or a chipmunk from falling in and not being able to escape, place a small branch or log in the pond that an animal can use to climb out.

After all the rocks are in place, the next step is to choose the plants. Just as we use layers of plants in a terrestrial habitat for wildlife diversity, use layers in the water garden to achieve the same effect. Ideally the pond will have enough plants to cover from one half to two-thirds of the surface area of the water. Select native aquatic plants suited to the different levels within the pond. Emergent plants root in the bottom, and their stems and leaves grow upright, out of the water. This is the area where salamanders and frogs spawn and lay their eggs, and the matrix of plant roots and stems will provide a good micro-habitat for breeding, as well as multiple places for tadpoles and other organisms to feed and to hide. Floating plants root in the bottom, and their leaves float on the water's surface. Submergent plants grow completely underwater.

To achieve the best plant diversity, bring a list with you to the aquatic garden center to make the selection (see chart at the end of this section, "Native Plants for Moist Sites or Aquatic Habitats"). Choose plants that are adapted for each of the pond layers (emergent, floating and submergent), as well as plants to place around the edge that will hang over the water and provide additional cover. Avoid using cattails from a local farm pond, because cattails are very aggressive and will fill a pond quickly and choke out other vegetation.

One other consideration is whether or not to consider using a recirculating pump or an aerator. The benefits of an aerator are that it provides water movement, keeps the water's oxygen content high, and minimizes algae build-up. Some amphibians prefer to live and breed in quiet

water, while others only live and breed in moving water. Therefore, if the pond is large enough and designed with different shelves for layers of varying depths, you can provide both types of micro-habitats (i.e. shallow, quiet water, and deeper water with a current) to support a broader range of species. If a pump or aerator will be used, have an electrician install a GFCI (ground-fault protected) outlet in the vicinity of the pond, during the digging stages.

However, if the pond is very small (less than 10 feet in diameter) and is filled with plants, the species that use the water garden will most likely be those that primarily associate with vernal or temporary pools. In this case, the abundance of diverse plants should support enough insect diversity to ensure there will be numerous predaceous insects as well as frogs eating any mosquito larvae, and a pump may not be necessary.

"Mosquito dunks" are not generally recommended for use in a frog pond. These pellets contain spores of bacteria known as Bt, which is widely used to control grasshoppers, caterpillars and other insects. Since the overarching goal of the aquatic habitat is to increase the diversity of organisms, which includes insects, using dunks may be counter-productive. As the water garden becomes established with a full complement of diverse plants, many predatory, carnivorous aquatic invertebrates will move into the habitat, such as copepods, water bugs, diving beetles, and dragonfly and damselfly nymphs. These insects and their larvae all feed on mosquito larvae, as do frogs and salamanders. The strain of Bt in the pellets is said to kill only mosquito larvae; however, according to some references such as the Tree Walkers International Pond Building Guide (http://www.amphibianark.org/pdf/Pond%20Building%20Guide.pdf), "despite many retailers' claims, Bt does infect non-target insects. Studies of Bt in ponds have shown general declines in aquatic invertebrate populations after two years of use."

Perhaps the most important recommendation for providing a safe haven for frogs and salamanders is: do NOT add fish. Fish prey on tadpoles; fish body wastes increase nitrogen in the water and can cause a nutrient imbalance; and goldfish and koi are non-native. Likewise, it is not recommended to purchase tadpoles or snails, as their genetic source cannot be fully confirmed, and releasing organisms from other areas into a new site can introduce pathogens to the environment that may be detrimental to the health of local aquatic populations.

A healthy aquatic habitat will gradually reach an equilibrium as various organisms become established. Over time, though, the pond is bound to gradually fill in with sediment from fallen leaves, and the amount of total water will gradually decrease as the plants' roots fill in and take over. Therefore, every two to three years in late winter (late February), remove any excessive amounts of decaying material or sediment, being careful to scoop out any newts, salamanders or frogs among the material, and temporarily hold them in a bucket, until the job is completed and they can be returned to the water.

Study Questions

13. What is a pollinator, and what is its role in the ecosystem?

14. To be most successful, a butterfly garden should (circle all that apply): a) be installed in very shady conditions. b) be mowed every year at the end of summer, to clean up the site. c) include host plants for larvae and nectar plants for the adults. d) be designed with plant species native to the region. e) only use one species of native plant. f) bloom only during August. g) include some tall grasses. h) be periodically sprayed with an insecticide to keep aphids in check.

15. Name the butterfly species that each of the following tree host species supports: Black cherry, Elm, Willow, Hackberry.

16. There are many ways to improve habitat for a diversity of bird species. List at least 6.

17. Describe the growth habits of the following (where do their roots, stems and leaves grow): a) Emergent plants b) Submergent plants c) Floating plants

Answers:
13 - Pollinators are wildlife species [hummingbirds, butterflies, moths, bees, wasps, beetles, flies and some species of bats] that move pollen from the flowers of male plants to the flowers of female plants of the same species; their role is to help fertilize female plants and enable the plants to produce seeds, nuts or other fruit; 14 - c, d, and g; 15 - Black cherry: swallowtails, painted ladies and luna moths, Elm: mourning cloak butterflies, Willow: tiger swallowtail, Hackberry: question mark butterflies. 16 - Answer should include examples for providing a diversity of food, water, cover and space, such as the following: Provide elements in an arrangement such that birds have enough space to establish a territory, engage in courtship, build a nest, raise and feed their young, and move about in the landscape to find food and escape cover; Plant a shrub border or a large shrub bed, Plant trees for an overhead canopy, Add a layer of pollinator habitat between the shrubs and trees to attract the insects and spiders that birds need to feed on, Add structural elements such as brush piles, snags, nest boxes and water features, Allow areas to naturalize and become shrubby thickets, Plant a hedgerow or fencerow as a corridor, Provide tubular-shaped flowers for hummingbirds, Provide berry-producing shrubs, Avoid pruning shrubs and trees until late winter, Keep dead leaves on the site. 17 - Emergent plants are those with roots in the bottom substrate, and their stems and leaves growing upright, out of the water; Floating plants root in the bottom, and their leaves float on the water's surface, All parts of a submergent plant grows completely underwater.

Troubleshooting Wildlife Conflicts

The adaptability of wildlife to our urban and suburban built environments is one of the leading causes of wildlife and human conflicts. As we've cleared the land for residences and commerce, and changed the landscape by adding a wider variety of ornamental plantings, the result has been that opportunistic wildlife species like deer, raccoons and opossums have made themselves right at home among our gardens, in our attics, and under our sheds. In some cases, the developed landscapes of today support even more of certain species than in historical times, such as deer, because habitat fragmentation caused by development has resulted in greater interspersion, increased availability of desirable landscape plants, and less hunting pressure than in bygone years.

Feeding Wildlife

Another primary reason for many of the wildlife conflicts encountered is that people just can't seem to keep themselves from feeding wildlife, whether deliberately or unwittingly. Each time a person feeds an animal, whether their love is birds or deer or squirrels, it naturally brings the animals closer to us, not further away, regardless of what species the animal is. Hence a bird feeder attracts a bear; dog food attracts a skunk; salt licks and apples attract deer; and kitchen scraps thrown in the yard, or a trash can with yesterday's leftovers attracts a raccoon.

Also, feeding wildlife can be problematic for the animals themselves, because bringing animals together artificially increases their numbers and makes it more likely they'll spread diseases to each other. Their behavior may also be altered, and they can become more aggressive towards each other or even towards people, because they gradually lose their fear of humans. Oftentimes when there's an escalating problem in a neighborhood—for example where deer are eating every dogwood and azalea in sight—it's attributed to someone who's been feeding deer. The very first step to resolving this type of problem would be to simply stop feeding. It's also important to remember that state regulations govern the feeding of deer. According to the DGIF 2015-16 Virginia Hunting and Trapping Regulations, "Department regulation makes it is illegal to place or distribute food, salt, or minerals to feed or attract deer or elk from September 1 through January 3 statewide; year-round in Buchanan, Clarke, Dickenson, Frederick, Shenandoah, Warren, and Wise counties (including the cities and towns within); or in any city, town or county during any deer or elk hunting season." [p. 42]

In addition, if a bird feeder is attracting a bear, the feeder must be taken down immediately, or the homeowner will be in violation of a regulation that prohibits the feeding of bears at any time.

The DGIF Regulations also state the following: "The Department does not encourage the feeding of wildlife at any time of the year. Feeding restrictions help control the transmission of diseases, nuisance problems, littering concerns, and enforcement issues about hunting with bait." [p. 23]

Therefore, some basic pointers abut feeding: 1) Do not throw large piles of old bread and kitchen scraps in the yard—this will attract crows, starlings, grackles, vultures, skunks, raccoons and opossums. 2) Do not feed apples and corn to deer and squirrels—this will only encourage them to keep coming back, and their numbers will increase until a conflict arises. It will be much harder to get rid of them later. 3) Do not put cat food or dog food out for wildlife. Avoid using a pet door in a garage for feeding pets, which may encourage wildlife to come into the building. 4) Keep charcoal grills and gas grills clean of grease and other food residue. 5) Take birdfeeders down in the summertime, to avoid attracting bears, and

Native Plants for Moist Sites or Aquatic Habitats			
Plant Type	*Common Name*	*Scientific Name*	*Approx. Height of Plant (ft)*
Trees - to plant near a water feature or in a buffer along the edge of a creek			
	Green Ash	*Fraxinus pennsylvanica*	50
	Sweetbay Magnolia	*Magnolia virginiana*	20-60
	River Birch	*Betula nigra*	45
	Northern Red Oak	*Quercus rubra*	100
	Red Mulberry	*Morus rubra*	35
	Black Willow	*Salix nigra*	40
Small Tree/Shrub - to plant near a water feature or in a buffer along the edge of a creek			
	Red Buckeye	*Aesculus pavia*	20
	American Elderberry	*Sambucus canadensis*	10
	American Beautyberry	*Callicarpa americana*	10
	Southern Bayberry	*Myrica cerifera*	8-20
Shrub - to plant near a water feature or in a buffer along the edge of a creek			
	Highbush Blueberry	*Vaccinium corymbosum*	10
	Possumhaw	*Viburnum nudum*	10
	Red Osier Dogwood	*Cornus sericea*	10
	Sweetshrub	*Calycanthus floridus*	10
	Buttonbush	*Cephalanthus occidentalis*	10
	Silky Dogwood	*Cornus amomum*	7
	Virginia Sweetspire	*Itea virginica*	3-6
	Inkberry	*Ilex glabra*	
Fern - to plant next to a water feature			
	Chain Fern	*Woodwardia areolata*	2
	Lady Fern	*Athyrium filix-femina*	2-3
	Maidenhair Fern	*Adiantum pedatum*	1-2
	Cinnamon Fern	*Osmunda cinnamomea*	3
	Royal Fern	*Osmunda regalis*	3-5
	Sensitive Fern	*Onoclea sensibilis*	1-2
Grass - to plant next to a water feature			
	Inland/River Sea Oats	*Chasmanthium latifolium*	2-4
	Eastern Gammagrass	*Tripsacum dactyloides*	4-6
	Bushy Bluestem	*Andropogon glomeratus*	3-5
	Switchgrass	*Panicum virgatum*	4-6
Herbaceous Flowering Plant - to plant next to a water feature, up to the water's edge			
	Cardinal Flower	*Lobelia cardinalis*	3-5
	Swamp Milkweed	*Asclepias incarnata*	5-6
	New York Ironweed	*Vernonia noveboracensis*	4-6
	Blue Vervain	*Verbena hastata*	4-6
	Joe Pyeweed	*Eupatorium purpureum*	4-6
	Common Boneset	*Eupatorium perfoliatum*	3-4
	Blue Mistflower	*Eupatorium coelestinum*	3
	Blazing Star	*Liatris spicata*	4
	Turtlehead	*Chelone glabra*	2-4
	New York Aster	*Symphotricum novi-belgii*	1-3
For growing requirements and range maps of these plants, refer to the plants listings provided in the "Resources for Further Reference" Section below.			

Native Plants for Moist Sites or Aquatic Habitats			
Plant Type	*Common Name*	*Scientific Name*	*Approx. Height of Plant (ft)*
	Northern Blue Flag	*Iris versicolor*	2-4
	Southern Blue Flag	*Iris virginica*	2-3
Sedge—to plant at the water's edge, or in the water up to 1 foot deep			
	Tussock Sedge	*Carex stricta*	2-4
	Fox Sedge	*Carex vulpinoidea*	3
	Shallow Sedge	*Carex lurida*	3
Emergent Flowering Plants - grow in 1-2 feet of water			
	Arrowhead	*Sagittaria lancifolia*	2-3
	Pickerelweed	*Pontedaria cordata*	2-3
	Soft Rush	*Juncus effuses*	3
Floating Plants - grow in 2-6 feet of water			
	American White Waterlily	*Nymphaea odorata*	NA
	Yellow Pond Lily	*Nuphar lutea*	NA
	Illinois Pondweed	*Potamogeton illinoensis*	NA
	Longleaf Pondweed	*Potamogeton nodosus*	NA
	Frogbit	*Limnobium spongia*	NA
Submerged Plant			
	Eel Grass	*Vallisneria americana*	
	Canadian Waterweed	*Anacharis Canadensis*	
	Coon's Tail	*Ceratophyllum demersum*	
For growing requirements and range maps of these plants, refer to the plants listings provided in the "Resources for Further Reference" Section below.			

because natural food sources are plentiful during the growing season. 6) Use specially-designed trash cans to exclude raccoons and bears; use clamps to tighten trash can lids.

Evaluating a Wildlife Conflict

The process for evaluating and dealing with wildlife conflicts is fairly straightforward. First, determine exactly which species is causing the damage or problem, rather than making assumptions. Just because there's a hole in the cedar soffit under the eaves doesn't necessarily mean a woodpecker made it. Second, once you know what species is involved, find out specific details about its life history and habits, in order to understand more about what the animal likely wants, or why it's doing what it's doing. The third step is to determine the various options available and start with the one that's least toxic or least invasive. These non-chemical, non-lethal options may include changing the habitat to make it less desirable to the animal, or implementing some sort of prevention or exclusion method that will deter the animal from causing the same problem again. The last step is to use chemical and/or lethal means, only if none of the previous options have worked. In some circumstances, more than one option may be necessary to fully address or eliminate the problem.

In the recommendations below, there are several references made to trapping wildlife, but it is not meant to imply that any animal can be trapped and transported somewhere else and released. It is illegal in the state of Virginia to trap and RELOCATE any animal to another area.

In the event that a situation presents itself where trapping will be necessary to address a wildlife conflict, consider contacting a licensed trapper who lives in your area and may be willing to assist you with the endeavor. A list of licensed trappers can be found on the DGIF web site (www.dgif.virginia.gov)

Also, several laws and regulations are quoted below, but this is by no means a comprehensive list. If you have any questions about legalities or conflict issues, the most practical and easiest thing to do is to call the DGIF WILDLIFE CONFLICT HELPLINE Toll Free Number

1-855-571-9003, 8:00 a.m.-4:30 p.m. Monday through Friday.

Legal Definition of "Nuisance Species"

While there may be many wildlife species we personally consider problematic, there are laws and regulations in the Code of Virginia that provide legal guidance on what actually constitutes a nuisance species. Per regulation, "the following animals: house mouse; Norway rat; black rat; coyote; groundhog; nutria; feral hog; European starling; English sparrow; mute swan; and pigeon (rock dove) are designated as nuisance species and may be taken at any time by use of a firearm or other weapon (unless prohibited by local ordinances), and on some public lands during certain time periods."

According to the Code of Virginia 29.1-100, nuisance species means "those species designated as such by regulations of the Board [as listed above], and those species found committing or about to commit depredation upon ornamental or shade trees, agricultural crops, wildlife, livestock or other property, or when concentrated in numbers and manners as to constitute a health hazard or other nuisance. However, the term nuisance does not include (i) animals designated as endangered or threatened…(ii) animals classified as game [bear, deer, rabbit, squirrel, bobcat, red fox, gray fox, raccoon] or fur-bearing animals [opossum, weasels (long-tailed and least weasels), striped skunk, spotted skunk, river otter, mink, beaver, muskrat] and (iii) those species protected by state or federal law [all songbirds, woodpeckers, hawks, vultures, waterfowl etc. under the federal Migratory Bird Treaty Act, and many other species under the federal Endangered Species Act]."

This means that if a woodpecker is banging on your siding, you are not authorized to harm, harass or "take" (kill) it, even though it definitely is a nuisance!

By law, the only people authorized to harm, harass or "take" (kill) nuisance species as defined above are DGIF personnel, Federal personnel with wildlife responsibilities, Animal Control Officers, Commercial Nuisance Animal Permittees, licensed hunters, licensed trappers, and landowners (under certain conditions).

When a Commercial Nuisance Animal Permittee receives a complaint from a private citizen, the Permittee is authorized to: 1) capture or remove wildlife from a building or dwelling and release the animal upon the "curtilage" of the building [the fenced-in ground and buildings immediately surrounding a house or dwelling]; 2) capture and temporarily possess injured, sick or orphaned wildlife for transport to Wildlife Rehabilitation Permittees; 3) capture and temporarily possess and transport wildlife for dispatch (killed); 4) capture wildlife for immediate dispatch; 5) immediately dispatch wildlife. Commercial Nuisance Animal Permittees are not authorized to capture, possess, transport or dispatch: 1) companion animals, including dogs and cats, whether owned or feral; 2) state or federal threatened or endangered species; 3) federally protected migratory bird species; 4) black bears; 5) white-tailed deer; 6) wild turkey. They are also NOT authorized to relocate (release) any live animals, except for squirrels trapped from areas where discharge of firearms is prohibited and when permission is obtained from the landowner where the squirrel is being released.

Control Options

For specific control recommendations for each of the animals listed below, please refer to VCE publication 456-018, Pest Management Guide (PMG), Home Grounds and Animals, section 8: "Other Animals: Vertebrates as Pests." All pesticide (bait, repellent, rodenticide, etc.) recommendations must come from this VCE publication 456-018.

Deer

Too many deer in a forested area can cause overbrowsing to the extent that available habitat is severely compromised for some wildlife species that rely on understory food and cover to survive. However, the effects vary among species. On the one hand, ground-nesting birds such as ovenbirds and shrub-nesting birds like buntings may be adversely affected from overbrowsing, whereas other species like cardinals and nuthatches are not influenced. In addition to the problems posed to other wildlife by overbrowsing, an overabundance of deer can result in the spread of more invasive plants throughout the ecosystem and substantially reduce understory regeneration of oaks and other trees.

Deer are opportunistic, and in a residential setting, if deer are hungry enough and presented with enough easily accessible ornamental plants, they'll selectively pick and choose the plants best suited to their needs at that particular point in time. There are excellent publications available online [such as Managing Deer Damage in Maryland, Bulletin 354] which contain strategic guidelines and plant lists for minimizing deer damage for different land uses. For example, a Christmas tree grower can use

repellents to protect new tree seedlings until they're tall enough to be out of reach of deer, whereas repellents are not cost-effective for an agricultural operator of a large nursery, orchard or vegetable farm. A homeowner may select a plant off the recommended list for their landscape bed ("Resistance of Ornamentals to Deer Damage"), but may subsequently find that deer will eat the plant anyway. Unfortunately, these kinds of "Resistance" lists are not consistently reliable, because deer will browse on plants for a variety of reasons: the health of the individual animal; the quality of the surrounding habitat; the amount of other available food in the area; the time of year; whether or not the animal is lactating; etc. Hence, deer may always eat hostas in one neighborhood, but in another part of the state, deer may rarely ever eat hostas at all.

The take-away point is that the plants do not "resist" or "deter" anything. Rather, it's the deer that's in control. Whether or not a deer eats certain plants will depend on how desirable that plant is, how hungry the deer is, and so on. Eating or not eating is a behavior that's up to the deer, not the plant. If a plant smells bad and has waxy, unpleasant leaves, a deer can walk away and eat something else. However, just because a deer walked away one time doesn't mean that another deer won't come along later and eat that plant in one big chomp. According to DGIF Deer Biologist Nelson Lafon, "It's a myth that you can deter deer by only using certain plants." [Lafon PowerPoint] Therefore, be wary of nurseries that make claims about a plant's deterrence properties. (Please see the Appendix for a table of native shrubs, which includes a column indicating species that are said to be "Not Preferred by Deer.")

Whether or not a planted bed is browsed by deer can also depend on where the plants are located. In general, deer are less likely to browse right up against a house or where dogs or people frequently move about—but here, too, there are always exceptions, if a deer is hungry, persistent or bold enough.

The best option in a home landscape is exclusion of plants using plastic fencing, or woven wire or chain link at least eight feet and preferably 10 feet tall around vegetable gardens and other small planted beds. Use tree protectors around young seedlings to cover the vulnerable bark, and use a cage made of woven wire to protect specimen plants.

For very large areas, electric fencing eight to 10 feet tall works best. There's another fencing design for rural properties that's been promoted by Cooperative Extension for many years, which entails setting the fence at an angle such that deer are said to be less likely to jump over it. However, anecdotal conversations with landowners by this author have indicated that this method is not always very effective, and it appears that more research may be needed to test the efficacy of this practice.

For smaller scale home gardens, try using a modified electric fence with aluminum foil "tents" or wrappers that attach to the wires and are rubbed with peanut butter. A deer is attracted to the peanut butter and receives a shock when its nose touches the foil that conducts the current. This results in aversive conditioning, which deters the deer from coming back to the same area again, at least for a while.

Some homeowners have had success with placing two, 4-foot sections three feet apart from each other. Apparently the panels are too close together for deer to feel 'comfortable' jumping over.

Commercial, chemical repellents can be applied to target plants as a deterrent, but they must be applied at the beginning of the growing season before deer begin browsing on the plants, and they should preferably be applied to so-called deer-resistant species, to maximize potential effect. However, the chemicals may gradually break down over time or get washed off in rain events, and they must therefore be re-applied regularly to maintain effectiveness. There are over a dozen commercially available chemical repellent products which contain a variety of ingredients that either emit a foul odor which deer find offensive, such as putrefied egg-based compounds, garlic, fish meal, or coyote urine; or various plant compounds like capsaicin (hot pepper) or other chemicals which are distasteful or injurious to the palate. Refer to VCE publication 456-018 for specific repellent recommendations.

When everything else fails, get a dog that will chase deer out of the yard!

Bear

Black bears occur throughout most of Virginia, and as human development increases, it becomes increasingly likely that people will encounter bear in residential areas. However, in this part of the bear's range, they do not exhibit predatory behavior, and it is extremely unlikely that a bear will attack or harm a human, unless

the animal is provoked or feels threatened. As described in the "Feeding Wildlife" section above, one of the primary reasons bear are attracted to human development is because of an available food source. At least 30% of complaints about bear are attributed to the presence of bird feeders, and 50% of complaints are associated with storage of garbage. A much smaller percentage (less than 10%) is related to agricultural food sources such as apiaries, orchards, other crops and livestock feed.

According to Virginia state law: "It shall be unlawful for any person as defined in §1-230 (Code of Virginia) to place, distribute, or allow the placement of food, minerals, carrion, trash, or similar substances to feed or attract bear. Nor, upon notification by department [DGIF] personnel, shall any person continue to place, distribute, or allow the placement of any food, mineral, carrion, trash, or similar substances for any purpose, if placement of these materials results in the presence of bear."

The simplest way to prevent bear encounters is to monitor bird feeders and other food sources outside the home to ensure that bear and other wild mammals are not being attracted. If it becomes apparent that a bear is using a feeder or frequenting a garbage can, or if bear are known to have been sighted in the area, remove all feeders and other open food sources immediately. A good rule of thumb is to take down bird feeders between April 1 and December 1 to prevent problems from occurring.

If a bear is sighted, keep your distance and allow the bear to leave the area. The goal is to keep a bear from feeling comfortable around residential areas, and if there's no food source available, the bear will likely just move through the area and continue on its way. If a bear is sighted in a tree, keep dogs and other pets away, so the bear will leave.

Vole

Voles are herbivores that eat bulbs and roots. They make tunnels near the surface of the sod as they travel from tree to tree to eat roots and strip the bark; they do NOT make mounds. A common vole deterrent is a bait-station ground trap that can be installed above or below ground. To confirm whether or not voles are indeed the ones eating bulbs, use an apple bait test: place the bait near the runway on the surface of the turf, and cover the bait with a bucket, then weight the bucket down with a brick to keep other animals out. Later inspect the bait to see if the apple has been chewed by a vole. Other methods include placing a mouse trap on the ground perpendicular to the runway, then baiting it and covering it as described above. For specific bait recommendations, please see VCE publication 456-018.

Other methods of deterring voles: 1) use only a thin layer of mulch around trees, and pull the mulch away from the trunk; 2) avoid killing snakes, which are a primary predator of voles and other small mammals. Owls and hawks are also predators of voles; 3) before planting bulbs, enclose them in a small wire basket, or place a layer of gravel or sharp shale bits ('Perma Till') in the hole when planting, to surround and protect the bulb.

Mole

Moles are insectivores that prey on worms, grubs, and other insects or larvae; they do NOT eat flower bulbs, contrary to popular opinion. Moles tunnel just below the soil surface and leave mounds as they go; they can dig up to 150 feet of new tunnels a day, and their action helps to aerate the soil. It is said they can consume their body weight in food daily, which makes them an important predator of problematic grubs such as Japanese beetle larvae. Moles, like any other wildlife species, have a specific role in the environment, and the first level of dealing with them is tolerance of their activities. Allow moles to continue feeding on the grubs in the soil and consider it a service. If tunneling becomes problematic, try collapsing the tunnels by walking over them, which may also prevent mice and voles from using them as easy runways, or use an underground barrier or baffle to edge around plant beds. When all other options are exhausted, use a mole trap to kill, or use baits. For specific bait recommendations, please see VCE publication 456-018.

Raccoon

Raccoons are wily creatures that can cause all kinds of damage, and they can carry rabies. Raccoons get into chimneys and attics; they get into barns and livestock feed stores or grain; they damage agricultural crops such as corn fields; they get into trash cans and dumpsters; etc. To manage: 1) make sure the chimney has a properly fitted and secure chimney cap; 2) close off any holes under the eaves or other openings where raccoons could get in; 3) remove or secure food sources; 4) if a raccoon is already in a building or attic, try harassment with a loud radio tuned to a talk station; or bright lights.

The legal provision for raccoon damage management, according to the Code of Virginia 29.1-517 Fur Bearing Animals: "When muskrats or raccoons are damaging crops or dams, the owner of the premises may kill them

or have them killed under a permit obtained from the Conservation Police Officer [of the Virginia Department of Game and Inland Fisheries]." Under Regulation 4-VAC 15-210-51 Open Season for Trapping-generally: "November 15 through last day in February… except there shall be a continuous open season to trap raccoon within the incorporated limits of any city or town in the Commonwealth and in the counties of Arlington, Chesterfield, Fairfax, Henrico, James City, Loudoun, Prince William, Spotsylvania, Stafford, Roanoke and York."

The above Code and Regulation indicate that if you live in a city or town or one of the counties listed, you can live trap a problem raccoon and release it outside (then seal up any entrances where it was able to get in). If you don't live in one of those areas, and the raccoon is causing conflict that doesn't involve crops or a dam, and you've tried all other options, then hire a professional (Commercial Nuisance Animal Permittee).

Another alternative is to find a licensed trapper who lives in your area and is willing to assist you with the endeavor. A list of licensed trappers can be found on the DGIF web site (www.dgif.virginia.gov)

Rabbit

Use chemical repellents similar to those used for deer, to discourage feeding on plant leaves and shoots. Plant a species like onions, which rabbits do not prefer, in between other plants that are more desirable. Fence the garden with two-foot high hardware cloth (wire mesh) or chicken wire, and extend it at least five inches below the ground, all around the bed. Individual plants or vulnerable seedlings can be covered with a basket.

See also the legal provision for trapping rabbits and squirrels under the "Squirrel" section, below. For specific repellent recommendations, please see VCE publication 455-018.

Squirrel

Squirrels can wreak havoc in a variety of ways. They can chew their way through the sill of a window, or chew a hole under the eaves to make an entrance and get into an attic. To keep them away from buildings, trim any overhanging tree branches to keep limbs well-away from the roof; staple hardware cloth over any openings under the eaves, or seal them over with a board or piece of metal flashing.

If a squirrel gets inside the house, place a loud radio tuned to a talk station near the room, and/or bright lights to scare them to leave. A "Hav-a-Heart" trap may be available from a local Animal Control Office to live trap the squirrel and release it directly outside, next to the building.

Around bird feeders, squirrels will chew the edges of the feeder if it's made of wood. Many advertised "squirrel-proof" feeders are available on the market, with various designs, such as one that slides a metal baffle over the seed hopper to close it off when a squirrel stands on the edge, or a feeder that has a battery-operated sensor which spins the feeder to throw the squirrel off. Despite their intended outcome, these feeders may not always work, because squirrels eventually seem to outwit the baffle device, and squirrels have been know to continue to attempt to climb onto the 'spin-feeder' until the feeder's batteries run out. In most cases it's usually best to take feeders down for a time, until the squirrel loses interest and moves on to something else.

The legal provision for squirrel damage management, according to the Code of Virginia 29.1-516 Game Animals: "Landowners, resident members of hunt clubs and tenants (with written permission of landowner) may kill rabbits or squirrels for their own use during the closed season.

Also—Code of Virginia 29.1-530 Open and Closed Season for Trapping, Bag Limits, etc: "a landowner or his agent may trap and dispose of, except by sale, squirrels causing a nuisance on his property at any time in any area where the use of firearms for such purpose is prohibited by law or local ordinance."

Skunk

Skunks are nocturnal, secretive, solitary and opportunistic. They prey on insects and will eat grasshoppers, crickets and also mice. They may knock over and empty the contents of trashcans; dig up lawns in search of grubs or insect nests; and like raccoons, they can carry rabies. To manage for skunks: 1) use a locking trash can to secure waste; 2) do not leave pet food outside; 3) remove brush and cover away from the foundation of dwellings or other buildings; 4) use a chemical treatment for the grubs in the lawn if their numbers exceed six per square foot; 5) if a skunk is in the crawl space under a building or has burrowed a hole under a shed, lay a board at the entrance as a ramp to try to encourage the skunk to come out; 6) when you're sure the skunk is no longer underneath

a building, tightly secure hardware cloth (wire mesh) along the edge of the building foundation to cover any burrow entrance or other opening; 7) use a covered bait trap that's designed to capture a skunk and protect others from being sprayed. Lay a towel or blanket over the trap as an added precaution.

Per Regulation 4 VAC 15-220-10 Continuous Open Season for Taking of Striped Skunks: "It shall be lawful to take striped skunks (Mephitis mephitis) at any time." And—Regulation 4 VAC 15-220-20 Taking of Spotted Skunks: "A landowner or tenant may take [kill], on his own land or land under his control, spotted skunks (*Spilogale putorius*) committing or about to commit depredation. However the pelt of the spotted skunk may not be sold."

Opossum

Opossums are also nocturnal. Since they're primarily tree-dwellers, they're inclined to enter attics without an invitation. As omnivores, they're also opportunistic when seeking food sources and will get into storage areas or outbuildings where bird seed or dog food is kept. To manage for opossum: 1) remove or secure food sources; 2) use hardware cloth or other screening or exclusion method to protect foundation openings; 3) repair eaves and areas under the roof overhang to keep animals out; and 4) trap as needed. Since Opossum is legally defined as a furbearer species, the following are applicable regulations for trapping:

29.1-517 Fur-Bearing Animals: "A landowner may shoot fur-bearing animals except muskrats or raccoons upon his own land during closed season."

29.1-530 Open and Closed Season for Trapping, Bag Limits, etc: "A landowner may trap fur-bearing animals, except beaver, muskrat and raccoons, upon his own land during closed season."

Regulation 4 VAC 15-210-51 Open Season for Trapping – generally: "November 15 through last day in February, except there shall be a continuous open season to trap opossum within the incorporated limits of any city or town in the Commonwealth and in the counties of Arlington, Chesterfield, Fairfax, Henrico, James City, Loudoun, Prince William, Spotsylvania, Stafford, Roanoke and York."

Groundhog

Groundhogs dig large burrows and can do damage beneath the foundation of a building. Their burrows can be 25 to 30 feet long and from two to five feet deep, and they usually have two entrances. Groundhogs also feed on agricultural crops and may damage fruit trees in orchards. Here it's important to remove fallen fruit as quickly as possible, to avoid attracting groundhogs to the free bounty.

The best measure for keeping groundhogs out of a structure is preventive maintenance, by ensuring that garages, porches, decks, sheds and other outbuildings do not have openings for access that will invite a groundhog's curiosity to explore and dig deeper.

In the garden, use a fence at least three feet high to keep groundhogs out, and extend the bottom of the fence under the ground at least one or two feet, as they may try to burrow underneath it.

Woodpecker

During the early spring, male woodpeckers establish their territory and attract a mate by pounding on dead trees and logs. If sufficient dead trees are not available, a woodpecker may decide that the hollow sound made by rapping on the siding of a house is just as good. In this scenario, one can try hanging reflective or noisy items from the building near where the bird has been striking, such as: old CD's; plastic grocery bags; bobbing balloons; rattling pie tins; or shiny metal flashing cut into strips.

Another possibility is that there may be some insect damage taking place underneath the siding or under the eaves that has attracted the woodpecker. Since woodpeckers are closely associated with dead trees and have a specialized tongue that's adapted for pulling grubs out of wood, these birds spend a lot of time climbing up and down trees listening for the sound of chewing insects beneath the bark, which are a clear signal that food is at hand. Therefore, if scare tactics have not worked in discouraging the woodpecker from leaving the building, it's possible that there's some decay beneath the fascia board. Check for water-damaged wood, which is often an indicator or rot, and replace any damaged material.

Also, stack firewood and lumber at least 10'-20' away from the house, to avoid insect damage from carpenter ants, termites, borers, powder post beetles, etc. which might attract woodpeckers as well.

Woodpeckers are protected by the Migratory Bird Treaty Act and may not be harmed, harassed or "taken" at any time.

Bat

Bats are very small and can squeeze between very narrow cracks and crevices underneath boards or eaves. Therefore, to reduce the likelihood of bats entering an attic space or getting into the walls, practice diligent preventative maintenance and make repairs as soon as damage is observed. It's especially important to do this before the breeding season, when nursery colonies will be looking for places to roost to raise their young. At the end of the breeding season, bats will look for shelter to hibernate over winter. Some simple practices for maintenance or repair: 1) Attach ¼ inch steel mesh (hardware cloth) to the inside of gable vents; 2) patch any holes fist size or larger with new siding, paneling, sheet metal, or plywood and paint; 3) Stuff smaller holes with steel wool or copper wool, and then cover with caulk.

If a bat does get into the house, don't panic but try to contain it in one room. Turn off all the lights and open all the windows, and continue watching the bat until you see it leave. If the bat appears to be resting quietly, try to trap it in a plastic container, and then release it outside.

If bats are living in the attic, turn on a loud radio and use bright lights as a deterrence. Another technique is to sit outside the building on a lawn chair at dusk and watch the house from the outside, to see how bats are getting in and out of the structure. Have a ladder and tools and materials ready. When darkness falls, the bats will leave the building en masse, which should provide an opportunity to make repairs and block access to their return. However, in the months of May through August, there may be young bats that stay behind when the adults come out to feed, and it's imperative there are no bats still present within the structure before sealing up the holes.

Sometimes placing a bat house on the wall near the opening where bats have been going in and out may entice them to use the bat house instead. However, if these methods are not successful and a large number of bats are still in the structure, seek professional assistance.

Bats are a nongame species and cannot be harmed or taken at any time. There are three federally endangered species of bats in Virginia. Therefore, before implementing a control technique that may cause harm, seek assistance in determining what species of bat is in question.

If a large number of bats are in the structure, seek professional assistance.

Snake

Despite people's fears, snakes are rather benign and will usually try to get away when they see anyone approaching. There are over 30 snake species in Virginia, and all but four are non-venomous. The most common venomous snake seen across the state is the copperhead, which may frequent firewood piles or other areas with protective cover.

The preventative for snakes is similar to that as mentioned early, namely keep the building maintained and seal up any small cracks, tears, or other openings around windows, doors and under the eaves. Black rat snakes are tree climbers and may get inside an attic space. Snakes may also find their way into a basement or crawl space. If a snake gets in, use a towel or small blanket to place over the snake and then secure it to release it outdoors.

Canada Goose

One goose produces a pound of manure every day. That's a lot of organic matter that can pollute ponds, lakes and other waterways. Feeding geese only makes the problem worse, because it encourages them to congregate, and the concentration of nitrogen and urea from their droppings will kill fish and other wildlife in the pond water and can also cause an algae bloom. The wisest rule of thumb is not to feed geese at all.

To manage goose conflict, use scare tactics such as reflective tape; noise makers such as horns and whistles; and predator replicas. There's also a bright yellow, inflatable plastic ball with a red eyeball on it that is sometimes used. Inflate the ball and hang it from a tree limb near the water, so it's easily visible to the geese. It's said that they apparently perceive the yellow ball and eye as a predator or something to be avoided. In large areas, such as around a lake in a big subdivision, a dog can be employed to chase geese and keep them from landing. This is most effective if initiated early in the season, when geese are flying over looking for places to land and a safe site to begin nest-building.

Geese prefer wide open lawns and fields, and another effective way to deter them is to leave a wide buffer of grasses, shrubs and other vegetation around the perimeter of the lake or pond. Geese usually approach land from the water's side, and if the bank is full of vegetation, they will not come up on land in that location. Therefore avoid

mowing down to the water's edge wherever possible. If a view of the water is desired, carefully select a few small areas between trees or shrubs ,where a few branches can be strategically removed to open a small 'window' to the water, in lieu of cutting out entire shrubs or mowing all the vegetation. Retaining a buffer will be more beneficial to aquatic organisms that live in the water or at the water's edge, too. If there's currently no vegetated buffer to work with, set up a temporary fence or other barrier such as rocks at the very edge of the water along the entire length of the bank, to discourage geese from walking up onto land from the water side.

If geese have already become well established and are nesting, another technique that field biologists use is called "egg addling." This is a mechanical method whereby the eggs in the nest are rapidly shaken in order to break up the contents within, so they won't hatch. Although the adults may still not leave, the method ensures that the goose population at that location will not grow any larger.

In some municipalities a special goose hunt may be organized to reduce their numbers. To inquire how to set this up, contact a DGIF Waterfowl Biologist or a Conservation Police Officer.

Study Questions

18. What are two primary causes of human-wildlife conflicts?

19. Feeding wildlife can be problematic, because when animals are concentrated together, it artificially _____and makes it more likely _____ _____. Their behavior may also be altered, and they can become more _____, because they gradually lose their fear of humans.

20. Which of the following statements are true? a) It is illegal in Virginia to place or distribute food, salt, or minerals to feed or attract deer or elk from September 1 through January 3 statewide, b) It is illegal in Virginia to trap and RELOCATE any animal to another area, c) It is illegal in Virginia to feed bears at any time; if a bear begins using a bird feeder, the feeder must be taken down.

21. List 5 recommendations about how to avoid attracting wildlife to food sources:

22. Put the following statements into the correct order to describe the process of evaluating and dealing with wildlife conflicts: a) Use chemical and/or lethal means, b) Find out details about the animals' life history and habits, c) Use non-chemical options, such as changing the habitat or exclusion, d) Determine which species is causing the damage or problem.

23. List 3 recommendations or ways that deer may be deterred from browsing plants.

Answers:
18 - Two primary causes of human-wildlife conflicts are: 1) The adaptability of wildlife to our urban and suburban built environments, and 2) people feeding wildlife (or leaving food out where wildlife can get to it); 19 - increases, they'll spread diseases to each other; aggressive towards each other; or even towards people; 20 - All of the statements are true; 21 - Recommendations about how to prevent feeding of wildlife—any of the following are correct: 1) Do not throw large piles of old bread and kitchen scraps in the yard—this will attract crows, starlings, grackles, vultures, skunks, raccoons and opossums. 2) Do not feed apples and corn to deer and squirrels—this will only encourage them to keep coming back, and their numbers will increase until a conflict arises. It will be much harder to get rid of them later. 3) Do not put cat food or dog food out for wildlife. Avoid using a pet door in a garage for feeding pets, which may encourage wildlife to come into the building. 4) Keep charcoal grills and gas grills clean of grease and other food residue. 5) Take birdfeeders down in the summertime, to avoid attracting bears, and because natural food sources are plentiful during the growing season. 6) Use specially-designed trash cans to exclude raccoons and bears; use clamps to tighten trash can lids; 22 - d, b, c, a; 23 - any of the following: Chemical repellents; home remedies; electrical fence at least 8-10 ft. high; modified electric fences made w. aluminum foil 'tents' coated w. peanut butter; dog chasing deer.

Resources for Further Reference

General Habitat Information

Habitat at Home©, by Heiser—8 pg. booklet provides an introductory overview and a basic plant list for general public audience. This and many other habitat fact sheets and resources are available for download from the VA Department of Game and Inland Fisheries Habitat Partners© Program. www.dgif.virginia.gov/habitat [DVD available for $7.95 from DGIF e-Store]

Backyard Wildlife Habitats, by Eaton and Wright; revised 2015; VA Cooperative Extension [Publication 426-070]; 7 pg. document for general public. https://pubs.ext.vt.edu/426/426-070/426-070_pdf.pdf

Bringing Nature Home: How You Can Sustain Wildlife with Native Plants, by Tallamy; 2009 edition; Timber Press; 360 pgs. Related articles are also available at http://bringingnaturehome.net

The Living Landscape: Designing for Beauty and Biodiversity in the Home Garden, by Darke and Tallamy; 2014; Timber Press; 392 pgs.

Wildlife Habitat Evaluation Program Manual—198 pg. document covers habitat concepts and numerous wildlife management practices. Originally published by National 4-H Council and Cooperative Extension; revised in 2011. http://utahenvirothon.org/wp-content/uploads/2011/09/WHEP_Manual_20103.pdf

The Woods in Your Backyard: Learning to Create and Enhance Natural Areas Around Your Home, by Kays, Drohan, Downing and Finley; 2006; Natural Resource, Agriculture and Engineering Service, Cooperative Extension [NRAES-184]; 138 pgs. Handbook for landowners of one to 10 acres; provides guidelines for assessing a site and planning land management; includes sections on wildlife ecology and habitat improvement methods.

Wild Ones: Landscaping with Native Plants, 4th edition, 2004; 28 pgs. Contains sections on planting woodlands, meadows, wet gardens, and landscaping for wildlife. https://www.csu.edu/cerc/documents/LANDSCAPINGWITHNATIVEPLANTS.pdf

Conservation Landscaping Guidelines: The Eight Essential Elements of Conservation Landscaping; Chesapeake Conservation Landscaping Council; 2013; 37 pgs. www.chesapeakelandscape.org

The Nature of Change: Preserving the Natural Heritage of a Dynamic Region [Northern VA], ed. by Waggener; 2005; National Audubon Society Inc. and The Audubon Society of Northern Virginia; 80 pgs. Contains photos of numerous habitat examples plus gardening tips for planning a habitat. https://audubonva.squarespace.com/s/Nature_of_Change.pdf

Wildlife Habitat Guide for Restoration and Landscaping in the Elizabeth River Watershed [Tidewater VA], by Pease; 1999; Elizabeth River Project; 141 pgs. Available for $5 at http://www.elizabethriver.org/#!native-plants/c1dqv

Bat House Builder's Handbook, by Tuttle and Kiser; updated and revised 2013; Bat Conservation International; 36 pgs. http://www.batcon.org/pdfs/BHBuildersHdbk13_Online.pdf

Native Plant Resources

Native Plants for Wildlife Habitat and Conservation Landscaping, by Slattery, Reshetiloff and Zwicker; 2003; 84 pgs. Booklet covers plants found throughout the mid-Atlantic states and is available for download at www.nps.gov/plants/pubs/chesapeake or as a searchable database at www.nativeplantcenter.net

Native Plants for Conservation, Restoration and Landscaping (VA Department of Conservation and Recreation, Natural Heritage Division): Plant lists for physiographic regions of the state (Coastal, Piedmont and Mountain), with a key indicating relative value of plants to wildlife. Also includes a link to a list of Virginia invasive plant species. http://www.dcr.virginia.gov/natural_heritage/nativeplants.shtml

Regional Native Plant Guides are available (such as Eastern Shore, Northern Neck, Northern Virginia) at VA Coastal Zone Management Program, www.deq.virginia.gov/Programs/CoastalZoneManagement/CZMIssuesInitiatives/NativePlants.aspx

Digital Atlas of Virginia Flora www.vaplantatlas.org Use the Atlas to see which plants are actually native in your own County.

Three complete listings of native "Herbaceous Plants," "Shrubs" and "Trees" are available online at http://blogs.lt.vt.edu/mastergardener/app-nativeplants-wildlife/, which are used with permission from the USDA-NRCS (2014) Field Office Technical Guide, Section 2, Plant Establishment Guide.

Gardening for Butterflies and Other Pollinators

U.S. Fish and Wildlife Service Pollinators web site http://www.fws.gov/pollinators/pollinatorpages/yourhelp.html

Numerous excellent publications are available from the Xerces Society for Invertebrate Conservation at www.xerces.org , as follows:

–Attracting Native Pollinators: Protecting North America's Bees and Butterflies, by Mader, Shepherd,

Vaughan and Black; 2011; Xerces Society; 380 pgs.

–XERCES "Invertebrate Conservation" FACT SHEETS (http://www.xerces.org/fact-sheets/):

* Pollinator Conservation: Three Simple Steps to Help Bees and Butterflies
* Butterfly Gardening
* Nests for Native Bees
* Protecting Bees from Neonicotinoid Insecticides in Your Garden http://www.xerces.org/wp-content/uploads/2013/06/NeonicsInYourGarden.pdf
* Pollinator Plants [for] Mid-Atlantic Region http://www.xerces.org/pollinator-conservation/plant-lists/

Conserving Bumble Bees: Guidelines for Creating and Managing Habitat for America's Declining Pollinators, by Hatfield, Jepsen, Mader, Black and Shepherd, 2012. http://ncagr.gov/spcap/bee/documents/ConservingBumbleBees.pdf

Pollinator Trial Results, by Schmotzer; 2013; Penn State Extension; 2 pg. Fact Sheet. http://extension.psu.edu/plants/master-gardener/counties/lancaster/pollinator-friendly-garden-certification/pollinator-trial-results-2013

Attracting Pollinators to Your Garden Using Native Plants, by Reel; U.S. Forest Service; 16 pg. color booklet, excellent for the general public http://www.fs.fed.us/wildflowers/pollinators/documents/AttractingPollinatorsEasternUS_V1.pdf

Urban and Suburban Meadows, by Zimmerman; 2010; Matrix Media Press; 272 pgs. Step-by-step guidelines for evaluating, designing, preparing and planting a site.

Gardening for Birds

Bird Gardening Book: The Complete Guide to Creating a Bird-Friendly Habitat in Your Backyard, by Stokes; 1998; Little, Brown & Co. 95 pgs.

Hummingbird Gardens: Turning Your Yard into Hummingbird Heaven, edited by Marinelli and Hanson; 2000; Handbook # 163, Brooklyn Botanic Garden Inc.; 111 pgs.

Attracting Birds, Butterflies and Other Backyard Wildlife, by Mizejewski; 2010 edition; National Wildlife Federation; 128 pgs.

Web Page – How to Attract Birds to Your Garden, National Wildlife Federation http://www.nwf.org/How-to-Help/Garden-for-Wildlife/Gardening-Tips/How-to-Attract-Birds-to-Your-Garden.aspx

Cornell Lab of Ornithology http://www.birds.cornell.edu/Page.aspx?pid=1478 [see also Nest Watch: All About Bird Houses http://nestwatch.org/learn/all-about-birdhouses/]

Woodworking for Wildlife: Homes for Birds and Animals, 3rd edition, by Henderson; 2010; Minnesota Department of Natural Resources; 164 pgs.

Gardening for Aquatic Wildlife

Backyard Ponds: Guidelines for Creating and Managing Habitat for Dragonflies and Damselflies, by Mazzacano, Paulson and Abbott; 2014; Migratory Dragonfly Partnership; 22 pgs. www.migratorydragonflypartnership.org

How to Create a Frog Pond (Emerging Wildlife Conservation Leaders); Amphibian Ark; 17 pgs. http://www.amphibianark.org/pdf/Husbandry/How%20to%20Create%20a%20Frog%20Pond.pdf

Pond-Building Guide (contains sections on "Characteristics of Amphibian Friendly Ponds" and "Mosquito Control"); 2015; 5 pgs. http://www.amphibianark.org/pdf/Pond%20Building%20Guide.pdf

A Guide to Creating Vernal Ponds: All the Information You Need to Build and Maintain an Ephemeral Wetland, by Biebighauser; 2002; USDA Forest Service and Izaak Walton League; 36 pgs. http://herpcenter.ipfw.edu/outreach/vernalponds/vernalpondguide.pdf or http://www.watershedconnect.com/documents/science_management_interventions_wetlands

Habitat Management Guidelines for Amphibians and Reptiles of the Southeastern United States [Technical Publication HMG-2], by Bailey, Holmes, Buhlmann and Mitchell; 2006; PARC (Partners in Amphibian and Reptile Conservation); 88 pgs. http://www.privatelandownernetwork.org/pdfs/seHabitatManagementGuide.pdf or https://separc.files.wordpress.com/2013/04/se-hmg.pdf

Wildlife Conflicts

WILDLIFE CONFLICT HELPLINE Toll Free Number 1-855-571-9003, 8:00 a.m.-4:30 p.m. Monday through Friday (VA Department of Game and Inland Fisheries).

VA Department of Game and Inland Fisheries—FACT SHEETS on 20 wildlife species available on web site, How to Prevent or Resolve Conflict with Wildlife. https://www.dgif.virginia.gov/wildlife/nuisance/

ARTICLES for the general public: When Wildlife Overstays its Welcome, and Feeding Wildlife: Food for Thought— www.dgif.virginia.gov/habitat

Wildlife Damage Control FACT SHEETS available on Beavers, Black Bears, Canada Goose, Moles, and Snakes, from VA Cooperative Extension https://pubs.ext.vt.edu/category/wildlife.html

Snakes of Virginia, VA Department of Game and Inland Fisheries [Booklet available for $4.95 through e-Store at www.dgif.virginia.gov]

A Guide to the Bats of Virginia, Special Publication No. 5, by Reynolds and Fernald; 2015; VA Department of Game and Inland Fisheries; 40 pgs. Includes information about how to handle bats in homes or buildings. [Booklet available for purchase through e-Store at www.dgif.virginia.gov]

DEER RESISTANT PLANTS: "Deer Resistant Plants," North Carolina Cooperative Extension, Urban Horticulture Fact Sheet 15; 8 pgs; http://pender.ces.ncsu.edu/files/library/71/Deer%20Resistant%20Plants.pdf

Resistance of Ornamentals to Deer Damage, Fact Sheet # 655; 2003; Maryland Cooperative Extension; 8 pgs. http://s130859622.onlinehome.us/ocg/wp-content/uploads/2011/06/DeerResistantOrnamentals.pdf

Deer: A Garden Pest [Hort 62NP], by Hussey; 2013; VA Cooperative Extension; 4 pg. Fact Sheet. http://www.pubs.ext.vt.edu/HORT/HORT-62/HORT-62-PDF.pdf

REPELLENTS: "White-Tailed Deer," [Wildlife Damage Management Fact Sheet Series], by Curtis and Sullivan; 2001; Cornell Cooperative Extension; 6 pgs. http://www.pgc.pa.gov/Wildlife/WildlifeSpecies/White-tailedDeer/Documents/Deer_factsheet.pdf

Managing Deer Damage in Maryland [Bulletin 354], by Kays; 2003; Maryland Cooperative Extension; 40 pgs. Excellent guidelines that can be applied to Virginia, not just Maryland! http://extension.umd.edu/sites/default/files/_docs/programs/woodland-steward/EB354_ManagingDeerDamage.pdf

Deer Proofing Your Yard and Garden, 2nd Edition, by Hart; 2005; Storey Publishing; 208 pgs.

Squirrel Wars: Backyard Wildlife Battles and How to Win Them, by Harrison; 2000; Willow Creek Press; 176 pgs.

Appendix: Selected Native Shrubs for Wildlife Habitat

Source: USDA-NRCS (2014). Field Office Technical Guide, Section 2, Plant Establishment Guide. [NOTE: This shrub list is excerpted and adapted from a much larger database.

Three complete listings of native "Herbaceous Plants," "Shrubs" and "Trees" are available online at http://blogs.lt.vt.edu/mastergardener/app-nativeplants-wildlife/]

Appendix: Selected Native Shrubs for Wildlife Habitat

Common Name	*Scientific Name*	*Height (feet) at 20 years*	*Not Preferred by Deer*	*Fruit / Seed Abundance*	*Value to Pollinating Insects*	*Bloom Period*	*Shade Tolerance*	*Anaerobic (Wet) Soil Tolerance*	*Drought Tolerance*
Highbush Blueberry	*Vaccinium corymbosus*	6		High	High	Spring	Tolerant	Medium	Medium
Buttonbush	*Cephalanthus occidentalis*	15		Medium	High	Summer	Tolerant	High	Medium
Eastern Red Cedar - EVERGREEN	*Juniperus virginiana*	20	x	Medium	High	Late Spring	Intermediate	Low	High
Black Chokeberry	*Photinia melanocarpa*	15	x	Medium	Moderate	Spring	Tolerant	Medium	Medium
Red Chokeberry	*Photinia pyrifolia*	5	x	Medium	Moderate	Mid Spring	Intolerant	Medium	Low
Coralberry	*Symphoricarpos orbiculatus*	2	x	High	Low	Mid Spring	Intermediate	None	Medium
Southern Crabapple	*Malus angustifolia*	30		High	High	Mid Spring	Intolerant	Low	Medium
Flowering Dogwood	*Cornus florida*	20		Medium	Low	Early Spring	Tolerant	None	Low
American Black Elderberry	*Sambucus nigra,* ssp. *canadensis*	7	x	High	Moderate	Spring	Intolerant	Low	Medium
White Fringetree	*Chionanthus virginicus*	20		High	Low	Mid Spring	Tolerant	Low	Medium
Cockspur Hawthorn	*Crataegus crus-galli*	30		High	High	Late Spring	Intolerant	None	High
American Holly-EVERGREEN	*Ilex opaca*	20	x	Low	High	Mid Spring	Tolerant	Low	Medium
Winterberry Holly	*Ilex verticillata*	6	x	High	High	Late Spring	Intermediate	High	Low
Indigobush	*Amorpha fruticosa*	6	x	High	High	Late Spring	Intolerant	None	Medium
Common Ninebark	*Physocarpus opulifolius*	10		High	Moderate	Late Spring	Intolerant	None	High
Pawpaw	*Asimina triloba*	25	x	Medium	Low	Mid Spring	Tolerant	Low	Low
American Plum	*Prunus americana*	24	x	Medium	Moderate	Mid Spring	Intolerant	Medium	High
Chickasaw Plum	*Prunus angustifolia*	12	x	Medium	Moderate	Early Spring	Intolerant	None	None
Eastern Redbud	*Cercis canadensis*	25		Medium	High	Spring	Tolerant	None	High
Swamp Rose	*Rosa palustris*	8		Medium	Moderate	Spring	Intolerant	High	Low
Canada Serviceberry	*Amelanchier canadensis*	20	x	High	Moderate	Mid Spring	Intermediate	Medium	Low
Northern Spicebush	*Lindera benzoin*	12	x	Low	High	Mid Spring	Intermediate	Medium	Low
Strawberrybush	*Euonymus americanus*	8		Medium	Low	Late Spring	Intolerant	Low	None
Smooth Sumac	*Rhus glabra*	12		High	Moderate	Mid Spring	Intolerant	Low	Medium
Winged Sumac	*Rhus copallinum*	8		High	Moderate	Mid Spring	Intolerant	Medium	Medium
Eastern Sweetshrub	*Calycanthus floridus*	7	x	Medium	Low	Summer	Intolerant	Low	Low
Blackhaw Viburnum	*Viburnum prunifolium*	16	x	Medium	Moderate	Spring	Tolerant	None	Medium
Southern Arrowwood Viburnum	*Viburnum dentatum* var. *dentatum*	15	x	Medium	Moderate	Early Spring	Intermediate	None	Low
Silky Willow	*Salix sericea*	12		Medium	High	Mid Spring	Intermediate	High	Low

Source: USDA-NRCS (2014). Field Office Technical Guide, Section 2, Plant Establishment Guide. [NOTE: This shrub list is excerpted and adapted from a much larger database. Three complete listings of native "Herbaceous Plants," "Shrubs" and "Trees" are available online at http://blogs.lt.vt.edu/mastergardener/app-nativeplants-wildlife/]

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Glossary

A

absorption: process where substances, such as water and minerals, are moved into the plant.

accumulative pesticides: persistent pesticides that can build up in the bodies of animals, including humans.

acid (reaction of soil): soil with a pH of less than 7. Most vegetables grow well at 6.5 to 6.8, which is slightly acidic; some, however, prefer more or less acid in the soil. The pH is lowered by adding sulfur or raised by adding calcium carbonate [lime] (see also pH and alkaline).

active ingredient: chemical in a pesticide which actually kills the pest.

adjuvant: a chemical added to a pesticide formulation or mix to enhance its effectiveness or safety.

adventitious: arising at a site other than the terminal or axillary position.

aeration: providing gaseous exchange around plant roots; techniques of loosening soil for turfgrass.

aggregate fruit: fruit from a single flower with many ovaries, e.g., strawberry.

alkaline (reaction of soil): soil with pH of above 7. Soil is made more alkaline by adding limestone (calcium carbonate) in significant quantities (see also pH, acid, and lime).

alternate leaf: arranged in alternate steps along the stem, with only one leaf at each node.

annual plant: a plant which completes its life cycle in one year. It grows, flowers, produces seed, and dies within one growing season; for example, beans, corn, cucumber, squash, etc.

anther: upper portion of a stamen containing the pollen grains (see stamen).

anthracnose: diseases caused by a certain group of fungi that produce acervuli (a type of fruiting body- a small blister on the lesion surface which in moist air may become pink from spore masses); characterized by dead spots on leaves, twigs, or fruit.

asexual propagation: propagation by using part of the body tissue of the parent plant, without sexual union.

axil: the angle between the main stalk and a leaf twig or branch arising from the stalk.

axillary bud: lateral bud arising in the leaf axil.

B

bacteria: minute, single-celled organisms, much smaller and simpler than fungi. Usually visible as bacterial slime or ooze, but more commonly not seen without a microscope.

bedding plants: plants sold in flats or packs to be used in flower beds or vegetable gardens; usually annual plants.

biennial plant: a plant which completes its life cycle in two growing seasons; vegetative structures and food storage organs are produced the first season; flowers, fruit, and seed are usually produced the second season; for example, cabbage, onion, parsley, etc.

binomial nomenclature: system of naming plants scientifically by the Latin genus and species.

biodegradable: refers to a material which decomposes (breaks down) readily by normal decay processes (insects, microorganisms).

biological pest control: elimination or control of pests by use of natural enemies or diseases of the pest.

blade (of leaf): the expanded, thin structure on either side of the midrib (central vein of a leaf).

blanching: (a) using soil, paper, or other material to keep light from certain parts of a vegetable to reduce formation of chlorophyll so that it will maintain its white coloring; cauliflower, celery, and sometimes asparagus are blanched; (b) heating vegetables to inactivate enzymes before processing.

blight: general killing of plant parts.

blood meal: dried, powdered blood collected from beef processors and used as a fertilizer. It is very rich in nitrogen.

blotch: large, superficially discolored areas of irregular shape on leaves, shoots, fruits, and stem.

bolting: production of flower and seed stalk by vegetable plants (generally triggered by long days at temperatures above crop optimum). Seed stalks produced by spinach, lettuce, radishes, celery, or other such plants are undesirable since the plants are grown for parts other than seed; development of leaves and roots slows down in favor of the production of seed.

bonsai: an art form that stems from ancient oriental culture; the process of severely dwarfing trees through careful pruning of both roots and shoots over many years, creating a miniature tree that is shaped to create the illusion of age.

bracts: specialized leaves, often brightly colored; for example, the showy structures on dogwoods and poinsettias are bracts, not petals.

branch: a stem that is more than one year old and, typically, has lateral stems.

branch collar: the swollen area of trunk tissue that forms around the base of a branch.

broadcasting: scattering seed, fertilizer, or other material evenly over the soil surface.

bud: an undeveloped shoot from which embryonic leaves or flower parts arise.

budding: the union of one bud and a small piece of bark from the scion with a rootstock.

bulb: plant storage structure which usually develops underground and is made of a compressed stem surrounded by fleshy scales; for example, onion, tulip.

buttoning: failure of cauliflower heads to gain in size after reaching about an inch in diameter; usually due to transplant stress or heat stress during the head formation period.

C

callus: protective covering that forms over a wounded plant surface.

cambium: a meristem, which is a site of cell division and active growth, located between the xylem and the phloem.

cane: a stem that has a relatively large pith, and usually lives only one or two years.

canker: necrotic (dead) areas in the bark of woody or herbaceous stems or twigs.

capillary action: adhesion of water to other particles; for example, the attraction of soil particles to water, which allows water to move up or down in the soil.

chelate: chemical "claws" that help to hold metal ions in solution so the plant can absorb them.

chitting: controlled sprouting of a seed potato.

chlorophyll: green pigment which traps light energy; has a vital role in photosynthesis and gives plants their green color.

chlorosis (chlorotic): yellowing of leaves due to lack of chlorophyll; usually caused by a nutrient deficiency or disease.

clay: finest soil particle.

cloche: traditionally, a bell-shaped glass jar set over delicate plants to protect them from the elements; portable structures that shelter plants from drying winds and cold air.

clones: plants that are genetically identical to their parent and can only be propagated asexually. cold frame: bottomless box (usually of wood) built on the ground with a removable top made of glass or plastic, used to protect, harden-off, or propagate plants.

cole crops: plants of the cabbage family, including broccoli, cauliflower, Brussels sprouts, kale, kohlrabi, turnips, and others.

companion crops: plants which are grown in the same area at the same time for the purpose of mutual benefits; for example, beans may be grown with corn - the corn uses nitrogen fixed by the bean plants, and the beans use the corn stalks to climb on.

complete flower: contains stamens, pistils, petals, and sepals.

compost: a decomposed mixture of organic wastes and other materials which, when added to soil, acts as a soil-builder.

compound leaf: a leaf composed of several separate leaflets arising from the same petiole.

conk: large, woody, shelf-like fruiting body of many of the wood decay (bracket) fungi.

contour planting: the practice of planting in rows that follow the contours of a slope or grade in order

to control erosion and hold water.

controlled-release: also called timed-release; chemical fertilizers which break down slowly so that all nutrients are not released at once.

cool-weather crops: vegetables which grow best in cool weather, usually having low heat tolerance; for example, spinach, lettuce, cabbage, etc.

Cooperative Extension: a government organization that provides agricultural and home economics information to residents.

corm: a solid, swollen, underground stem whose scales have been reduced to a dry, leaf-like covering.

cottonseed meal: a by-product of cotton manufacturing used as a fertilizer; acid in reaction.

cotyledon: leaf of a plant embryo (also known as a seed leaf); it is the first leaf appearing after radicle emergence and contains stored food for the seedling's early life (see also dicot and monocot).

cover crop: crop grown to add organic matter to the soil and help prevent soil erosion; also known as "green manure." Cover crops are usually sown in fall and turned under in early spring; commonly used are clover and winter rye.

crop rotation: practice of planting vegetables in different places within the garden each year or within the same growing season to help prevent buildup of insect and disease problems in the soil, as well as help prevent soil from losing the same nutrients year after year (see rotation).

cross-pollination: transfer of pollen from the male parts of a flower of one plant to the female flower parts of another.

crown: a type of compressed stem having leaves and flowers on short internodes; located at soil level so that roots support them upright and the central growing point is never covered with soil.

cultivar: a cultivated variety; specific type of horticultural plant not found outside of cultivation.

cultivation: (a) a broad term referring to the planting, tending, and harvesting of crops; (b) tilling or otherwise loosening the soil after plants have appeared above ground, usually to reduce weed growth and prevent formation of a hard crust on the soil surface.

cultural control: control of pests through cultural practices such as crop rotation, removal of weeds and old crop residues in which pests breed, etc.

cuticle: composed of a waxy substance called cutin; serves to protect the leaf from dehydration and prevent penetration of some diseases.

cutting: a vegetative plant part which is severed from the parent plant in order to regenerate itself, thereby forming a whole new plant.

D

damping-off: a disease of seedlings caused by fungi; seedlings either rot before breaking through the soil surface or fall over and die shortly after emerging.

day-neutral: applies to a plant in which flowering or other processes are not affected by length of light and dark periods.

deadheading: removing spent flowers.

deciduous: plants that lose their leaves during part of the year.

decompose: to break down into smaller pieces.

desiccation: drying out that occurs when water leaves the plant faster than it is taken up.

determinate: refers to a plant, such as a bush-type tomato plant, in which the terminal, or end, bud sets fruit and the stem stops growing (no further height increase).

dicot (dicotyledon): having two cotyledon or seed leaves; for example, cabbage, tomato. (See also cotyledon and monocot).

dilute: watered-down; less than original strength.

dioecious: species in which the sexes are separated into staminate and pistillate plants.

disbudding: removing small side buds to allow the plant to form one or a few larger blooms.

dolomitic limestone: limestone which contains magnesium.

dormancy: period when a plant "rests" and slows down its growth, usually during winter; onion sets, for example, are dormant until planted (or until warm temperatures and high humidity cause them to sprout).

drainage: term used to describe how water passes through

the soil; drainage material is coarse material such as sharp sand or perlite added to the soil to help water move downward through the soil.

dust: a pesticide in the form of a fine mixture of toxic chemical material and an inert filler (usually talc). Dusts are generally applied with a shaker canister or a pump-type duster which spreads the mixture evenly.

dwarf: plant which is bred or grafted to be of smaller size than others of the same species when mature.

E

early: vegetables which are bred to mature faster than others of their own species.

ecology: study of living organisms and the way they interact with other organisms and the environment.

embryo: miniature plant in an arrested state of development.

endosperm: a built-in food supply which can be made up of proteins, carbohydrates, or fats; found in seeds.

environment: all that surrounds an organism.

epidermis: outermost layer of cells.

epinasty: bending down of leaves due to abnormal growth in part of the petiole.

erosion: when soil particles are carried off by water or wind and deposited somewhere else such as into a stream or at the bottom of a bay.

espalier: a form of plant training (requiring considerable pruning) in which the plant grows flat against a surface such as a trellis or wall.

everbearing: producing fruit throughout most of the growing season.

evergreen: plants with leaves that persist during the entire year.

exoskeleton: a tough body wall that supports an insect's body, which lacks an internal skeleton.

F

F1 hybrid: first generation of plants following cross-pollination; many bedding plants are F1 hybrids which have characteristics more desirable than those of either of the parent plants individually.

fertilizer: material which provides nutrients to plants.

fibrous roots: root system in which the roots branch and become finely divided (compare with taproot).

filament: long, supportive structure of stamen that supports the anther.

filler (in fertilizer): an inert material added to bulk up a fertilizer, lower the analysis, and allow a more even spreading pattern.

fish emulsion: a complete fertilizer made from a partially decomposed blend of finely pulverized fish.

flat: a shallow box, usually made of plastic or wood, used for starting seeds.

flower: the reproductive organ of a seed-bearing plant, generally the showiest part.

foliage: the leaves of a plant.

foliar feeding: providing nutrients to a plant by spraying foliage with special dilute fertilizers.

frost: the formation of ice particles on plants and other objects due to the freezing of water vapor when air temperature drops below freezing.

fruit: the ripened ovary.

fungi: lower order of plants which contain no chlorophyll and do not form roots, stems, and leaves. Some fungi are grown for food (mushrooms) and others may cause plant disease. Fungi also have an important part in the decomposition of dead plant and animal material.

fungicide: chemical which kills or inhibits fungi.

furrow: depression in the soil surface dug for planting seed or other purposes.

G

gall: structure of deformed plant tissue.

geophytes: herbaceous plants with underground storage organs, rather than fibrous root systems.

germination: sprouting of seed and the beginning of plant growth.

girdling: when roots or other materials circle around the trunk and begin a process of strangulation.

grafting: an asexual method of propagation that joins a scion and rootstock from different plants so they will grow as one plant.

granule or granular: particle-like, as in grains of sand.

green manure: see cover crop.

ground cover: a plant that covers the ground surface so that the ground cannot be seen from above, and so that rain does not strike it directly.

growing medium: soil or soil substitute (i.e., peat moss mixes) for growing plants.

growing season: the period during which plants grow; usually between the last plant-killing frost in the spring to the first killing frost in the fall.

guard cells: cells on the leaf epidermis that are capable of opening and closing, guarding the interior of the leaf and regulating the passage of water, oxygen, and carbon dioxide through the leaf.

gummosis: production and exudation of a thick, gummy liquid in response to injury or disease.

H

hardening or hardening-off: preparing plants for outdoor planting by gradually shifting them from a sheltered to a less sheltered environment, usually by placing them outdoors for a few hours every day, and increasing the outdoor time each day until they are ready to be transplanted or by reducing the amount of water they receive (i.e., cuttings in a mist bed).

hardy plant: plant with the ability to resist frost or freezing conditions; plants that perform well in difficult environments.

heading: reducing the height of a plant by cutting back lateral branches and removing terminal buds; cuts are made at nodal areas.

heaving: shifting of soil due to alternate freezing and thawing; often forces plants or bulbs out of the soil.

heavy soil: usually a soil that contains a lot of clay and is difficult to work.

heeling-in: covering plant roots with moist soil, sawdust, or other material to store the plants temporarily until they can be properly planted; often done with bare-root trees and shrubs and with strawberries.

herbaceous stem: a stem that contains only small amounts of xylem tissue, usually lives for only one growing season.

herbicide: a chemical which kills plants.

hills: planting in hills refers to a method of sowing seed in a group and thinning to the best 3 or 4 plants when they have germinated. Melons, potatoes, cucumbers, and squash are often planted in hills.

host: plant or animal upon which another organism (usually a parasite) lives.

hotbed: a cold frame heated by soil-heating cables, steam-carrying pipes, or fresh manure buried beneath the rooting zones.

hotcap (or hotkap): a “miniature greenhouse” of plastic or glass used to protect seeds or small plants from cold temperatures while allowing sunlight in to warm the soil.

humus: organic matter which is completely decomposed and which produces the dark color in soil; improves water retention properties.

hybrid: plant which results from the crossing of two parent plants with different characteristics (also see F1 hybrid and cross-pollination).

hydrated lime: also called “burnt” lime; specially treated limestone which is faster-acting than regular limestone.

hydroponics: growing of plants in water or a soilless medium to which nutrients are added on a regular basis (see also soilless culture).

hydrozone: an area of plants grouped according to similar irrigation needs.

I

imperfect flower: lacks either stamen or pistils.

incomplete flower: missing one or more of pistil, stamen, petals, or sepals.

indeterminate: growth habit that can continue indefinitely; usually refers to a plant such as certain tomato varieties that require staking (compare with determinate).

inert ingredients: added chemicals which dilute or extend a pesticide and may make it easier and safer to handle; also called inactive ingredient.

infect: become established on/in the plant and initiate

disease development.

inflorescence: a cluster of flowers, and how they are arranged on the stem.

inhibit: to slow down or prevent.

inoculum: part of a pathogen that can cause infection.

inorganic: not made up of or derived from plant or animal materials; specifically, not containing carbon.

insecticide: chemical that kills insects.

instar: insect life stage between each molt.

Integrated Pest Management (IPM): method of pest control using all types of control measures available, with chemical control as a last resort; emphasizes timing and awareness of pest's life cycles.

intercropping or interplanting: growing two or more crops near each other at the same time, usually for the purpose of getting maximum production; one intercropping practice, for example, is planting radish seeds along with carrot seeds in the same row. The radishes are harvested by the time the carrots begin to need the space.

internode: stem section between nodes.

irrigation: applying water to the soil, especially when there is not enough rainfall.

K

knot garden: planting design that looks from above like a knot; usually done with herbs or bedding plants.

L

lateral: located at the side.

layering: a method of vegetative propagation where stems attached to a parent plant form roots where they touch a rooting medium, then are severed to become a separate, new plant.

leaching: loss of soluble salts (nutrients) from soil by water percolating downward, carrying the salts with it.

leggy: plant that is spindly, with a long stem and a few lower leaves, usually due to too much light, overcrowding, or too much nitrogen.

legume: plant of the Leguminosae family, with a pea-like fruit pod, and with a root system that is invaded by nitrogen-fixing bacteria which can convert nitrogen gas from the air into forms that can be used by the plant.

lesion: well-defined area of diseased or injured tissue, often with dead spots or areas.

light soil: coarse-textured soil, such as sandy soil, which is easy to work.

lime: usually ground limestone added to the soil to increase pH. It adds calcium and in the case of dolomitic limestone, it also adds magnesium (see also dolomitic limestone and hydrated lime).

loam soil: a soil made up of a good balance of sand, silt, and clay.

long-season crop: a crop which must have a long period of frost-free days in order to produce well; for example, sweet potatoes, watermelon.

M

macro: large; a macronutrient is needed in large quantities by plants.

manure: animal excretions added to gardens as a fertilizer and soil builder (see also green manure).

meristem: an area where new cells are manufactured, such as the tip of a stem or root.

metamorphosis: a marked or abrupt change in form or structure.

micro: small; a micronutrient is needed in small quantities by plants.

micro irrigation: drip systems, micro-sprinklers, soaker hoses, and other methods that conserve water during irrigation by applying it directly to the root zone to minimize evaporation and runoff.

molt: shedding of the outer skeleton.

monocot (monocotyledon): plant whose embryo has only one cotyledon (seed leaf); for example, corn, other grasses (compare with dicot).

monoecious: species in which separate male and female flowers are on the same plant.

mosaic/mottle: irregular light and dark areas on the leaves, with distinct (mosaic) or less distinct

(mottle) margins.

mulch: variety of materials applied to the soil surface around plants to hold moisture, keep soil temperatures even, and inhibit weed growth; may be inorganic or organic.

multiple fruit: fruit from a tight cluster of separate, independent flowers borne on a single structure; for example, pineapple, fig.

mycelia: the main body of fungi, consisting of threadlike masses which grow on plant or animal material or in the soil.

N

necrosis: tissue death.

nematode: nonsegmented roundworm. Plant parasitic nematodes are always small, usually very thin, and many live in the soil, feeding on roots. A few kinds live in leaves or shoots.

nitrogen (chemical symbol N): one of the three major essential plant nutrients; responsible in part for the green color in plants and vigorous vegetative growth (see also NPK).

nitrogen-fixing: referring to the bacteria which live on the roots of legume plants and which are able to extract or "fix" nitrogen from the air for use by the plant (see legume).

node: point where leaves are attached to a stem.

NPK: the chemical symbols for the three major macro-nutrients used by plants: nitrogen (N), phosphorus (P), and potassium (K). The percentage of each nutrient is listed on fertilizer packages in NPK order: 16-10-12 means 16% nitrogen (N), 10% phosphorus (P2O5), and 12% potassium (K2O).

nutrient: element a plant or other organism needs for growth.

nutrient solution: a liquid containing plant growth elements, especially as used in hydroponics.

O

oedema: a physiological problem associated with overwatering.

offset: a new shoot arising at the base or in leaf axils of a plant with a rosetted stem; can be separated and used for propagation.

opposite leaf: positioned across the stem from each other, two leaves at each node.

organic: of plant or animal origin; specifically, containing carbon.

organic gardening: gardening without the use of synthetic chemicals, such as man-made fertilizers or pesticides; organic gardeners use compost and other organic wastes as fertilizer, and cultural, biological, and mechanical pest control methods; soil building is a major factor in organic gardening success.

ovary: part of the pistil that contains the eggs.

ovules: part of the ovary that develops into seeds.

P

palmate: extending outward, like the ribs of a fan, from one central point. Can apply to both leaf venation and compound leaf arrangement.

parasite: organism that lives on or within another species of plant or animal, feeding off that host during at least one part of their life cycle.

parthogenesis: reproduction without fertilization of egg by sperm.

pathogen:

peat or peat moss: partially decayed organic plant matter which comes from boggy areas (see also sphagnum moss).

peat pellet or Jiffy-7: container for seedlings made of compressed peat moss covered with netting; expands when soaked in water.

peat pot: a pot made of compressed peat moss used to raise seedlings.

perennial: plant which lives from year to year, not dying after flowering once.

perfect flower: contains functional stamens and pistils.

perlite: white, porous, volcanic mineral used to aerate soil and for rooting cuttings; has no nutritional value.

persistent pesticide: pesticides that break down slowly and stay in the environment a long time.

pesticide: substance used to control pests, such as

insects, fungi, weeds, rodents, etc.

petiole: the stalk that supports the leaf blade.

pH: chemical expression of acidity and alkalinity; reading taken from a scale that measures the hydrogen (acid-forming) ion activity of soil or growth media; pH 7 is neutral, below 7 is acid, above pH 7 is alkaline (see also acid and alkaline).

phloem: tubes that conduct food in plants; found in the vascular system.

phosphorus (chemical symbol P): one of the three major macro-nutrients required for plant growth (see also NPK).

photosynthesis: process where plants internally manufacture their own food; literally means "to put together with light."

pinnate venation: veins extending laterally at an angle from the midrib to the edge, as in apple, cherry, and peach leaves.

pistil: female part of the plant. Generally shaped like a bowling pin and located in the center of the flower; consists of stigma, style, and ovaries.

pistillate flower: female flowers; possess pistils but lack stamens.

pith: the central, strength-giving tissue of a stem.

pot-bound: condition in which the roots of a potted plant become matted together, circle in the shape of the pot, and/or emerge from the drainage holes when they have nowhere else to grow; requires repotting in a larger container.

potting: planting in a container.

potting mixture (or potting medium): combination of ingredients (soil and other materials) for growing and cutting or breaking apart plants in containers to stop circling.

pregermination: sprouting seeds before they are planted in pots or in the garden. This reduces the time to germination, as the temperature and moisture are easy to control.

preharvest interval: period between the time of pesticide application and the time it is safe to pick and use the crop.

primary symptom: symptoms at the point where the pathogen is active.

propagation: reproduction of plant from seed (sexual) or by cuttings, grafting, division, or layering (asexual).

prune: to cut off or cut back plant parts for better shape or more fruitful growth.

R

radicle: root originating at the lower end of the embryo of a seedling plant.

relative humidity: ratio of water vapor in the air to the amount of water air could hold at a given temperature and pressure, expressed as a percent.

relaying: overlapping successive plantings of one crop.

resistant varieties: ones that have been bred for resistance to certain diseases; not resistant to all diseases, but only those for which it has been developed.

respiration: in plants, the process by which a plant takes in oxygen and releases energy by breaking down sugars.

rest period: natural period in a plant's life when it does not grow (see dormancy).

rhizome: horizontal underground stem.

ripe: in harvesting fruits and vegetables, describes the stage at which the product is mature for its intended use.

root: lower portion of a plant that usually develops underground and anchors the plant in the soil, absorbing moisture and nutrients; aerial roots are those that develop above-ground, in the air.

root-bound: see pot-bound.

root cap: outermost tip of the root, consists of cells that are sloughed off as the root grows through the soil. It covers and protects the meristem.

root crops: those crops grown for their edible roots; for example, beets, turnips, carrots.

root hairs: extremely fine roots found along the main root; perform much of the actual work of water/nutrient absorption.

rootstock: provides the new plant's root system and sometimes the lower part of the stem in grafting or budding.

rosulate: arrangement where leaves form a rosette with

extremely short nodes around the stem.

rotation: changing crops grown on a piece of land from one year to the next or within a growing season in order to help prevent disease or insect problems, or to build soil (see crop rotation).

runner: long, trailing shoot off the main plant that forms a new plant; e.g., strawberry runner.

runoff: water that does not soak into the ground but flows over the surface and runs into another area such as into storm drains, streams, or lakes.

S

scaffold branches: those that form the structure of the canopy.

scarification: breaking, scratching, or softening the seed coat so that water can enter and begin the germination process.

scion: portion of a cultivar that is to be propagated by grafting; piece of shoot with dormant buds that will produce stems and branches.

secondary symptoms: result of pathogen activity somewhere else in the plant.

seed: reproductive structure produced by flowering plants after fertilization, containing the embryo of a new plant. Mature ovule.

seed coat: hard outer covering that protects seed from disease and insects and prevents water from entering the seed before the seed is ready for germination.

seed leaves: the cotyledons; first leaves to grow on a seedling, containing nutrients needed for early life (see cotyledon, dicot, monocot).

seed tape: a plastic-like ribbon which holds seeds at the proper spacing for planting. The tape is laid out and then covered with soil. With adequate moisture, it breaks down, allowing the seeds to germinate and come up in straight rows, eliminating the need for thinning as well.

seedbed: garden soil which has been prepared for sowing seed; that is, weeds and other debris have been cleared and the soil has been turned and raked to a fine surface.

seedling: the young plant which emerges from germinating seed.

semi-evergreen: plants that hold their leaves late into the winter when others are leafless, but eventually lose their leaves and turn brown.

sepals: small, green, leaf-like structures on the base of the flower that protect the flower bud. Collectively called the calyx.

set: small propagative plant part, such as a bulb, suitable for planting; for example, onion set.

sewer sludge: a recycled product of municipal sewage treatment plants, used as a fertilizer, commonly available as activated and composted forms.

sexual propagation: propagation by fusing of male and female genetic material to form a new individual.

shoot: the young, upper portion of a plant, usually arising from a root, underground stem, or bulb.

short-season crop: crop that is ready to harvest in a short period of time after planting; for example, radishes.

shrub: woody plants that remain quite low and usually produce multiple shoots or stems from the base (height 15 feet or less).

side-dressing: additional fertilizer applied close to plants, usually 4-6 weeks after flowers or vegetables are growing.

sign: structures or products of the pathogen as seen on a host plant; i.e., mold, fungi, bacterial slime/ooze.

silt: type of soil particles between sand and clay in size.

simple fruit: fruit that develops from a single ovary.

simple leaf: a leaf blade that is a single, continuous unit.

slip: a cutting of a plant used to start new plants.

slow-release fertilizer: releases nutrients at a rate that makes them available to plants over a long period of time.

small fruits: fruits produced on vines or low-growing plants (as compared with tree fruits); for example, strawberry, grape, raspberry.

soil: the thin upper layer of the earth's surface which is made up of minerals, organic matter, and living organisms (see also subsoil, topsoil).

soil-borne: living in the soil.

soil sterilization: a process by which organisms in soil are destroyed, usually by heat, steam, or chemical fumigation.

soil testing: scientific analysis to determine the available nutrients and pH of soil.

soil texture: refers to the size of soil particles and proportion of sand, clay, and silt in a soil sample (see also loam).

soilless culture: growing plants in a nutrient solution not with soil but with non-soil media for root support (i.e., rockwool, perlite, etc.; see also hydroponics)..

soilless mix: mixture of materials substituting for soil, usually containing a combination of peat moss, sand, vermiculite, perlite, and/or other non-soil materials.

species: a group of plants which have certain common characteristics and which usually interbreed freely with each other.

sphagnum or sphagnum moss: mosses which grow in boggy areas; peat moss is usually decomposed sphagnum moss. Milled sphagnum moss has been ground into finer particles.

spines: specialized modified leaves that protect the plant.

sprout: the development of new growth from a seed or of new shoots from an established plant (see also germination, seedling, shoot).

spurs: short, stubby, side stems that arise from the main stem.

staking: vertical support of a plant using 1 to 3 poles driven into the ground nearby.

stamen: male organ of the flower, produces pollen; usually composed of anther and filament.

staminate flower: male flowers; contain stamens but no pistils.

starch: compound formed from sugars; carbohydrates in plants are most often stored as starch.

starter solution: fertilizer dissolved in water and applied when planting or transplanting to give seedlings a better chance of development; usually a very diluted solution since regular strength would be harmful.

stem: structure that supports buds and leaves and serves as a conduit for water, minerals, and sugars.

sterile: refers to (a) plants that are unable to reproduce; or (b) soil or other material that contains no living organisms.

sterilization: to get rid of living organisms (see soil sterilization).

stigma: upper portion of the pistil, connected by the style; the receiving surface for pollen grains.

stolon: horizontal stem that is fleshy or semi-woody and lies along the top of the ground; may take root at the nodes or apex to form new plants.

stoma/stomata: openings in the leaf surface that allow for the exchange of water and air.

stratification: chilling of seeds to satisfy cold dormancy requirements before germination.

suberization (suberizing): healing the wounded plant tissue by formation of a corky or waxy layer, as in potatoes cut and left to dry.

subsoil: layers of soil beneath the topsoil (see also topsoil).

succession planting: growing two or more crops on the same land, one after the other, in one growing season.

succulent: containing a high percentage of water; particularly referring to plants with thickened, juicy leaves or stems.

sucker: an unwanted shoot that arises from roots, stems, or crown of a plant.

symptom: physical expression of disease in the host tissue; i.e., change in color, appearance, integrity, etc.

syndrome: symptoms and signs that indicate or characterize the presence of disease or other abnormal condition.

synthetic: man-made.

systemic: within the plant's system; for example, a systemic pesticide is taken up by the plant roots, making plant juices toxic to pests. Systemic pesticides should not be used on edible plants.

T

tamping: firming the soil around seeds or transplants to give them better contact with the soil.

tap root: a main root which extends down into the

soil, with small lateral branch roots arising from it; for example, carrot, dandelion, parsnip (compare with fibrous roots).

taxonomy: the science of biological classification of plants and animals. It is the methodology of systematic botany (and zoology), putting plants (and animals) in the form of superior and subordinate groups.

tender plant: a plant which is injured or killed by frost or freezing conditions (compare with hardy plant).

tendril: a twining, string-like structure on a vine which helps the plant to climb and cling to its support.

terminal: located at the apex of a stem.

terrarium: a "miniature garden" in which plants are contained within a tightly closed glass or clear plastic vessel, usually with a moveable top and requiring very little attention.

texture (of soil): relative amounts of sand, silt, or clay; or, the fineness/coarseness of the mineral particles in the soil.

thatch: tightly woven layer of living and dead stems, leaves, and roots that exists between the green blades of grass and the soil surface.

thermoperiod: difference in temperature between day and night.

thigmotropism: plant's response to touch; for example the leaves of Mimosa pudica, the "sensitive plant," which closes when touched.

thinning: (a) removing some plants from a crowded row or pot so that the remaining plants have more space to grow; (b) in pruning, removing branches at their point of origin, stimulating growth throughout the plant.

tilling: cultivating land.

tissue: group of organized plant cells that perform a specific function.

tolerant varieties: ones that yield or grow relatively well in spite of infection.

top-dressing: application of a material (fertilizer, mulch, compost, etc.) to the top of the soil without mixing it in.

topiary: special pruning and training techniques to create unusually shaped shrubs, vines, and trees. Typical topiary forms include spiral, turret, and tiered globe shapes. Animals are also popular topiary forms.

topping: pruning cuts made indiscriminately at internode areas. Usually refers to the practice of pruning the leader and/or upward reaching branches of trees.

topsoil: upper portion of the soil surface, usually less compacted and containing more organic matter and living organisms than the layers beneath (see subsoil).

toxic: poisonous.

trace elements: nutrients needed by plants in very small quantities; also called micronutrients; for example, copper and zinc.

translocation: movement of water, minerals, and nutrients through the plant's vascular system.

transpiration: loss of water from plant tissues in the form of water vapor, usually through leaves and stems.

transpiration stream: the upward flow of water in a plant due to transpiration.

trees: woody plants that produce one main trunk and a more or less distinct and elevated head (height 15 feet or more).

trellis: a lattice (criss-cross) structure used to support and train plants.

trunk: main stem of a woody plant.

tuber: enlarged portion of an underground stem that serves as a food storage organ; has "eyes" or buds; for example, potato.

tuberous root: enlarged root, without "eyes" or buds, which stores food for the plant; for example, sweet potato.

tuberous stem: a stem that is shortened, flattened, enlarged, and underground; for example, begonia, cyclamen.

turgor: firmness or fullness of plant tissue, maintained by adequate water supply.

twig: a stem that is less than one year old and has no leaves since it is still in the winter-dormant stage.

V

vaporization/volatilization: evaporation of an active ingredient during or after application.

variety: subgroup.

vascular system: the system that transports food, water, and minerals and offers support for the plant.

vegetative: tissues or processes concerned with maintenance of the plant body; not reproductive.

vermiculite: heat-treated, expanded mica product used to condition soil, start seeds, or root cuttings; holds moisture and nutrients well, acting as a soil substitute.

viable seed: one which is capable of germination.

vines: climbing or crawling plants without self-supporting upright stems.

virus: infectious molecules that take over plant metabolism and use it to produce more virus.

W

water sprout: an unwanted shoot that arises along branches, usually at pruning sites.

weed: plant growing where it is not wanted.

whorled: leaves arranged in circles along the stem.

witches-broom: a dense, broom-like clustering of branches resulting from development of numerous adventitious buds at one region.

woody stem: a stem that contains relatively large amounts of hardened xylem tissue in the central core, typical of most tree fruits, ornamental trees, and shrubs.

X

xylem: tubes that conduct water and minerals in plants; found in the vascular system.

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