

PennState Extension

MASTER GARDENER MANUAL

Dedication

To the Penn State Extension Master Gardeners in recognition of their outstanding volunteer efforts promoting sustainable horticultural practices and environmental stewardship in Pennsylvania communities.

Acknowledgments

The following University faculty members, extension educators, and Master Gardeners contributed to this edition of the training manual by updating and reviewing content, offering valuable comments, and providing illustrations and photos. Material was adapted from the original *Penn State Extension Master Gardener Manual*, *The Maryland Master Gardener Handbook*, *The Virginia Master Gardener Handbook*, and various Penn State Extension publications.

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Introduction to the Penn State Extension Master Gardener Program

As a volunteer for the Penn State Extension Master Gardener program, you will be representing Penn State. For this reason, it is important for you to become familiar with the history and organization of Penn State Extension and understand the responsibilities of a Master Gardener.

THE LAND-GRANT SYSTEM AND COOPERATIVE EXTENSION

Land-grant institutions constitute a uniquely American educational system. Before the latter half of the nineteenth century, when the land-grant system was created, America's colleges and universities existed primarily to prepare wealthier citizens for the professions of medicine, law, and the ministry. As the need for higher education grew, educators and politicians proposed a different kind of university—one devoted to educating all people, particularly those seeking a vocation in the nation's businesses, farms, and trades. The result was the land-grant institution.

A remarkable cooperation among federal and state governments, university educators, and laypeople marked the creation and growth of the land-grant system. It was established with the Morrill Act of 1862, by which Congress provided large grants of federal land for each state to sell. The states were to use these funds to create an endowment, on which interest would accrue to sustain the colleges. It soon became apparent that these monies were insufficient, and with the second Morrill Act of 1890, Congress provided for additional federal funding. The act also established funding for a second system of land-grant institutions in 16 southern states where existing land-grant colleges practiced segregation. Thus, historically black land-grant institutions joined the system.

At this time, colleges were severely hampered by the general lack of sound research in support of teaching. In 1887, Congress passed the Hatch Act to create and support experiment stations. Then in 1914, the Smith-Lever Act created Cooperative Extension as a partnership among federal, state, and county governments for its support and oversight. The Smith-Lever Act gave land-grant institutions the responsibility "to aid in diffusing among the people of the various states, useful and practical information on subjects relating to agriculture and home economics; and to encourage the application of the same."

The land-grant idea evolved to include three central functions: resident teaching, research, and extension. Cooperative Extension is the premier organization for fulfilling the extension function of each state's land-grant institution.

Cooperative Extension's ultimate goal is personal development—to enable people to be self-directed, manage their resources, and handle change in primary dimensions of their lives. The means for personal development is education, which empowers people by helping them acquire knowledge, attitudes, skills, and aspirations. Cooperative Extension's methods are informal, off campus, and oriented toward people's problems and needs.

PENN STATE EXTENSION

The Penn State College of Agricultural Sciences has nine traditional academic departments (Agricultural and Biological Engineering; Agricultural Economics, Sociology, and Education; Animal Science; Ecosystem Science and Management; Entomology; Food Science; Plant Pathology and Environmental Microbiology; Plant Science; and Veterinary and Biomedical Sciences). These units include faculty with extension education, resident education, and research responsibilities. Faculty members with extension responsibilities prepare content for extension programs.

The College of Agricultural Sciences also operates four research and extension centers. The Russell E. Larson Agricultural Research Center located in Rock Springs is in close proximity to University Park. The other three research facilities are located in areas with high concentrations of agricultural production: Biglerville, Erie, and Landisville. Each has a different focus and provides University faculty with the opportunity to conduct research under the same environmental conditions facing the agriculture industries in Pennsylvania. The Fruit Research and Extension Center (FREC) in Biglerville is located in the heart of apple and peach country, while the Lake Erie Regional Grape Research and Extension Center in Erie is nestled between the escarpment and shores of Lake Erie with deep soils and an ideal climate for growing grapes. The Southeast Agricultural Research and Extension Center (SEAREC) in Landisville is located near some of the highest concentrations of vegetable, small fruit, and agronomic crop production in the state of Pennsylvania.

Each of Pennsylvania's 67 counties has a physical presence through a Penn State Extension office. The county extension staff may include extension educators, nutrition education advisers, a Master Gardener coordinator or horticulture assistant, and support staff. The extension educators may be working in the agriculture, family living, 4-H, urban forestry, community development, or water quality subject matter areas. County staff deliver information to the community.

The Penn State Extension Master Gardener program is led by the state coordinator under the direction of the assistant director for horticultural programs. Counties are grouped into geographic regions that are supervised by area Master Gardener coordinators, who provide leadership to the county coordinator.

At the county level, a Master Gardener coordinator directs the program with support from the area Master Gardener coordinator, extension educators, and office staff working directly with Master Gardener volunteers. Faculty with extension education appointments in areas such as horticulture, agronomy, entomology, and plant pathology contribute technical support in their areas of expertise.

THE MASTER GARDENER PROGRAM

The Master Gardener program was designed to use the services of trained volunteers who have horticultural knowledge and a willingness to share that knowledge with other county residents through Cooperative Extension. The program was initiated in 1972 in Seattle. David Gibby, King County extension agent, found that keeping up with the growing number of gardening questions was impossible. Dr. Gibby and

Dr. Arlen Davison, then the extension plant pathologist, discussed potential solutions and conceived a plan for the initial Master Gardener program.

The guiding philosophy, as stated by Dr. Davison, was to develop a core of knowledgeable volunteers to assist Cooperative Extension in meeting the demand for reliable gardening information. In 1973, 120 Master Gardeners were trained by extension specialists in King and Pierce Counties. The program's success was remarkable. Today, there are Master Gardener programs in all 50 states; however, funding solutions, organizational styles, and program scope may vary from county to county and state to state.

In Pennsylvania, Philip N. Rhinehart is recognized as the program's initiator. In 1980 Mr. Rhinehart, then vice president of the Clearfield County Extension Executive Committee, came across an article on the Master Gardener program describing how the program had begun and grown. Aware that the extension staff in Clearfield County was inundated with gardening questions, he immediately identified with the problem that had led Drs. Gibby and Davison to recruit and organize volunteers in Washington. Mr. Rhinehart requested information on the program from Washington and other states involved with the program. He then conveyed the information to Harold R. Bock, at that time county extension director, who in turn proposed the idea of a Master Gardener program in Pennsylvania to Penn State. The University supported the idea, and in 1981 a committee was formed to organize the program. In 1982 the first Penn State Extension Master Gardeners completed their training.

MASTER GARDENER VOLUNTEERS

Master Gardeners receive a minimum of 40 hours of instruction. Along with an orientation, volunteers are given core training in botany, plant propagation, soil health, plant pathology, plant diagnostics, entomology, integrated pest management, lawn care, vegetable gardening, woody and herbaceous plants, native plants, weeds and invasive species, pruning, and communication skills. The core section of the manual gives the Master Gardener trainee the basic horticultural knowledge necessary to assist extension staff effectively. The remaining elective classes cover specific gardening topics, including indoor plants, garden wildlife, tree fruit and small fruit culture, landscape design, and gardening equipment.

After training is completed, the volunteers are ready for action. Each new Master Gardener provides the county extension office with 50 hours of horticulture-related volunteer work in the first year. Volunteer activities must have an educational purpose and/or a teaching component. The following are examples of acceptable volunteer opportunities:

- Answer consumer/home gardeners' telephone and email inquiries, assist extension office visitors with plant and insect samples for identification or diagnosis, and give general pesticide recommendations.
- Assist with extension educational programming, such as poison prevention programs, talks for local organizations, extension-sponsored workshops, exhibits, and displays.
- Write research-based gardening and horticultural information for fact sheets, newsletters, newspapers, magazines, websites, and blogs.
- Design or assist with establishing and maintaining educational demonstration

gardens, such as community, healing, school, pollinator, and extension office gardens.

- Develop or assist with community-based environmental stewardship projects.
- Assist teachers, 4-H volunteers and youth, and/or children with gardening education projects.
- Conduct/teach horticulture-related clinics, pruning, or other demonstrations at extension offices, local libraries, farmers markets, government centers, fairs, expos, garden clubs, civic groups, community events, and flower shows.
- Serve as neighborhood "plant expert" in the community by answering home gardening questions, diagnosing plant problems, and/or instructing neighbors on proper care of lawn, landscape, garden, or houseplants.
- Teach Master Gardener training sessions.

After trainees have satisfactorily completed the formal training and 50 hours of volunteer service, they are awarded a Penn State Extension Master Gardener certificate. To maintain the title "Certified Master Gardener," volunteers are required to attend a minimum of 10 hours of continuing education training per year and serve a minimum of 20 hours of volunteer time per year. When an individual ceases active participation, his or her designation as a Master Gardener becomes void.

By every measure, the Master Gardener program has been highly successful and provides benefits for everyone involved. The public benefits by being able to talk with knowledgeable gardeners face to face. Master Gardeners enjoy the feeling of accomplishment that comes through their service and appreciate the professional training they receive. Cooperative Extension benefits because Master Gardeners extend the organization's reach to a greater number of gardeners.

Teaching and Communication

CHAPTER 1

LEARNING OBJECTIVES

- Develop effective communication skills.
- Understand how to organize and simplify information.
- Explain how to prepare and present a program, and create an effective display.
- Understand the value of publicity and marketing.

INTRODUCTION

We are here to learn, but we're also here to help others learn; this means learning not only about plants, pests, and gardens but also how to share what we know with others.

TEACHING

Teaching is a large part of what Master Gardeners do. The mission of the Master Gardener program is to provide research-based information to the community. There is more to this task than simply talking at the front of a room or showing a PowerPoint presentation. Teaching involves preparation, careful attention to questions and discussion, and a willingness to explore. Learning is also a big part of teaching. Teaching things to others is a great way to learn about them!

Teaching can be hard work, but it's also very rewarding. Your challenge is to make learning fun, informative, and satisfying for both your students and yourself.

Understanding Your Students

You may do Master Gardener work with young people, but many times you will be teaching other adults. Children, teens, and adults all approach learning in different ways. When teaching adults, keep the following in mind:

- Adults are participating by choice. Adults are generally more invested in learning and attach more value to the process.
- Adults have a broad base of experience from which to draw and share with others. Keep in mind that some previous experiences might lead adult students to make incorrect assumptions about the material they are learning; for example, an amateur gardener may be following outdated wisdom about using pruning paint on freshly cut wounds. Check with your students often to make sure everyone is on the same page.
- Adults have busy, complicated lives. While adults are generally invested in learning, they also have many other obligations. Family, job, community, and social responsibilities could require adult students to be flexible about the amount of time and energy they can invest.
- Many adults face barriers to learning. Some examples of this are having unrealistic goals or diminished vision and hearing. Work with your students to find ways around frustration and make the material accessible to everyone.
- Adults are sensitive to failure in learning situations.
- Adults want information to be relevant to their needs and immediately applicable. Most adults want to learn how to perform a task or accomplish a goal and will be focused on the steps they need to take.
- Adults respond better when the material is presented through a variety of different senses. Try to design your lessons with hands-on experiences that engage as many of the senses (sight, sound, scent, taste, and touch) as possible.

Effective adult educators are confident in their abilities, accepting of themselves and others, flexible, capable of admitting their limitations, and appreciative of the contributions of others.

When teaching children, keep the following in mind:

- Younger students have less experience on which to ground new knowledge. Establishing context can be helpful to younger learners.
- Children are motivated to learn through exploration and curiosity. Give younger students the freedom to explore a topic in a way that makes sense to them.
- Children have different strengths and learning styles. Try to give students many ways to approach the material.
- Let children choose how they learn. This will help them process and retain new material.
- Give students choices. Some children learn by reading, some by watching, and some by doing. Letting children find their own way will make the lesson more relevant and give the students an opportunity to find their motivation to learn.

Learning is a step-by-step process, and it's important to make sure that younger students are comfortable with the current step before moving on to the next.

What People Retain

Increased involvement on the part of the learner leads to increased retention of the subject matter. The more involved learners are, the more they will retain. Students are better able to retain information when they are active participants.

When designing learning activities, try to incorporate a hands-on component to the lesson. As an example, if you are giving a presentation on pruning, a live demonstration is good, but even better is allowing students to prune a plant themselves. Not all subject material lends itself to this kind of instruction, but lessons that offer hands-on experience will be more effective in helping the students remember the material.

What People Ask

When students are trying to understand new material, they will ask a lot of questions. Students may ask specific questions to better understand a detail, while other questions may be about broader topics or asking about context. Listen carefully to questions when teaching—the kinds of questions your students are asking can help you understand what parts of the material they are comfortable with and where they might be having trouble.

Answering Questions

There are many useful strategies for answering questions well. First, make sure you understand the question! It is helpful to repeat the question back to the student to ensure that the entire room has heard the question, and it gives the student a chance to correct or amend the question if necessary. This also gives you some time to think about the question and prepare to answer it.

When answering questions, remember that the student knows different things than you do. The student may or may not have a good grasp of plant nomenclature or may not have experience with a particular propagation technique. Try to use vocabulary that is familiar to the student.

It is always better to give yourself time to offer a good answer than to give a poor answer quickly. If you cannot answer a question during the lesson, make a note of it and follow up with the answer later.

Basic Botany

CHAPTER 2

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LEARNING OBJECTIVES

- Describe the way plants are classified and grouped using the proper nomenclature.
- Explain the parts of a plant and their functions.
- Understand the three basic processes for plant growth and development: photosynthesis, respiration, and transpiration.
- Become familiar with the environmental factors that affect plant growth.
- Describe the life cycles of annuals, biennials, and perennials.
- Explain the differences between monocots and dicots.

INTRODUCTION

Botany is the science of plants. A study of botany is important for understanding horticulture, the art and science of cultivating vegetables, fruits, and ornamental plants. Home horticulture is the use of these arts and sciences by the home gardener. Taxonomy is the science dealing with the naming and classification of plants and animals.

To gain a working knowledge of horticulture, it is necessary to understand the structure and function of plants, as well as the environmental factors that affect their growth. All plants have certain structures and functions in common, as discussed throughout this chapter. Much of the information presented relates to higher plants, the seed-producing flowering plants and gymnosperms that are of greatest importance to horticulture, rather than more primitive spore-producing plants such as mosses, ferns, and their relatives. All vegetable and flowering ornamental plants are angiosperms, which produce seeds inside a fruit, while conifers and their relatives are gymnosperms, which produce seeds but lack protective fruits.

Life Cycles

Plants are classified by the number of growing seasons required to complete their life cycle.

Annuals pass through their entire life cycle, from seed germination to seed production, in one growing season and then die. Examples are sunflowers and pot marigolds.

Biennials start from seed and produce vegetative structures and food-storage organs the first season. During the first winter, a hardy evergreen rosette of basal leaves persists. During the second season, the rapid elongation of the flower stalks, called bolting, occurs; flowers, fruit, and seeds develop to complete the life cycle. The plant then dies. Carrots, beets, cabbage, celery, and onions are biennials whose flowers produce seeds that develop the second year of growth. Hollyhock, Canterbury bells, foxglove, and sweet William are biennials commonly grown for their attractive flowers.

Perennial plants live for two or more years. After reaching maturity, they typically produce flowers and seeds each year. In areas of the country that experience frost, perennials are classified as herbaceous if the top dies back to the ground each winter and new stems grow from the crown each spring. They are classified as woody if the top persists, as in shrubs or trees.

CLASSIFICATION OF THE PLANT WORLD

Plants are vital to our existence. In an effort to provide a means to catalog information about the vast number of living plants, scientists have classified them into various groups based on shared characteristics that are inherited from one generation to the next (Fig. 2-1).

Individual plants are grouped into species, or groups of individuals that share close genetic relationships, interbreed freely, and are very similar in their morphology (form and structure).

Closely related species are grouped into genera (plural of genus), which are groups of genetically related and thus morphologically similar species. Genera with similar traits are grouped into families. Families are grouped into orders, which are then grouped into classes. Classes are grouped into divisions. Many of our gardening and landscape activities use species in the angiosperm and gymnosperm divisions. The divisions are together classified in the plant kingdom, a group that includes all plants.

As you move through plant classification from species to kingdom, similarities among individuals become less distinct. The modern classification of plants is based on DNA characteristics that reflect underlying evolutionary relationships. Such a classification is called a natural classification, while one based on superficial similarities that do not reflect evolutionary relationship is said to be an artificial classification.

History of Plant Classification

Over the centuries there have been numerous attempts to name and classify plants in a natural fashion. Early attempts at naming relied on Latin words to describe various aspects of a plant. As more and more plants were identified and classified, the length of individual names increased as well. It was not uncommon to have plants named or described with eight or more words.

In the mid-1750s Carl von Linne, a Swedish botanist using the pen name Carolus Linnaeus, published a book titled *Species Plantarum* and changed the way plants are named. He gave all the plant species that were known at that time a name consisting of two words. The first word identifies the genus; the second is the specific epithet.

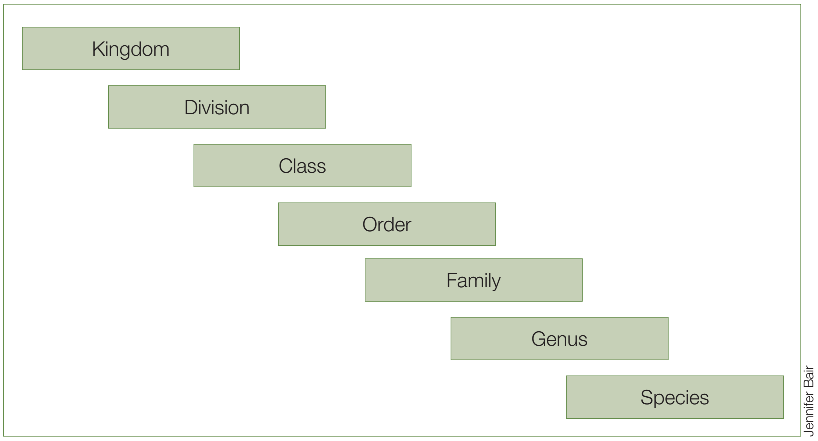

Fig. 2-1. Plant classification.

This format is known as the Latin system of binomial nomenclature, and it is still the basic structure of our modern system of nomenclature.

In the eighteenth century, Latin was the language of science and thus formed the basis for the language of nomenclature. Many Latin plant names were carefully constructed to provide information about the plant. Latinized descriptive phrases often reflect a particular plant quality. Examples are “alba” (white), “rubra” (red), and “serrata” (toothed). The medicinal value of some plants is seen in their names, such as lungwort (*Pulmonaria*).

Some plant names are tributes to mythological Greek and Roman characters. Plant names in this category include Narcissus, Dianthus, and Andromeda.

A number of plant names commemorate significant contributions from botanists, plant explorers, or other people. Most generic names ending in “-ia” honor people. Gardeners will be familiar with *Magnolia*, *Forsythia*, and *Zinnia*, named for Pierre Magnol, William Forsyth, and Johann Zinn, respectively.

Everyday Nomenclature

The complete name of any plant used in commercial trade includes the genus and the specific epithet. Many plants also have

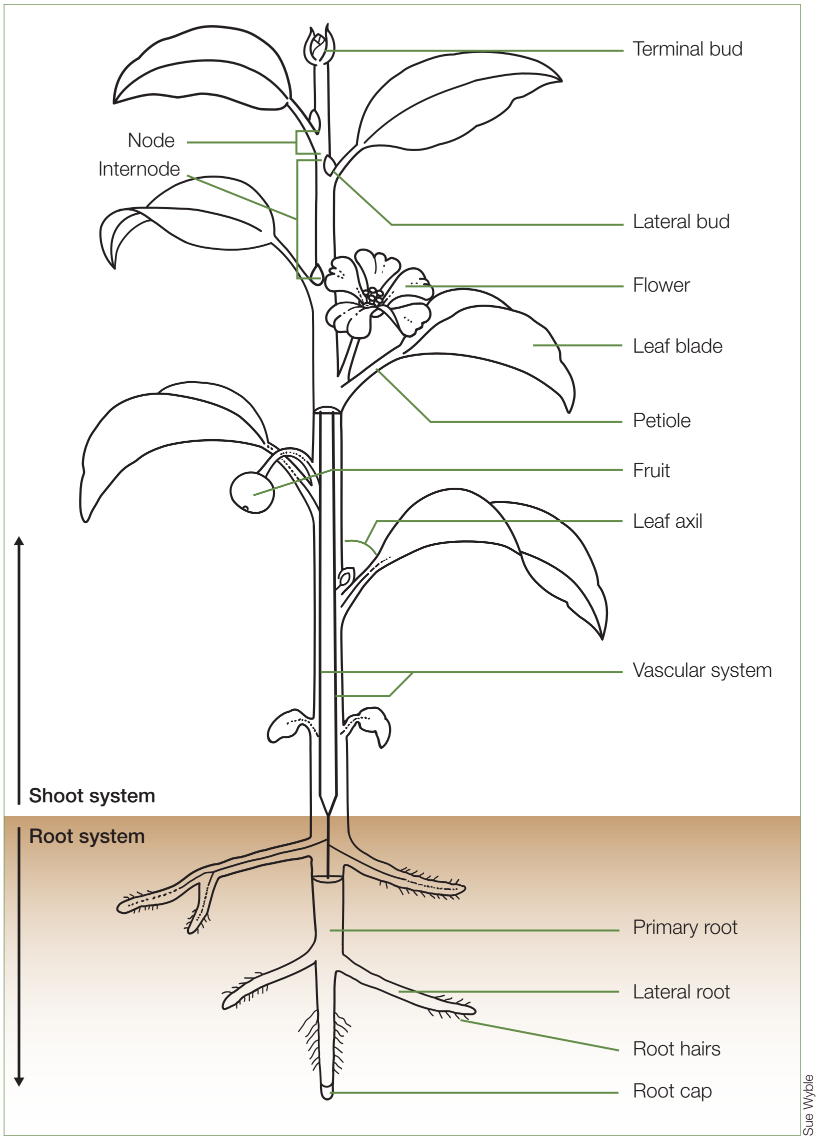

Fig. 2-2. Principal parts of a vascular plant.

a common or vernacular name. The first letter of the genus is capitalized, the specific epithet is lowercased, and both are either underlined or written in italics. Examples of species names are *Cucumis sativus* (cucumber), *Lathryus odoratus* (sweet pea), and *Cercis canadensis* (eastern redbud).

The Latinized species name is a universal format used worldwide and should be understood by everyone discussing a plant. Common names, on the other hand, are just that—common to a particular area, region, or country—and may not provide accurate identification of a plant in all situations. *Nymphaea alba* (European white waterlily), for example, has 245 different common names across Europe. The Latinized species name is thus best used in discussions of plants since it is unique to this species.

Some plants may have a third Latinized name after the genus and specific epithet. Used to designate a variety, it is preceded by "var.," which signifies a group of plants subordinate to the species. The differences between varieties within a particular species are inheritable and passed on to succeeding generations. However, the morphological differences between two varieties of a particular species are smaller than the morphological differences between two different species. Varieties of a species are usually interfertile, while different species are usually not. Examples of varieties include *Cercis canadensis* var. *alba*, which has white flowers, and *Gleditsia triacanthos* var. *inermis*, a thornless variety of common honeylocust.

Another common horticultural term is cultivar, short for cultivated variety A cultivar is a collection of cultivated plants that are clearly distinguished by certain characteristics and when reproduced (sexually or asexually) retain their distinguishing characteristics. Cultivars do not occur in nature and must be maintained under cultivation. Cultivar names are written in a modern language, not italicized, set within single quotation marks, and with the first letter of each word capitalized.

Examples of cultivars are *Acer platanoides* 'Crimson King', and *Cornus florida* var. *rubra* 'Cherokee Chief'. 'Crimson King' maple has purple foliage instead of green like the species, and 'Cherokee Chief' dogwood has flowers of a deeper red than the variety *rubra*.

Occasionally, a plant name may have "×" between the genus and species. This represents an interspecific hybrid resulting from a cross between two species within the genus. An example is *Viburnum × burkwoodii*—Burkwood viburnum that resulted from a cross between *V. carlesii* and *V. utile*.

Plant Propagation

CHAPTER 3

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appear, there is less chance it will spread. Seedlings in rows are easier to label and handle at transplanting time than those that have been sown in a broadcast manner. Sow the seeds thinly and uniformly in the rows by gently tapping the packet of seed while moving it along the row. Lightly cover the seeds 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 that of petunia, begonia, and snapdragon are not covered but lightly pressed into the medium or watered in with a fine-mist spray. If these seeds are broadcast, strive for a uniform stand by sowing half the seeds in one direction and then sowing the remaining seeds in the other direction.

Large seeds are frequently sown into some sort of a small container or cell pack, eliminating the need for early transplanting. Usually two or three seeds per unit are sown and then thinned later to allow the strongest seedling to grow.

Seed Tape

Most garden stores and seed catalogs offer indoor and outdoor seed tapes, which have precisely spaced seeds enclosed in an organic, water-soluble material. When planted, the tape dissolves and the seeds germinate normally. Seed tapes are especially convenient for tiny, hard-to-handle seeds. However, tapes are much more expensive per seed. Seed tapes allow uniform emergence of seedlings, eliminate overcrowding of seedlings, and permit sowing in perfectly straight rows. The tapes can be cut at any point for multiple row plantings, and thinning is rarely necessary.

Pregermination

Another method of starting seeds is pregermination, which involves sprouting the seeds before they are planted in pots or the

Table 3-1. Seed requirements.

Plant	Approximate Germination Time (Days)	Germination Temperature (0°F)	Germinate in Light or Dark
12 Weeks or More to Seed before Last Spring Frost			
Begonia	10–15	70	Light
Browallia	15–20	70	Light
Geranium	10–20	70	Light
Larkspur	5–10	55	Dark
Pansy (Viola)	5–10	65	Dark
Vinca	10–15	70	Dark
10 Weeks to Seed before Last Spring Frost			
Dianthus	5–10	70	Either
Impatiens	15–20	70	Light
Petunia	5–10	70	Light
Portulaca	5–10	70	Dark
Snapdragon	5–10	65	Light
Stock	10–15	70	Either
Verbena	15–20	65	Dark
8 Weeks to Seed before Last Spring Frost			
Ageratum	5–10	70	Light
Alyssum	5–10	70	Either
Broccoli	5–10	70	Either
Cabbage	5–10	70	Either
Cauliflower	5–10	70	Either
Celosia	5–10	70	Either
Coleus	5–10	65	Light
Dahlia	5–10	70	Either
Eggplant	5–10	70	Either
Head Lettuce	5–10	70	Light
Nicotiana	10–15	70	Light
Pepper	5–10	80	Either
Phlox	5–10	65	Dark
6 Weeks to Seed before Last Spring Frost			
Aster	5–10	70	Either
Balsam	5–10	70	Either
Centurea	5–10	65	Dark
Marigold	5–10	70	Either
Tomato	5–10	80	Either
Zinnia	5–10	70	Either
4 Weeks to Seed before Last Spring Frost			
Cosmos	5–10	70	Either
Cucumber	5–10	85	Either
Muskmelon	5–10	85	Either
Squash	5–10	85	Either
Watermelon	5–10	85	Either


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Fig. 3-5. Thermostatically controlled heating mat.

garden. By controlling temperature and moisture, a higher and quicker rate of germination can be achieved. To begin the process, lay seeds between two moistened paper towels and place them in a clear plastic bag. Keep seeds moist and in a warm place. When roots begin to show, place the seeds in containers or plant them directly in the garden. When transplanting seedlings, be careful not to break off tender roots. After planting, continued attention to watering is critical.

When planting pregerminated seeds in a container to set in the garden later, place one seed in a 2- to 3-inch container. Plant the seeds to only half the recommended depth. Gently press a little bit of moistened soilless medium over the sprouted seed and add about ¼ 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 the pots in a warm place and care for them just as you would for any other newly transplanted seedling.

Watering

After the seed has been sown, moisten the planting mix thoroughly with warm water. Use a fine-mist spray or place the containers in a pan or tray that has about 1 inch of warm water in the bottom. Avoid splashing or excessive flooding, which could 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 so that you do not need to add water. One way to maintain this level of moisture is to cover the flat with a plastic dome lid. Smaller pots can be placed into a plastic bag and sealed. Keep the container out of direct sunlight; otherwise, the temperature may rise to the point where the seeds will be damaged. Be sure to remove the plastic bag or dome lid as soon as the first seedlings appear.

Lack of uniformity, overwatering, and drying out are problems associated with hand watering. Subirrigation (watering from below) works well to keep the flats moist. Subirrigate the flats when the surface of the medium begins to dry out, and then remove them from the water.

Temperature and Light

Several factors that ensure 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, special warm areas often must be provided. The use of a thermostatically controlled heating mat is an excellent way to supply constant heat (Fig. 3-5).

After germination and seedling establishment, move the flats to a light, airy, cooler location. Ideal temperatures range from 55 to 60°F at night and 65 to 70°F during the day. This will prevent soft, leggy growth and minimize disease troubles. A few plants may germinate or grow best at a different temperature range and must be handled separately from the bulk of the plants.

Seedlings must receive bright light after germination. Ideally, place the seedlings under fluorescent lights or LED grow lights.

Use two 40-watt cool white fluorescent tubes or special plant-growing lights. Position the plants 2 to 4 inches from the tubes and keep the lights on for 14 to 16 hours each day. As the seedlings grow, the lights should be raised. Do not use incandescent lights for germination because they produce too much heat and will cause the seedlings to stretch.

Damping-off Disease

Damping-off causes seeds to rot and seedlings to collapse and die. The disease is carried in soil and may be present in planting containers and on tools. Soil moisture and temperature that are necessary for seeds to germinate are also ideal for the development of damping-off. Once the disease appears in a seed flat, it may quickly travel through the flat and kill all the seedlings. To prevent damping-off, use sterile soil and containers or seeds that have been pretreated with a fungicide.

Transplanting and Hardening Plants

If plants have not been seeded in individualized containers, they must be transplanted to give them proper growing space. One of the most common mistakes plant growers make is to leave the seedlings in the seed flat for too long. The ideal time to transplant young seedlings is when they are small and there is little danger from setback (Fig. 3-6). This is usually about the time the first 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 too tall and leggy.

Seedling growing mixes and containers can be purchased or prepared similarly to those for germinating seed. However, the medium should contain more plant nutrients than a germination mix. Some commercial soilless mixes have added fertilizer. When fertilizing, use a soluble houseplant fertilizer at the dilution recommended by the manufacturer about every two weeks after the seedlings are established. Remember that too much fertilizer can easily damage young seedlings, especially if they are under any moisture stress.

Nancy Knauss

Fig. 3-6. Proper stage for transplanting.

To transplant seedlings, carefully lift the small plants out of the container. Gently ease them apart in small groups to make separating individual plants easier. Avoid tearing roots in the process. 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 that the seedling can be placed at the same depth at which it was growing in the seed flat. Small plants or slow growers should be placed 1 inch apart, and rapid-growing, large seedlings at about 2 inches. 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. Continue watering and fertilizing as you did for the seed flats.

Most plants transplant well and can be started indoors, but a few are difficult to transplant (e.g., zinnias and cucurbits such as melons and squash). These are generally directly seeded outdoors or sown indoors into individual containers that will be planted outside after danger of first frost has passed.

Soil Health and Fertilizer Management

CHAPTER 4

Bigstock

per square inch (psi) of pressure—approximately the pressure under a typical person's footprint—is all that is needed to cause compaction. The wetter the soil, the easier it is to compact. When a soil is compacted and its structural units are broken down, pore space is reduced. This has a number of impacts on the soil. Reduced pore space limits aeration, which is necessary for root growth and biological activity. A compacted soil has less water-holding capacity, and the water that is in the soil is less available to plants and soil organisms. Water movement is also limited in compacted soils. This impedes soil drainage and reduces water movement to the roots. Root growth is usually reduced in compacted soils. This lowers plant's ability to get water and nutrients. Compacted soils are also more difficult to till.

Soil moisture is probably the most important factor to consider when trying to prevent compaction. Compaction is much more severe on wet soils than dry soils. Don't walk or drive on wet soils, and never till wet soils. If you need to go into a wet garden on a regular basis, make paths and stay on them. This will limit the compaction to a small area. Also, using boards as walkways in heavily traveled areas will distribute the weight and reduce pressure on the soil.

In special cases, coarse sand, vermiculite, perlite, and calcined clay are added to heavy clays to improve the physical conditions of the soil. These materials can be expensive, however, and large quantities are needed to do any good. For example, if sand is added, a minimum of 50 percent by volume is needed to improve drainage and aeration in a medium- or fine-textured soil. Sometimes, coarse materials can make the situation worse by causing clays to "set up" like concrete. Compost, manures, and other organic amendments are usually more effective and economical for modifying soil conditions in the home garden.

Organic matter greatly improves both clay and sandy soils. Good sources include peats (moss, reed-sedge), green and animal manures, leaf mold, sawdust, composted sludge, and straw. These materials are decomposed in the soil by soil organisms. Factors such as moisture, aeration, pH, 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.

Rapid decomposition requires a proper balance of carbon and nitrogen in the material. Nitrogen may need to be added if large amounts of undecomposed low-nitrogen material such as dried leaves, straw, or sawdust are used. Add about 1 to 1.5 pounds of nitrogen for every 100 pounds (dry) of these low-nitrogen materials. Fresh green wastes, such as grass clippings, are higher in nitrogen than dry material. Microbes use nitrogen to break down organic matter, which may cause a nitrogen deficiency in the plants if the nutrient is not present in sufficient amounts.

Value of Compost

Using compost made from plant wastes is one way to avoid tying up nitrogen during decomposition. Correct composting is an art that can produce a valuable nutrient and source of humus for any garden. The process involves the microbial decomposition of mixed raw organic materials to humus, a dark, fluffy product resembling rich soil, which is then spread on and incorporated into garden soil.

Finished compost will be black and crumbly, like good soil, with a pleasant, earthy smell. Only a few leftover corncobs or stalks will remain undecayed. These can be sifted out and added to the next batch. For use in potting mixtures, a relatively fine sieve (¼-inch hardware cloth) will take out the larger chunks. Otherwise, the compost can be spread in the garden as is and dug or tilled under. Detailed instructions are included in the "Composting" chapter of this manual.

Use of Cover Crops

Planting a cover crop is another inexpensive soil improvement method that should not be underestimated (Fig. 4-8). Green manures or cover crops such as annual rye are planted in the garden in the fall for incorporation in the spring. For best results, sow seed shortly 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 topsoil loss.

Legume cover crops, such as red clover, crimson clover, or hairy vetch, can increase the amount of nitrogen in the soil and reduce fertilizer needs. A deep-rooted cover crop that is allowed to grow for a season in problem soil can help break up compacted soil and greatly improve tilth. Incorporate green manures at least two weeks before planting vegetables. Do not allow cover crops to go to seed.

Regularly adding manures, compost, cover crops, and other organic materials can raise the nutrient level and physical quality of the soil, thus reducing the need for synthetic fertilizers. Desirable soil health does not happen with a single addition, or even several additions, of organic material—it requires a serious soil-building program.

Garden Management

Tilling

Excessive tillage is harmful to soil health in a number of ways. Tillage increases oxygen in the soil, stimulating microbial activity, and results in the decomposition of organic matter. If additions of organic matter are not sufficient to counteract the losses from decomposition, organic matter levels will decline over time, reducing soil health. Inversion tillage and rototilling also reduce the soil coverage provided by crop residues, leaving soil more exposed to erosion. Tillage can also disrupt the network of soil fungi, which can lead to their decline over time. When not managed carefully, most tillage methods compact the subsoil, creating a plow pan that restricts the growth of roots and their access to water and nutrients in the subsoil. Excessive wheel and foot traffic can compact the surface soil, reducing macroporosity and impeding root growth.

Physical disturbances like rototilling can have profound effects on the biological properties of soil. Compaction and the removal of surface residue may contribute to a reduction in soil moisture and living space for soil-dwelling organisms. Diversity and abundance of arthropod predators associated with the soil surface can be greater under reduced-tillage management in comparison to conventional tillage, and natural control of pest insects in soil may be enhanced in reduced-tillage systems. Beneficial insects

Sandy Feather

Fig. 4-8. Cover crop of buckwheat (white flowers) incorporated with sunflowers and other annuals.

Composting

CHAPTER 5

Nancy Knauss

LEARNING OBJECTIVES

- Be able to define compost.
- Understand the benefits and uses of compost in the garden.
- Explain the composting process.
- Describe methods of composting.
- Describe maintenance of the compost pile.

INTRODUCTION

Compost is a dark, crumbly, earthy-smelling material produced by the natural decomposition of leaves, grass clippings, and many other organic materials. It is much like the natural organic matter existing in all soil and can be easily made by any gardener.

Composting is a natural process and "happens" every day in our fields, forests, lawns, and gardens. Soil microbes, insects, and animals are constantly decomposing plant and animal remains. Gardeners can speed up this process by following some simple composting guidelines. The resulting compost can be used to enrich the quality of soil used for gardens, lawns, and landscape plantings. Just about every gardener or homeowner can make compost from many kinds of organic materials. These materials can be from the garden (e.g., mature plants, weeds, harvested crops, prunings, lawn clippings, and leaves), kitchen residuals (e.g., vegetable and fruit scraps), and various paper items (e.g., cardboard, paper, and cartons).

WHY MAKE COMPOST?

Reduce the Waste Stream

The National Composting Council estimates that the average U.S. household generates 650 pounds of compostables every year. Composting helps us reduce the quantity of materials in our waste stream. Nationwide, municipal waste is 9 percent yard materials, 21 percent food residuals, and 15 percent paper and paperboard—all of which can be processed through a composting system. Also, limited landfill space can be reserved for materials that cannot be composted or recycled.

Save Money

Garbage handling is the fourth largest expense for many cities. Collection and disposal of yard and food materials is expensive and requires fossil fuels and landfill space. Composting these materials in our own backyards saves money on collection costs and tipping fees. Compost is a valuable and free soil amendment that can be used in place of many purchased soil additives.

Improve the Soil

Nearly all Pennsylvania soils are low in organic matter. An increase in organic matter of only 1 to 1.5 percent will greatly improve a soil's physical quality and result in better root penetration. Composted organic matter can also be an effective soil mulch that, in time, will decompose to enhance soil quality. As a soil amendment, compost improves the physical, chemical, and biological properties of soil.

Physical properties. In sandy soils, compost binds sand particles together to improve water-holding capacity and aeration. In heavy clay soils, compost loosens clay particles and allows water and roots to move more easily.

Chemical properties. Compost improves the cation exchange capacity (CEC) of soils, increasing their ability to hold nutrients for use by plants. Compost also contains plant nutrients and essential trace elements in a slow-release form.

Biological properties. Compost provides beneficial organisms essential for productive soils and healthy plants. Research has also shown that increasing the population of certain microorganisms may suppress specific soilborne plant diseases.

Composting Is Easy

Composting is a practical and convenient way to handle your garden wastes. You can make useful compost with no more effort than it takes to bag and haul the garden waste away.

THE COMPOSTING PROCESS

Composting uses the natural process of decay to change organic materials into a valuable humus-like material. Decay occurs naturally, but composting allows you to speed up the process by managing the environmental factors that control the rate of decay.

Composting can be done in open piles or within an enclosure. The term “compost pile” is used in this chapter to include any type of composting system.

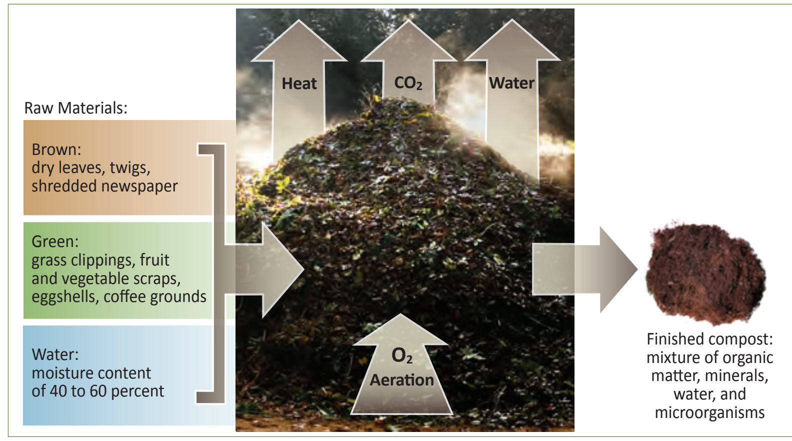
The following important factors control the compost process:

- Decomposers (the microorganisms that digest the organic matter)
- Food, water, and air for the decomposers
- Size of the food particles
- Volume of the pile

Expressed as an equation, the compost process is as follows (Fig. 5-1):

Organic yard and food materials + oxygen + water + soil organisms = compost + carbon dioxide + water + heat

Fig. 5-1. Compost equation.



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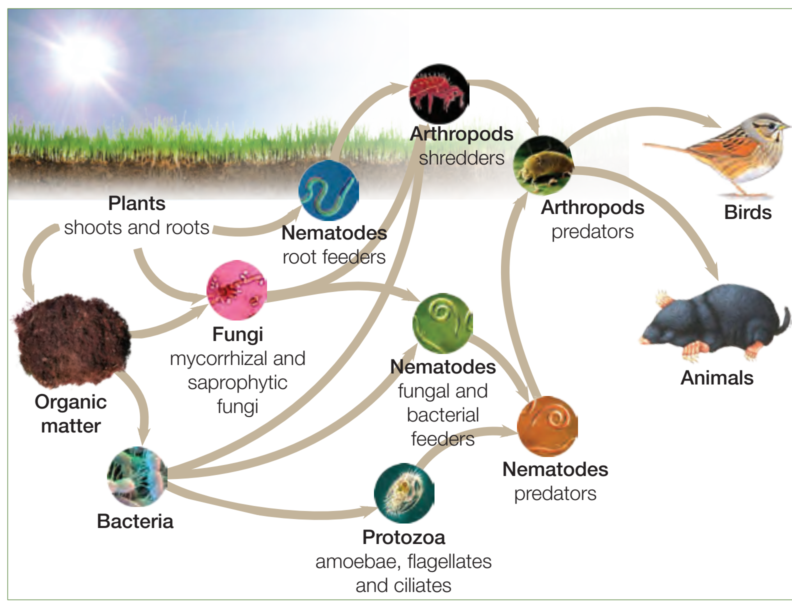

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Fig. 5-2. Soil food web.

Decomposers

Bacteria, fungi, and other microbes are the key players in composting. These organisms “feed” on organic matter and use the carbon and nitrogen it contains to grow and reproduce. They are assisted by many larger organisms like millipedes, sowbugs, slugs and snails, and various worms and insect larvae that also feed on the decaying organic matter in soil. All these organisms are known as decomposers (Fig. 5-2). They are naturally present in soil, on leaves, on food scraps, in manure, and so forth. These same

Table 5-1. Carbon-to-nitrogen ratios of compostable materials.

Material	Ratio
Browns (Materials with High Carbon Levels)	
Cornstalks	60:1
Leaves (dried)	30–80:1
Mushroom compost	40:1
Newspaper or corrugated cardboard	560:1
Paper, mixed	150–200:1
Pine needles	250:1
Straw	40–100:1
Tree bark	100–130:1
Wood chips and sawdust	100–500:1
Greens (Materials with High Nitrogen Levels)	
Coffee grounds	20:1
Grass clippings (freshly cut)	15–25:1
Cow manure	12–25:1
Horse manure	25:1
Horse manure with litter	30–60:1
Poultry manure	10:1
Poultry manure with litter	13–18:1
Pig manure	5–7:1
Vegetable scraps	15–20:1
Weeds (freshly pulled)	19:1

decomposers are responsible for the decay of forest floor litter or the corn stubble left in a farm field.

The gardener's goal is to provide optimum conditions for these decomposers. This will ensure the rapid and total breakdown of organic matter.

Food: Carbon and Nitrogen

Microbes need carbon for energy and nitrogen for growth. Optimal composting occurs when the materials contain a carbon-to-nitrogen ratio (C:N ratio) of 30 parts carbon to 1 part nitrogen. This proportion is not critical, and the microbes will function well at ratios from 25:1 to 40:1. Because most organic materials do not fit the 30:1 ratio exactly, different materials should be mixed together. With the proper mix, microbes begin to decompose organic material quickly.

Organic matter for composting comes in two broad forms, green materials and brown materials.

Green Materials

Green materials are high in nitrogen and moisture. These nitrogen-rich materials provide protein to the microbes. Known to composters as "greens," these materials include fresh grass and other garden clippings, weeds, manure, and kitchen residuals.

Brown Materials

Brown materials are high in carbon, low in moisture, and slow to break down. These materials are rich in sugar and provide energy for the organisms. Known as "browns," these materials include fallen leaves, straw, wood chips, dead plant material, paper, and cardboard.

A proper blending of browns and greens allows the microbes to function most efficiently. Table 5-1 provides the carbon-to-nitrogen ratios of compostable materials.

Greens are most available during the spring and summer growing seasons. Browns are most available in the fall and winter. To make sure you have the right combination of carbon and nitrogen for your compost, you may want to stockpile extra browns or greens to take you through the seasons.

Oxygen

Most life on Earth needs oxygen and water to sustain itself. The microorganisms that produce compost are no different. You can control air and water in the composting system to enhance the activity of fungi and bacteria.

Composting occurs with oxygen (aerobic) or without oxygen (anaerobic). Microbes exist under both these conditions,

Controlling Pests Safely

CHAPTER 6

Sue Wyble

LEARNING OBJECTIVES

- Understand how to use and apply pesticides safely.
- Differentiate between the types of pesticides and their modes of action and formulations.
- Demonstrate knowledge of the pesticide label, including signal words.
- Understand the differences in the types of application equipment.
- Demonstrate safe practices, including cleaning of equipment and proper storage and disposal of pesticides.
- Explain LD_{50} (lethal dosage) values and their importance.
- Recognize the symptoms of pesticide poisoning.
- Describe integrated pest management (IPM).
- Discuss the impact of pesticides on the environment.

INTRODUCTION

Although it is debatable whether or not we could raise the crops needed to feed the ever-growing world population without using pesticides, we can reduce the amount of pesticides we use by considering all pest management options. When pesticide use is necessary, careful product selection and application according to all label directions is critical to successful control of the pest while protecting the environment and the applicator.

Integrated pest management (IPM) is the best answer for pest control because it utilizes many alternative control methods rather than relying on spraying alone.

Before automatically turning to the use of a pesticide, first determine whether or not control measures are really needed. Is the problem severe enough to warrant treatment? If the cost of treatment is less than the predicted loss, the economic threshold has been reached and treatment is necessary. Second, consider alternative control measures (e.g., pulling weeds instead of using an herbicide, and removing and destroying diseased plant parts rather than using a fungicide). For example, if Japanese beetles were a problem the previous summer, consider the following simple IPM program that could be used on a home lawn for grub proofing against Japanese beetle larvae. First, scout the lawn area to determine if grubs are present and at a level that requires control. An otherwise healthy lawn can tolerate five to ten grubs per square foot, but this is somewhat dependent on the species of grub. There about ten different species of scarab beetles whose larval stage are white grubs. Milky spore disease, a commercially produced biological control for Japanese beetle larvae, could be applied. Accurate identification of the grub species is important since the available strains of milky spore disease are only effective against Japanese beetle larvae. If necessary, a chemical pesticide could be used to protect the more heavily infested areas. The chemical pesticide would give immediate protection to the severely affected areas while the milky spore disease becomes established in other areas of the lawn. Then, as the chemical breaks down in the more infested areas, milky spore disease would move in. Once milky spore disease is established, chemical treatment may no longer be required to protect the turf.

The information in this chapter will discuss in detail the decision-making process of using IPM, including the safe use of pesticides when necessary.

WHAT IS A PEST?

The *Merriam-Webster Dictionary* defines a pest as “one that pesters or annoys” and “a plant or animal detrimental to humans or human concerns.” In a sense, humans have been dealing with pests throughout history. In this section, we will examine the nature of certain pests and the means for minimizing their impacts.

Pests come in many forms, and their classification is often a matter of judgment. Ranchers may view predators that prey on livestock as pests, while others may consider them to be valuable members of the ecological community. More commonly, we encounter less-controversial pests, such as insects that feed on stored grain products; fungi that attack fruits and vegetables; weeds that choke gardens and row crops; vertebrates, such as rodents, that destroy or contaminate a wide variety of foodstuffs and nonfood products; and a host of other species that compete with humans for food, water, fiber, space, and other resources or transmit organisms that cause human and animal diseases.

Typically, homeowners are concerned about a limited number of pests. Garden produce, tree fruits, and ornamental plants may suffer from the activities of insects, weeds, diseases, and rodents. Termites may threaten the integrity of a home's structure. Squirrels, birds, and bats may nest and breed in attics and under eaves. Home lawn hobbyists are often frustrated by crabgrass and broadleaf weeds such as dandelion and plantain.

Understanding and managing even a limited variety of organisms can be quite a challenge for the home gardener. When and how we respond to those challenges depends primarily on the level of infestation we are willing or able to tolerate. For example, even a small population of deer ticks in the backyard may be unacceptable because of the threat of Lyme disease. On the other hand, some homeowners may tolerate or even enjoy the presence of large numbers of dandelions in their lawn. In this case, the decision is based strictly on aesthetics.

PEST MANAGEMENT

The control or manipulation of other species for the benefit of humans has become a topic of great controversy during the last several decades.

Our purpose here is to show how pest populations can affect humans, and describe the options available for managing them. Given the variation among individuals as to what is considered a pest, or more correctly, what is an "acceptable" level of pest infestation, each person will need to decide what is an appropriate action—within certain guidelines—when faced with a pest problem.

Goals

Before introducing methods and strategies for managing pests, we should first think about the goals of a pest management program and how to determine them. Some pests cause predominantly aesthetic problems, such as moderate weed infestations in home lawns. Others, such as mosquitoes, may pose a direct threat to human health through the transmission of disease-causing organisms. In these cases, the nature of the pest and its impact may make the decision to act against it quite clear. In other cases, an economic analysis of the pest's impact and control costs is necessary to determine what measures, if any, should be taken to protect against it. This is especially true for pests that attack agricultural commodities. In all cases, a certain level of infestation is likely to be tolerated since the complete eradication of a species is technically infeasible, prohibitively expensive, and ethically questionable.

Understanding how to determine an acceptable level of pest infestation is crucial to setting pest management goals. An acceptable level of pest infestation or damage is a function of the potential damage (economic, health, or other) from the pest's activity and the standards of quality that are established for the pest's target. Turfgrass is an excellent example of this concept. The quality needs and management inputs of a home lawn, a football field, and a golf green are quite different based

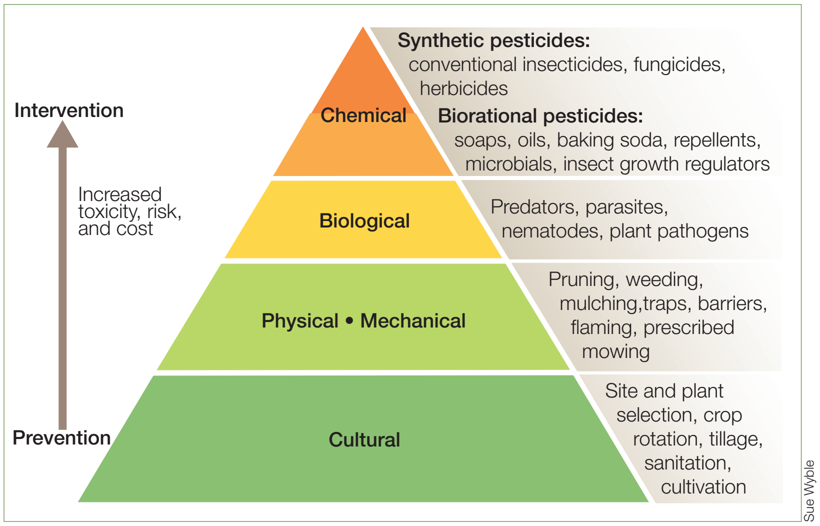


Fig. 6-1. IPM pyramid.

on their use patterns. The predominant functions of the home lawn are soil stabilization and aesthetics. Traction and shock absorption are important functions of athletic fields because player safety has been related to these characteristics. In both cases, the presence of minor weed infestations is tolerable because they do not interfere with the function of the stand. However, athletic fields may require higher levels of pest management to maintain a similar level of quality because the higher intensity of use makes it difficult for the turfgrass to compete with pests.

The golf green, on the other hand, must be maintained in a close-cropped, weed-free condition, or the roll of the ball during putting will be affected. This factor, coupled with the stresses imparted by player traffic and close mowing, generally requires intensive cultural management and pesticide use. Another example is the difference in quality required for fresh-market fruits and vegetables compared with those grown for processing. Levels of acceptable pest damage will be lower for fresh-market crops than those grown for processing.

Pest management choices for homeowners are seldom as economically critical as those facing commercial crop producers, unless the structural integrity of a home is threatened by wood-destroying pests or other pests that can permanently affect property values. Pest activity may lower the aesthetic quality of a residential property, threaten the viability of a prize ornamental planting, or even present a health hazard, as in the case of hornet or wasp colonies. However, the small scale and relative ease of manipulating the home environment may offer a variety of choices that are not practical for the professional pest manager.

Tactics

Pest management specialists should subscribe to a philosophy of pest control that involves the use of many tactics. Integrated pest management (IPM) is a pest management strategy that uses a full range of pest control methods or tactics in a cost-efficient and environmentally sound manner (Fig. 6-1). The goal of this strategy is to prevent pests from reaching economically damaging populations. The principle is pest management rather than pest eradication. Pest management programs based on the identification of pests, an accurate measurement of pest populations, an assessment of damage levels, and knowledge of available pest management strategies or tactics enable informed and intelligent decision-making regarding control.

IPM offers the possibility of improving the efficacy of pest control programs while reducing some of the negative effects. Many successful IPM programs have reduced energy and pesticide use. Integrated pest management systems vary with each situation. Consider the following steps when developing any program.

Steps of IPM

1. Identify the pest(s) to be managed. The first step in any pest management program is to identify the pest, whether it's an insect, weed, plant disease, or vertebrate. Do

Basics of Entomology

CHAPTER 7

Connie Schmotzer

Table 7-2. **Orders of the class Insecta (adult characteristics).**

Order	Common Name	Metamorphosis	Mouthparts	Wings
Archaeognatha	Jumping bristletails	Simple	Exposed; chewing	None
Blattodea	Cockroaches, termites	Simple	Chewing	None or two pair
Coleoptera	Beetles, weevils	Complete	Chewing	Two pair
Collembola	Springtails	Simple	Concealed in the head; chewing	None
Dermaptera	Earwigs	Simple	Chewing	None or two pair
Diplura	Diplurans	Simple	Concealed in the head; chewing	None
Diptera	Flies	Complete	Sponging/lapping or piercing-sucking	One pair
Embiidina	Webspinners	Simple	Chewing	None or two pair
Ephemeroptera	Mayflies	Simple	Chewing	Two pair
Grylloblattodea	Rock crawlers	Simple	Chewing	None
Hemiptera	Aphids, scale insects, true bugs, cicadas, psyllids, leafhoppers, whiteflies	Simple	Piercing-sucking	None, one pair, or two pair
Hymenoptera	Bees, wasps, ants, sawflies	Complete	Chewing; modified for sucking/lapping	Two pair
Lepidoptera	Butterflies, moths	Complete	Chewing or siphoning	Two pair
Mantodea	Mantids	Simple	Chewing	Two pair
Mantophasmatodea		Simple	Chewing	None
Mecoptera	Scorpionflies and hangingflies	Complete	Chewing	Two pair
Megaloptera	Alderflies, fishflies, dobsonflies	Complete	Chewing	Two pair
Neuroptera	Lacewings, antlions	Complete	Chewing or sucking	Two pair
Odonata	Dragonflies, damselflies	Simple	Chewing	Two pair
Orthoptera	Crickets, grasshoppers, katydids	Simple	Chewing	None or two pair
Phasmatodea	Walkingsticks, leaf insects	Simple	Chewing	Most have none
Phthiraptera	Lice	Simple	Chewing or sucking	None
Plecoptera	Stoneflies	Simple	Chewing	Two pair
Protura	Proturans	Simple	Concealed in the head; scraping/sucking	None
Psocoptera	Psocids	Simple	Chewing	None or two pair
Siphonaptera	Fleas	Complete	Chewing or piercing-sucking	None
Strepsiptera	Twisted-wing parasites	Complete	Chewing	None or one functioning pair
Thysanoptera	Thrips	Simple	“Punch and suck”	None or two pair
Thysanura	Silverfish, firebrats	Simple	Chewing	None
Trichoptera	Caddisflies	Complete	Chewing	Two pair
Zoraptera	Angel insects	Simple	Chewing	None or two pair

The life strategies of insects are complicated and interrelated in ways that scientists are just beginning to understand. How are hosts or prey chosen? How are they found? Why are some insects very specific feeders while others seem to generalize their food selection? How can some insects feed on very poisonous plants when others cannot? The answers for these questions are as numerous and diverse as the insects that generate them.

INSECT FORM AND STRUCTURE: MORPHOLOGY

All adults in the class Insecta possess the following characteristics: three body regions; three pairs of legs; one pair of antennae; and either zero, one, or two pairs of wings. Legs and other appendages are often greatly modified to suit the insect's environment; the form of its appendages is often used to classify the insect.

Exoskeleton

Insects are structured very differently from humans and many other organisms. An insect's body is not supported internally by a bony skeleton. Insects have their "skeleton" on the outside. Their tough outer body wall is called the exoskeleton. It provides protection from abrasion, helps regulate water loss, protects internal organs, and is the support structure to which the muscles are attached. The exoskeleton is made of hardened plates called sclerites. The outside covering, or integument, is made of layers. The layer closest to the inside of the insect is called the basement membrane. The layer next to the basement membrane toward the outside of the insect is the epidermis. The epidermis secretes a layer called the cuticle, which is the outermost covering of the insect. The cuticle is made up of chitin in a protein matrix. The exact chemical composition of the cuticle varies among insects and even between areas on the same insect. The cuticle is also coated with a series of layers, one of which is the wax layer. The wax layer is the primary mechanism responsible for water regulation, which is extremely important to insect survival. Their small size and relatively large surface area predispose insects to desiccation in the many terrestrial habitats they frequent. If it weren't for the wax layer of their cuticle, insects would be bound to habitats that would provide enough humidity to prevent their bodies from drying out. Because the exoskeleton is fairly rigid and the cuticle is nonliving, the exoskeleton must be shed and replaced to accommodate growth. This process is called molting. Hormones regulate the digestion of the old exoskeleton and the formation of the new one. All insects go through a series of molts as they grow and reach maturity.

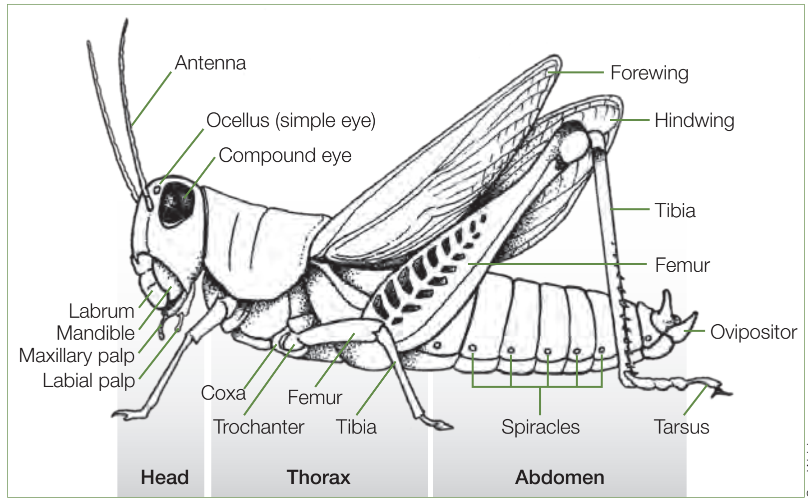


Fig. 7-1. Female grasshopper external anatomy.

Body Regions

The insect's body is made up of three regions: head, thorax, and abdomen (Fig. 7-1). The head houses the brain and includes important sensory organs, like the eyes and antennae, as well as the

Fig. 7-2. Female grasshopper internal anatomy.

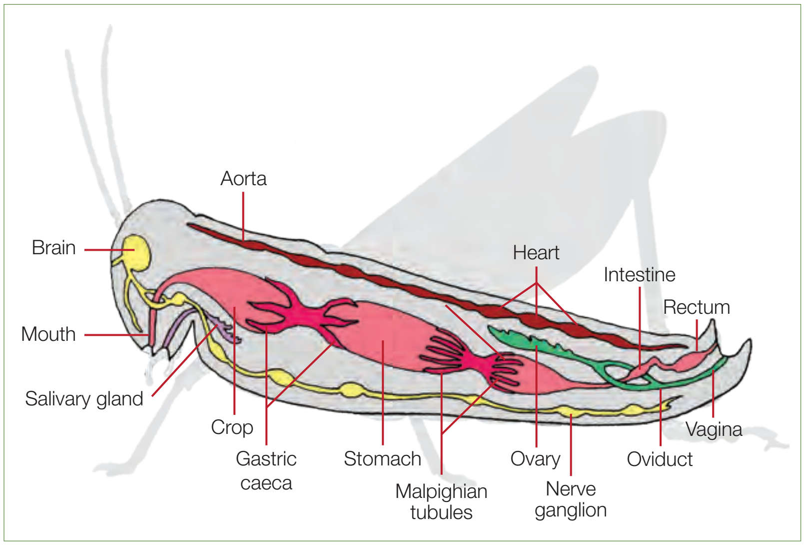
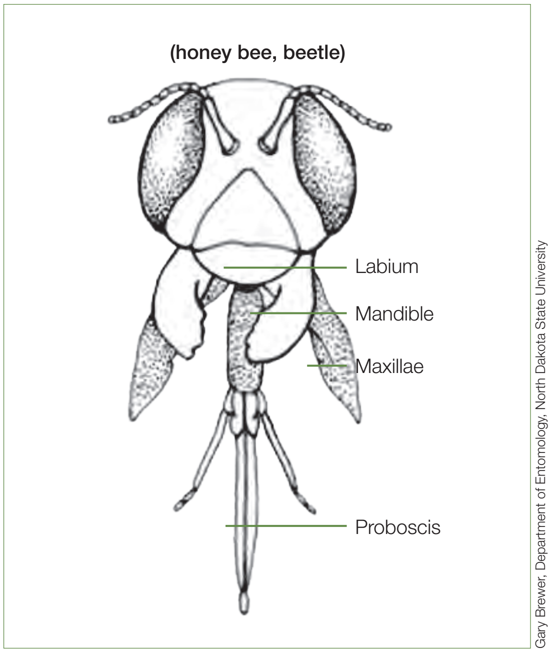


Fig. 7-4. Chewing-lapping mouthparts (e.g., honey bee and beetle).



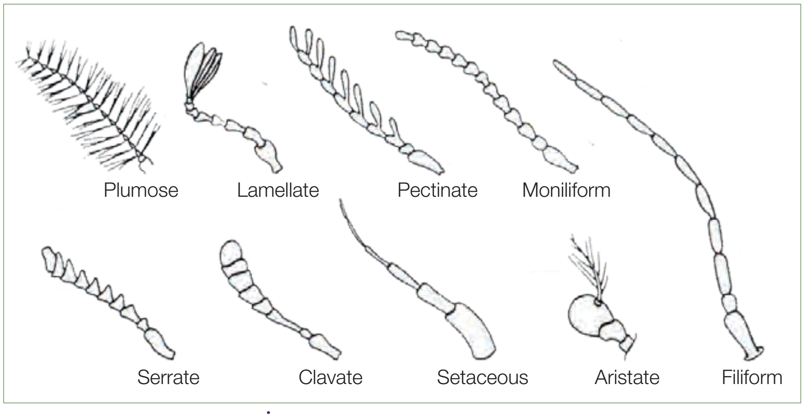


Fig. 7-3. Forms of antennae.

mouthparts. The thorax functions in locomotion and is where the wings and legs are attached. The abdomen houses many internal organs, including those associated with digestion, excretion, respiration, and reproduction (Fig. 7-2).

Head

The main structures located on the insect's head are the eyes, antennae, and mouthparts.

Antennae

The antennae are prominent and distinctive features of insects (Fig. 7-3). Insects have one pair of antennae located on the adult's head, usually between or in front of the eyes. Often referred to as horns or "feelers," antennae are segmented and vary greatly in form and complexity. Their shape is characteristic and can be used in identification—in some cases, to distinguish between sexes of the same species. Antennae have many sensory functions, including touch, smell, hearing, navigation, and perception of humidity.

Mouthparts

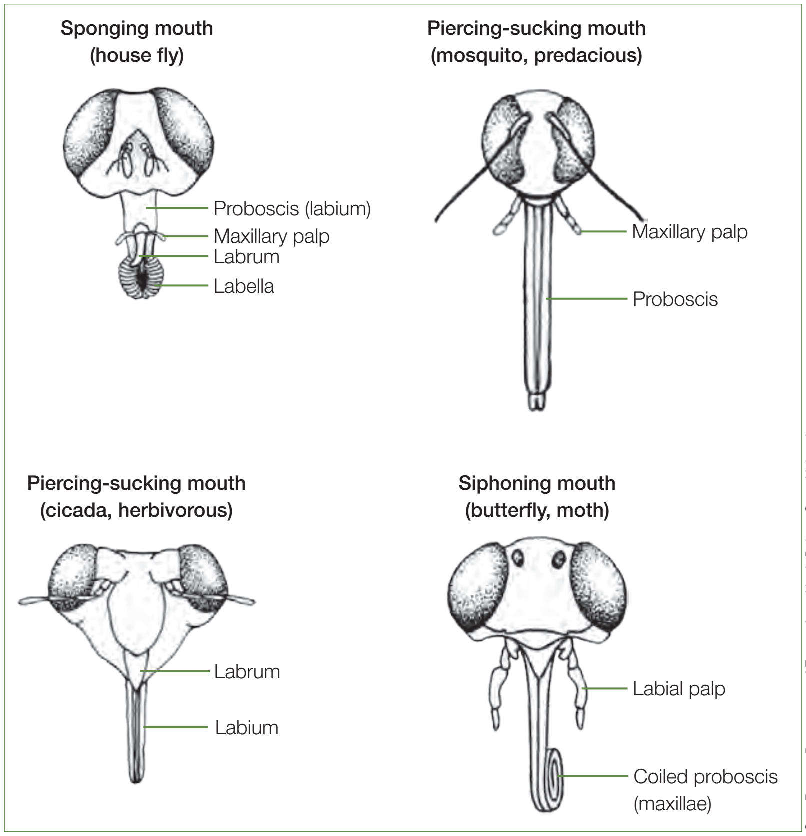
Insect mouths are made up of five main component parts: the labrum (upper lip), a pair of mandibles (unsegmented jaws), a pair of maxillae (segmented, behind the mandibles), the labium (lower lip), and the hypopharynx (tongue-like organ). The labium and maxillae may have palpi, which are segmented structures that help the insect feel, manipulate, and taste food. Great variations exist in the form and function of insect mouthparts. Although insect mouthparts differ considerably in appearance, the same basic components are modified to comprise the different kinds used for consumption of varying types of food.

Most insects are divided into two broad categories by the type of mouthparts they possess—those with mouthparts adapted for chewing, and those with mouthparts adapted for sucking. Chewing mouthparts are also called mandibulate mouthparts since the mandibles move from side to side and can bite off and chew food (Fig. 7-4). Some examples of insects with chewing mouthparts are beetles, grasshoppers, and butterfly larvae (caterpillars).

Sucking mouthparts are also called haustellate and used to ingest food in a liquid form (Fig. 7-5). Piercing-sucking, sponging, and siphoning mouthparts are all considered haustellate. Piercing-sucking mouthparts may include a stylet, which functions like a needle to puncture plant or animal tissue to access fluids used for nourishment. These mouthparts all function like a straw to suck out fluids. Examples of insects with piercing-sucking mouthparts are mosquitoes, aphids, and true bugs. Sucking mouthparts that do not include a stylet are therefore unable to penetrate tissue.

House flies have sponging mouthparts that take up liquids, which are also considered haustellate but without a stylet. Insects with siphoning mouthparts (e.g., butterflies and moths) simply siphon fluids that are accessible, like plant nectar. The proboscis refers to the extended beak-like mouthparts common to sucking insects. The proboscis of butterflies and moths is coiled under the head when not in use and extended for feeding.

There are many modifications of these basic types of mouthparts, such as chewing-lapping mouthparts found in honey bees, wasps, and bumble bees. Some adult insects have what are called vestigial (nonfunctioning) mouthparts. Since they don't live long and their focus is reproduction, not feeding, functioning mouthparts aren't really necessary.



Gary Brewer, Department of Entomology, North Dakota State University

Fig. 7-5. Various sucking mouthparts.

The mouthparts of immature insects may be different from or the same as those possessed by adults. A great deal of variation also exists in larval mouthparts. These variations are necessary for insects to make the most efficient use of their particular food source.

Mouthparts can be very useful in identification. Certain insects, such as true bugs and beetles, may resemble one another from the top, but after close inspection of the mouthparts, the difference is obvious. Also, when examining damage symptoms on plants, it may be possible to narrow down the possible insect causal organism based on feeding characteristics.

Eyes

Eyes are of two types: compound and ocelli. Compound eyes are the main organs of vision. They are composed of individual units called ommatidia, which form what we might consider a mosaic image. Eyes of

Sometimes, purchased natural predators are effective for only a short period since they tend not to remain where they are released. The larval stages of lady beetles and green lacewings are less mobile and stay in one place longer, so they are more effective than their adult stages. Research the likes and dislikes of these beneficials as to foods, habitat, etc., and provide these conditions where possible. Some beneficial insect suppliers offer a formulation for feeding and attracting beneficials to keep them in the garden longer.

Some predatory insects, such as beetles, praying mantids, and true bugs like ambush bugs, are general feeders. They are opportunists that will capture and eat either pests or other beneficial insects. While these natural predators are friends to the gardener, they may not be the most effective purchased form of natural control. More specialized parasitoids will feed only on certain pest species and are therefore much more effective as biological control.

Learn to recognize the eggs, nymphs, and larvae of beneficial insects, and avoid harming them. A good example is the wheel bug (Figs. 7-33 and 7-34). You can also find praying mantid egg cases in weedy lots; just bring the twig with the cluster into the garden and set it in a place where it will not be disturbed. As another example, consider the tomato hornworm, a common pest of tomatoes. The large, green caterpillar is often seen with a number of white cocoons (a little larger than a grain of rice) on its back. These result from a parasitic wasp laying eggs inside the hornworm larva (Fig. 7-35). The hornworm larva will die and more wasps will emerge from these cocoons. Obviously, it is to your advantage to leave the parasitized caterpillar in the garden.

Some biological microbial products can help in the battle against certain insect pests. *Bacillus thuringiensis*, or Bt, is a naturally occurring soil bacterium that has been mass produced and commercialized as a biological control agent. It provides effective insect control without harming other animals or the environment. More than 400 insect pest species are known to be affected by this important insect pathogen. Specific strains of Bt are effective against moth or butterfly larvae, others are effective only against beetles, and some work only against fly or mosquito larvae.

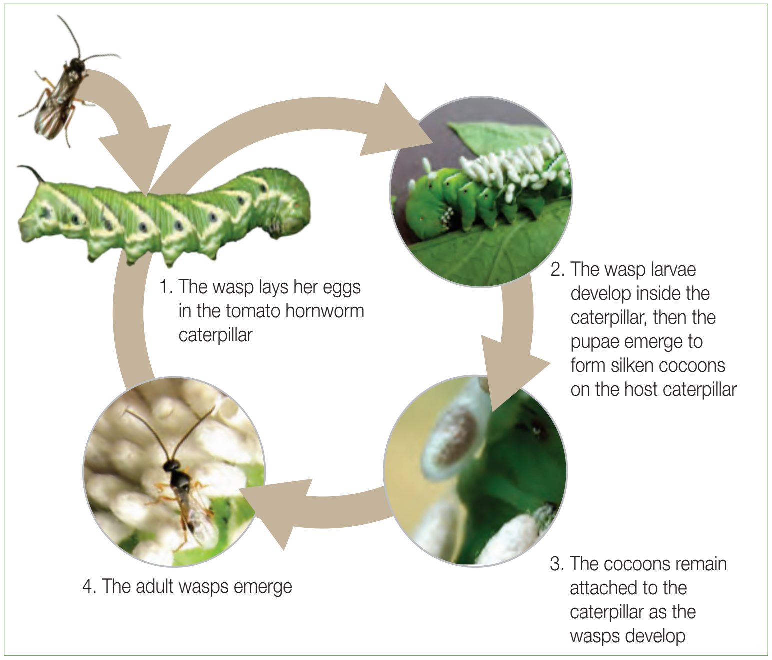
Fig. 7-33. Wheel bug egg mass and nymphs.

Nancy Knauss

Sandy Feather

Fig. 7-34. Wheel bug adult.

Fig. 7-35. Braconid wasp life cycle.



Paul Woods (braconid cocoon with larva), Beatriz Moisset (braconid wasp), Sandy Feather (parasitized tobacco hornworm), Whitney Cranshaw, Colorado State University, Bugwood.org #5304032 (tomato hornworm), R. J. Reynolds Tobacco Company Slide Set, Bugwood.org #1440135 (braconid wasp)

Sandy Feather

Fig. 7-36. Black and yellow garden spider (*Argiope aurantia*).

Be sure to pick the strain that will be effective against the particular target pest. Read the product label to determine if it will control the target pest and for application directions.

The activity of biological controls may not be as rapid or obvious as that of chemical pesticides, so the gardener must be educated to expect slower results. For example, Bt is quite slow in its action. Caterpillars that consume some of the spores will stop eating within two hours and won't cause damage after that. However, they may continue to live and move around for as long as 72 hours before dying. A gardener may assume the material was ineffective and impatiently apply a chemical pesticide unnecessarily.

Many other animals can help in the battle against insects. Spiders, toads, and bats are also beneficial and should not be a source of fright to the gardener (Fig. 7-36); in most cases, they are harmless to people. Enlist the aid of birds. In rural areas, chickens, guineas, and other domestic fowl can be released in unused areas of the garden to eat grubs and insects. Wild birds will also help, but they aren't as controllable. Provide appropriate conditions in the form of shelter, nesting material, and water to encourage insect-eating birds.

Chemical Controls

Insecticides are chemicals that are used to kill, repel, or otherwise affect the development of insect pests. Insecticides vary in their level of toxicity to insect pests and nontarget creatures, such as the gardener, pets, wildlife, and other nonpest insects. The use of insecticides can be somewhat controversial. A more complete discussion of insecticides is included in the "Controlling Pests Safely" chapter. However, a brief discussion is necessary here to highlight some of the considerations about insect management and insecticide selection.

Insecticides are an important production tool in many agricultural and horticultural systems, and they can be an important part of an integrated pest management program. Insecticides are regulated by the federal government through the Environmental Protection Agency. In order for an insecticide to be sold and legally used in the United States, it must go through a rigorous testing process and be granted a label. A pesticide is tested to assess any human or environmental hazards and to determine the pests and plants on which it can be used effectively. The label is a legal document that regulates how that particular product can be applied. It is a violation of federal law to use pesticides in a manner that is inconsistent with the label directions.

Insecticides can be derived from natural or synthetic materials. There are a many different modes of action, or ways the active ingredient affects target pests—for example, some insecticides are nerve poisons, some rupture cells, some disrupt feeding, and some interfere with molting and normal growth.

Gardeners must consider many factors when deciding to choose and use insecticides, including evaluating whether the insect population warrants treatment, the toxicity of the material, alternative control methods, time of year and whether application of an insecticide will be effective then, application equipment needed to do the job, potential for damage to nontarget organisms, and how the insecticide may impact the environment. Another consideration in pesticide selection is resistance management. Insects can develop resistance to certain insecticides if they are used repeatedly. To avoid or delay resistance development, alternate products with different modes of action when multiple applications are necessary.

Most plants can tolerate a certain amount of insect feeding. Treating insect pests is not always necessary, especially when their populations have not reached the level at which economic loss occurs. For many agricultural cropping systems, research has determined the lowest number of pests that result in economic loss, called the economic injury level. For other crop/pest systems, the economic data is not available. Most ornamental plants are judged by aesthetics, and what appears damaged to one person may not be considered a problem by someone else. So the decision whether or not to treat an insect pest is not always straightforward.

Accurate identification of the target pest insect and an understanding of its biology are necessary before choosing an insecticide. If the insect is not correctly identified, it's impossible to know when to apply an insecticide or whether an insecticide is even needed.

Once the insect has been correctly identified and determined to be a pest, learn about the biology and habits by reading fact sheets such as those available from the Penn State Department of Entomology.

First, try the recommended methods for nonchemical controls, such as culture and exclusion. If only a few pests are present, remove them by hand or prune the affected plant parts. Consider biological controls and determine whether they are appropriate. If an insecticide is necessary, do your homework. Choose the least-toxic product to do the job. In many cases, using insecticidal soap or horticultural oil (described below) is effective. Both are very safe to the applicator and nontarget organisms. Read and follow all label directions for the selected product. Pay attention to protective clothing required, target pests controlled, and plant sensitivity. Spot treat only infected plants to reduce the overall amount of pesticide used.

Insecticidal Soaps

Commercial insecticidal soap (a special formulation of the potassium salts of fatty acids) is an effective insecticide that can be used against many insect pests, including adelgids, leafhoppers, mealybugs, mites, scale insects (applied when the immature life stage, or crawler, is active), thrips, and whiteflies. These soft-bodied insects are killed when the insecticidal soap spray solution contacts them. Adult stages, which have thicker cuticles, are often spared, so insecticidal soap can help preserve adult beneficial insects that may be present during an application. Although it may be tempting to make your own soap, sprays created with soap flakes are not the same product. Such mixtures are not effective for optimal control and may even cause plant injury.

Horticultural Spray Oil

Horticultural oils can be used to manage mites and certain immature insects. Depending on the particular product and target pest, horticultural oils can be used during the dormant season or the growing season. During the dormant season, they are commonly referred to as "dormant oil treatments" and used to control overwintering eggs and scale insects, especially on fruit trees and woody ornamentals. During the growing season, they can be used to control a number of pests and insect eggs on actively growing foliage. The timing, potential plant injury, and insects targeted vary according to product formulation and are specified on individual product labels.

~ ~ ~

Finally, insects are an inevitable part of gardening. They are also an inevitable part of every other habitat frequented by humans. As Master Gardeners, part of the challenge is to help educate the public about the roles insects play in nature. It's also important to help others assess the risk posed by insects to their health, home, and landscape. Accurate identification is the key, and it can be accomplished by using the resources available through universities and extension offices, textbooks, and the Internet. With identification comes knowledge of the insect's biology and habits, and a determination can be made whether human intervention or just plain awe are required. In either case, there is plenty to learn and admire in the wonderful world of insects.

Plant Diseases

CHAPTER 8

Nancy Knauss

Fig. 8-2. Fungal fruiting bodies.

Bacteria

Bacteria are single cells surrounded by a cell wall. Bacteria lack a true nucleus (i.e., have no membrane surrounding the genetic material). Plant-parasitic bacteria lack chlorophyll and obtain nutrients from living or nonliving sources. None of the plant-parasitic bacteria now known are obligate parasites.

Plant-parasitic bacteria are rod shaped and reproduce by fission. One cell pinches off to give rise to two cells after the DNA (genetic material) has replicated.

Bacteria enter plants through natural openings (e.g., stomata, hydathodes, lenticels, and nectaries) or wounds made by insect feeding, mechanical injuries, and pruning or grafting.

Fungi

Fungi are plants with a thread-like structure. They contain no chlorophyll and therefore do not produce their own food through photosynthesis. They have a true nucleus—a nuclear membrane surrounding the area inside the cell that contains the genetic material. Fungi enter plants through natural openings or wounds, or they penetrate directly through intact tissues.

Since fungi cannot manufacture their own food, they obtain nutrients from the following:

- **Living tissues of other organisms.** A living organism that obtains its food in this way is termed a parasite. If the fungus or other living organism can obtain nutrients only from living plant tissues, it is called an obligate parasite. Rusts, powdery mildews, and downy mildews are fungi that are obligate parasites.
- **Dead organic matter.** An organism that obtains nutrients from dead organic matter is termed a saprophyte. Many fungi have parasitic and saprophytic stages in their life history.

Fungi produce spores, which are sexual or asexual reproductive structures capable of surviving adverse conditions and dispersing themselves. Sexual reproduction involves the mating of two separate cells or individuals; in asexual reproduction, no mating occurs. The way the spores are formed and their size, color, and structure are all used in identifying fungi. Many fungi form spores in characteristic structures called fruiting structures or fruiting bodies (Fig. 8-2).

Nematodes

Nematodes are nonsegmented roundworms. They have a digestive system, a reproductive system, and a rudimentary nervous system, but they lack lungs and a heart. They reproduce by laying eggs. All plant-parasitic nematodes have a spear-like mouthpart called a stylet and are obligate parasites. Most plant-parasitic nematodes are small (less than 0.5 millimeter in length). Four different lifestyles are found among plant-parasitic nematodes:

- **Migratory ectoparasites** move throughout their lives and stay outside the plant while feeding.
- **Migratory endoparasites** enter the plant and move inside its tissues throughout their lives while they feed.

Fig. 8-3. Foliar nematode damage on anemone.

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Fig. 8-4. Dodder.

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Fig. 8-5. Mistletoe.

- **Sedentary ectoparasites** stop moving and establish a permanent feeding site where they remain outside tissues.
- **Sedentary endoparasites** establish a permanent feeding site within plant tissues and stop moving once they're established.

To determine if nematodes are the cause of a plant disease, roots and other tissue must be collected and examined to detect endoparasites, while soil must be collected and assayed to detect ectoparasites (Fig. 8-3).

Phytoplasmas

Phytoplasmas are similar to bacteria, except they have no cell wall. They reproduce as bacteria do and are usually found in the water- and food-conducting vessels of an infected plant. Symptoms caused by these organisms include growth abnormalities, yellowing, very short internodes, and distortion of leaf and flower tissue. Leafhoppers transmit phytoplasmas.

Vascular Plants

Vascular plants that parasitize other plants include dodder (Fig. 8-4), mistletoe (Fig. 8-5), witchweed, Indian pipe, and beech-

Fig. 8-6. Virus-infected spicebush leaf (top) and unaffected leaf (bottom).

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Fig. 8-7. Dogwood anthracnose.

drops. These seed-bearing plants gain all or some of their nutrients by parasitizing other seed-bearing plants.

Viroids

A viroid is a piece of genetic material that, unlike a virus, has no protein coat. Viroids divert plant metabolism to produce more viroids. They spread by vegetative propagation.

Viruses

Viruses are composed of a piece of genetic material (either RNA or DNA) surrounded by a protein coat. They are submicroscopic and replicate only inside living cells. Viruses take over plant cell metabolism and direct the cell to manufacture more virus components (Fig. 8-6). Viruses gain entry to cells either through a wound or during insect feeding. Viruses can be maintained in a population of plants or transferred from plant to plant in the following ways:

- Vegetative propagation (all can be carried this way)
- Grafting
- Dodder (*Cuscuta*), a parasitic plant that sends vines from one plant to another and allows virus-carrying sap to pass between them
- Mechanically in sap on hands, tools, ropes, and other equipment
- Feeding by aphids, leafhoppers, mites, nematodes, thrips, and whiteflies
- Seeds
- Pollen
- Certain root-infecting fungi

Common Symptoms of Biotic Diseases and Their Causes

Anthracnose, Blights, Leaf Scorch, and Leaf Spots

Anthracnose refers to dead areas on leaves, usually along leaf margins and veins (Fig. 8-7). Spots frequently have concentric line patterns or dark, pimple-like fruiting structures in them.

Blight is the rapid killing of leaves and branches. They are usually caused by bacteria and fungi. Since cankers on stems and branches, as well as root rots, can also result in the rapid death of leaves higher on the plant, affected plants must be examined

Indoor Plants

CHAPTER 9

Sue Wyble

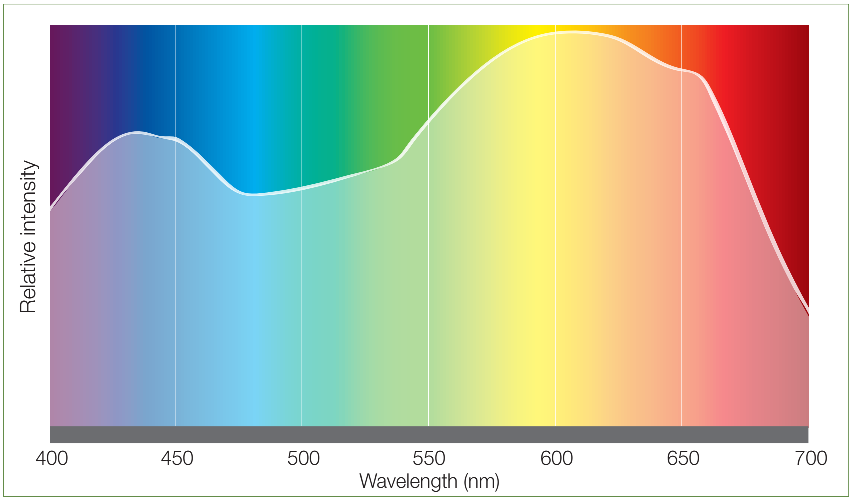

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Fig. 9-8. Visible light used by plants.

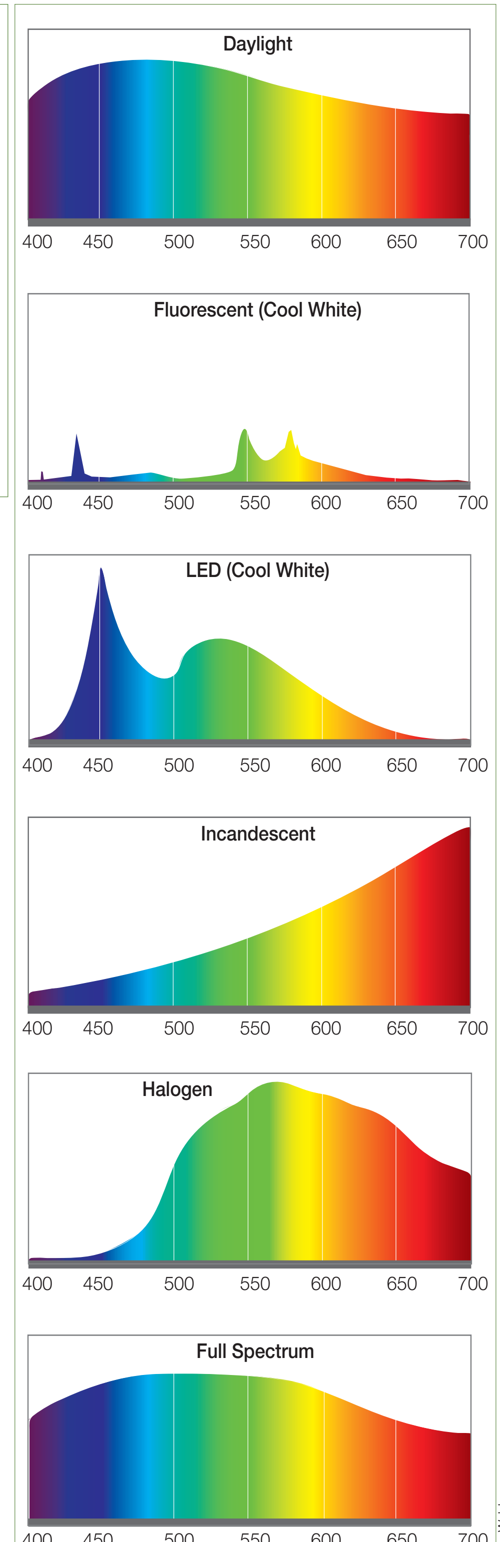
plants require extra infrared light, which can be supplied by special horticultural lights.

LED lights for plant growth are becoming more affordable and the technology is improving. Scientists are currently researching the effects of LED wavelengths on plant growth, and the technology for producing some wavelengths of LEDs is still in development. Most LED lights for plant growth utilize both red and blue LEDs to target spectra where photosynthesis is more efficient, although some research is finding that orange and green LEDs are also beneficial for plant growth.

Distribution

In order for a plant to maintain its natural habit and uniform shape, it should receive an even distribution of light. Foliage plants grown indoors are often subjected to uneven light levels. When a plant is sited near a window, it tends to grow toward the light and become one sided. This growth toward a light source is called positive phototropism (Fig. 9-10).

The growth hormone auxin is responsible for how the plant reacts to light. Auxin is produced in the apical meristem. As auxin is produced, it accumulates in the top part of the plant stem as the plant grows. When the plant receives direct overhead light, auxin is distributed evenly in the stem, and the stem grows straight. When part of the plant is in



Sue Wyble

Fig. 9-9. Spectra of common sources of visible light.

shade, auxin will accumulate on the side of the stem away from the light. High accumulations of auxin will cause the cells on the shaded side of the stem to elongate as they grow, pushing the stem over and turning its growth toward the light. Indoor plants that only get light from one direction will grow more in that direction, leading to a lopsided plant. To maintain a natural habit, rotate the plant a quarter turn (always in the same direction) with every watering.

Duration

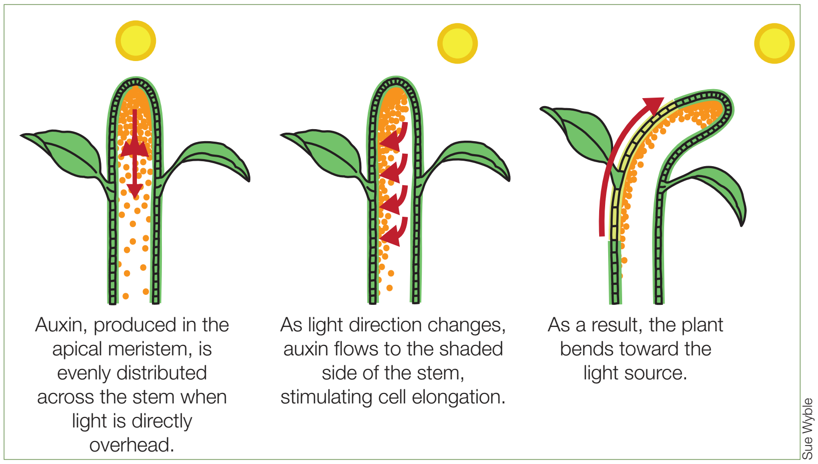
Plants are affected by the duration of light they receive in their environment. Duration of light can affect many parts of a plant's growth, including growth of foliage and the initiation of flowers and fruit. The plant's response to the amount and pattern of light it receives is referred to as photoperiodism, which is defined in terms of how much light and dark a plant needs over a 24-hour period to set flower buds and fruit. Day length, or duration of light received by plants, is also of some importance but generally only for houseplants that are photosensitive. Poinsettia, kalanchoe, and Christmas cactus bud and flower only when day length is short (11 hours of daylight or less). Most flowering houseplants are indifferent to day length.

As the days get shorter in the fall, plants get their cue from the change in lighting to begin winter preparations. Plants are grouped roughly as long-day, short-day, and day-neutral based on their response to photoperiod. Photoperiod is defined as the time that plants are exposed to light during a 24-hour period. A 10-hour photoperiod has 10 hours of light and 14 hours of darkness and would naturally occur twice each year, once in the late winter in early February and again in the fall at the beginning of November. It's interesting enough just to know that plants run on a 24-hour cycle.

Long-day plants create blossoms as the days get longer. Therefore, these plants set their flower buds as soon as the days get long enough in the spring. Most sunflowers are long-day plants, so they bloom in the summer. Other common long-day plants include petunia, snapdragon, black-eyed Susan, shasta daisy, purple coneflower, African marigold, and hosta.

Short-day plants have pretty much the opposite reaction to day length. These plants set flower buds and bloom as the days shorten in late summer going into fall. Since the amount of darkness is actually more important than day length, these plants should really be called long-night plants. The length of darkness is so important that even a short flash of light will interrupt their cycle and prevent the plants from flowering (Fig. 9-11). Chrysanthemums, Christmas cactus,

Fig. 9-10. Phototropism.



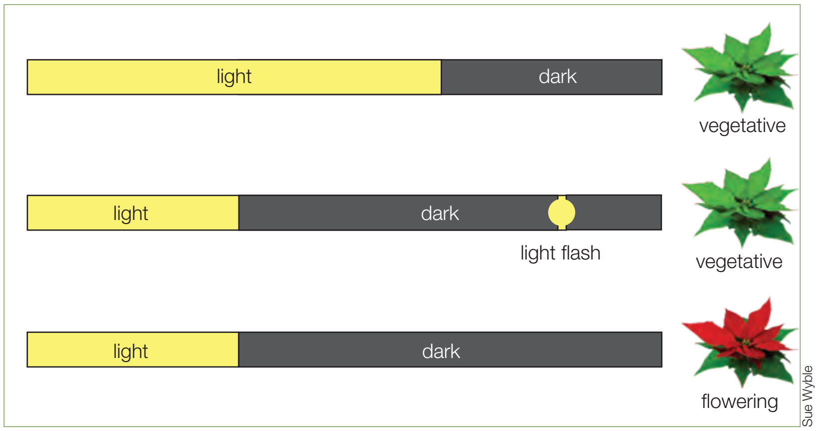


Fig. 9-11. Photoperiodism in short-day plants.

The Vegetable Garden

CHAPTER 10

pollination. Saving seeds from cross-pollinated crops is generally not recommended for the novice because of problems with selection, requirements for hand pollination and isolation, biennial habits, and genetic variability.

Some common self-pollinated annual plants from which seeds may be saved include lettuce, beans and peas, herbs, and some tomatoes (most are hybrids); see Table 10-1.

For all kinds of saved seeds, be sure to mark their storage containers clearly with permanent (preferably waterproof) ink, indicating the cultivar and date saved. When properly stored, seeds will remain viable for some time. To test for germination, sprout the seeds between moist paper towels; if germination is low, either discard the seeds or plant enough extra to get the desirable number of plants.

Saving Beans and Peas

Allow seed pods to turn brown on the plant. Harvest the pods, dry them for one to two weeks, shell and place them in a paper bag, and then store them in a cool (below 50°F), dry environment.

Saving Lettuce Seeds

Cut off seed stalks when they're fluffy in appearance, just before all the seeds are completely dried. Seeds will fall off the stalk and be lost if they're allowed to mature on the plant. Place the harvested seed stalks in a bag to collect the seeds as they dry. Shake the seeds off, and then store them in an envelope or small glass jar in a cool, dry environment.

Saving Herb Seeds

Herbs vary in the way their seeds are produced. In general, allow herb seeds to dry 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

Table 10-1. Average number of years seeds may be saved.

Vegetable	Years
Asparagus	3
Bean	3
Beet	4
Broccoli	5
Brussels sprouts	5
Cabbage	5
Cabbage, Chinese	5
Carrot	3
Cauliflower	5
Celery	5
Collard	5
Corn	5
Corn, sweet	1
Cucumber	5
Eggplant	5
Endive	5
Kale	5
Kohlrabi	5
Leek	1
Lettuce	5
Muskmelon	5
Mustard	4
Okra	2
Onion	1
Parsley	2
Parsnip	1
Pea	3
Pepper	4
Pumpkin	4
Radish	5
Rutabaga	5
Spinach	5
Squash	5
Tomato	4
Turnip	5
Watercress	5
Watermelon	5

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 them in envelopes or small glass jars. Some herb seeds, dill, celery, anise, cumin, and others used for flavoring are ready to use once they're dry.

Saving Tomato Seeds

Pick fruit from desirable plants when they're ripe. Cut the fruit and squeeze the pulp out into a container. Add a little water, then let it ferment for two to four days at room temperature, stirring occasionally. When seeds settle out, pour off the pulp and spread the seeds in a thin layer to dry thoroughly. Store the seeds in an envelope or glass jar in a cool, dry place.

Starting Seeds Indoors

The main reason to start seeds indoors is to give slower-growing plants time to mature. Tomatoes are a good example. In Pennsylvania, tomatoes grown from seeds outdoors will usually not have enough time to mature and set fruit before the first frost. By starting the seeds indoors, tomato plants can get a head start, and there will be enough time in the growing season for the plants to produce mature fruit.

To start seeds indoors, it is important to have enough light. More homegrown seedlings are probably lost to this one factor than 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 grow lights will suffice. See the "Plant Propagation" chapter for more information.

Containers for Starting Seeds

Many types of containers can be used to start seeds. Flats or other large containers may be planted in rows and the seedlings grown until they have one or two sets of true leaves. Seedlings may also be started in pots, cut-off milk cartons, margarine tubs, egg cartons, or other throwaways; always make sure there are sufficient drainage holes. The pop-out trays found at garden centers are easy to use and are reusable; however, wash them with soap and water and then disinfect them with a 10 percent solution of chlorine bleach before reusing them.

Peat pots are nice, especially for large seeds and herbs. Peat pots may be planted directly into soil; remove one side or cut large holes into the pot and cut off any edge of the lip of the pot that is not buried. Do not allow the edges of the pot to stick out above the soil; they will act as a wick and moisture will evaporate from this exposed surface, which can cause plants to dry out.

Sow one or two large seeds or 10 to 12 small herb seeds directly in each peat pot. Thin the former to one seedling per pot, but allow all the herb seeds to grow together. They hold one another up and grow much better than when they're sown singly. When the time to transplant comes, they are strong enough to take some dividing, if desired.

Planting Medium

It is best to use a soilless or peat-lite mix to start seedlings. Garden soil may contain disease-causing organisms that can be highly destructive to small plants, and it can have poor drainage in containers. You can mix your own peat-lite mix; half vermiculite or perlite and half fine sphagnum peat is excellent for starting seeds. Mix together thoroughly, and fertilize at half the normal strength.

Regardless of the type of container you choose, fill it full with seed-starting mixture and sow the seeds. If the mixture is dry, moisten it before placing it in the container. Place seeds to the specified depth and water the mix. If your home is dry, it may help to cover the containers with plastic wrap to maintain soil moisture. 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 disease caused by a fungus that is deadly to seedlings. You can prevent or reduce damping-off 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 they're wet, and then seeds are planted in the holes provided. The whole pellet or cube may then be planted without disturbing the roots. The only disadvantage of this method is the expense.

Depth of Planting

The depth to cover seeds when you plant them depends on a number of factors, such as seed size, the type of soil you have, and the season. As a general rule, vegetable seeds should be planted twice as deep as the width of the seed, but there are exceptions. Always read the packet directions for planting instructions. Some seeds require light for germination and should not be covered.

Starting Seeds Outdoors

Many seeds may be sown directly in garden soil. If garden soil is quite sandy or has 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 to only two or three times their diameter. In such soils, it may be helpful to apply a band of sand, fine compost, or vermiculite that is 4 inches wide and ¼ inch thick over the seeds after they are planted. This will help retain soil moisture and reduce crusting of the soil, 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. Table 10-2 provides optimum soil temperatures.

When planting your fall garden in midsummer, you will notice that the soil is

Table 10-2. Plant production data.

Crop	Days to Emergence from Seeding	Optimum Soil Temperature Range for Germination	Number of Weeks to Grow Transplants
Beans	5 to 10	65 to 85	*
Beets	7 to 10	50 to 85	*
Broccoli	3 to 10	50 to 85	5 to 7
Cabbage	4 to 10	50 to 85	5 to 7
Carrots	12 to 18	50 to 85	*
Cauliflower	4 to 10	50 to 85	5 to 7
Celery	9 to 21	50 to 65	10 to 12
Chard, Swiss	7 to 10	65 to 85	*
Cucumbers	6 to 10	65 to 85	4 (peat pots)
Eggplant	6 to 10	65 to 85	6 to 9
Lettuce	6 to 8	50 to 65	3 to 5
Melons	6 to 8	65 to 85	3 to 4 (peat pots)
Okra	7 to 10	65 to 85	*
Onions	7 to 10	65 to 85	8
Parsley	15 to 21	50 to 85	8
Peas	6 to 10	50 to 65	*
Peppers	9 to 14	65 to 85	6 to 8
Radishes	3 to 6	50 to 65	*
Spinach	7 to 12	50 to 65	*
Squash	4 to 6	65 to 85	3 to 4 (peat pots)
Sweet corn	5 to 8	65 to 85	*
Sweet potatoes	(slips)	65 to 85	5 to 6
Tomatoes	6 to 12	65 to 85	5 to 7
Turnips	4 to 8	50 to 65	*

*Transplants not recommended.

Lawn Care

CHAPTER 11

Bigstock

LEARNING OBJECTIVES

- Explain the species and characteristics of turfgrasses best suited for growing in Pennsylvania.
- Describe the methods necessary for establishing turfgrass, including site preparation, seeding, and sodding.
- Understand best management practices for growing turfgrass in Pennsylvania, including mowing, fertilization, irrigation, thatch control, and aeration.
- Become familiar with weed, insect, and disease problems and remedies associated with growing turfgrass.

INTRODUCTION

Turfgrasses are fine-textured grass species that form a uniform, persistent population of plants that tolerate traffic and low-mowing heights (usually 3 inches or lower). A properly managed turf creates a uniform groundcover to complement a well-planned landscape. While trees and shrubs provide color and texture in a mostly vertical orientation, turfgrasses add coherence, pulling together the divergent parts of the landscape. A poorly maintained turf that is weedy and thin can detract from the natural beauty of the property.

In addition to their aesthetic value, turfgrasses have an important functional role as a living groundcover. Turfgrasses stabilize soil, thereby reducing runoff and erosion in residential areas. Compared to surfaces without vegetation, turfgrasses have a significant cooling effect around homes and other buildings. A dense stand of turf can also provide better footing and cushions the impact of athletes on playing fields.

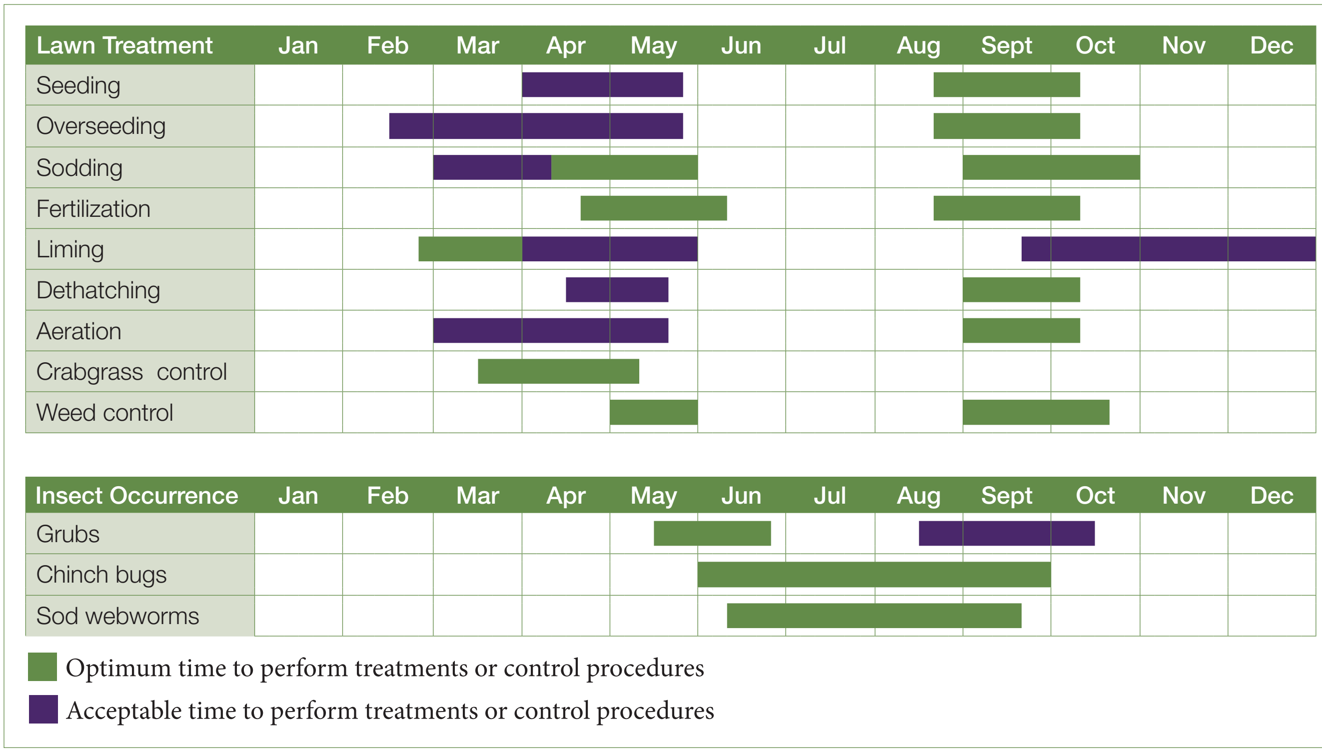
Good-quality lawns and other turf areas depend on the proper selection and management of turfgrasses. For best turf performance, it is important to use the appropriate management practices at the correct times of the year (Fig. 11-1).

TURFGRASS SPECIES USED IN PENNSYLVANIA

Only a few grass species produce acceptable turf in Pennsylvania. These grasses can be divided into two groups, the cool-season and the warm-season turfgrasses. Cool-season turfgrasses include species that are adapted to the cooler (northern) portions of the United States and make their maximum growth during cool spring and fall weather. They may become semi-dormant during hot and/or dry periods of summer. Cool-season grasses adapted for turf use in Pennsylvania include Kentucky bluegrass, rough bluegrass, perennial ryegrass, the fine fescues, tall fescue, and the bentgrasses.

Warm-season turfgrasses include species that are best adapted to southern areas of the United States. Some of the warm-season turfgrasses are also adapted to the transitional regions between the northern and the southern states. These grasses make their maximum growth during hot weather and are dormant during late fall, winter, and early spring. Zoysiagrass is the only warm-season turfgrass that has sufficient winter hardiness to survive and persist as high-quality turf, and then only in the southernmost portions of Pennsylvania.

Turfgrass species vary in their adaptation to soil moisture, temperature extremes, soil fertility, pH levels, disease and insect resistance, wear tolerance, and mowing tolerance. They may also vary in such characteristics as leaf texture, color, growth habit, density, growth rate, and uniformity. Considerable variation in these attributes can also occur within an individual species. Turfgrasses exhibiting characteristics that differ from other members of the same species are called varieties or cultivars.



Jennifer Bair and Sue Wyble

Fig. 11-1. Lawn care calendar.

Kentucky Bluegrass

Kentucky bluegrass (*Poa pratensis*) is a persistent and attractive species used in many home lawns, institutional grounds, parks, and athletic fields. This species has a medium to fine leaf texture and a medium to dark green color when properly fertilized. It produces extensive underground stems, called rhizomes, which provide good sod-forming characteristics and superior recuperative potential when compared to most other cool-season turfgrasses.

Kentucky bluegrass is tolerant of cold, wear, and moderate heat. It makes optimal growth during the spring and fall and becomes semi-dormant under prolonged periods of heat and drought. It usually recovers quickly from dormancy with the advent of cooler temperatures and adequate soil moisture.

Kentucky bluegrass performs best when grown in well-drained soils and open, sunny areas. This grass does not tolerate poorly drained soils or heavily shaded conditions (although a few varieties have improved shade tolerance).

Kentucky bluegrass generally requires higher amounts of nitrogen (N) fertilizer (3 to 4 pounds per 1,000 square feet per growing season) than other cool-season turfgrasses, and tends to produce a significant amount of thatch. In lawns, Kentucky bluegrass should be maintained at 2 to 3 inches in height. The germination and establishment period for Kentucky bluegrass is longer than for most other turfgrasses, requiring two to three weeks for emergence and two full growing seasons (fall and spring) to become fully established.

Rough Bluegrass

Rough bluegrass (*Poa trivialis*) is similar to Kentucky bluegrass in appearance, but it has a lighter green color and produces aboveground stems, called stolons, which allow it to spread and generate new tillers

Tree Fruit

CHAPTER 13

Bigstock

Table 13-1. Apple cultivars not resistant to apple scab but recommended for home planting in Pennsylvania.

Cultivar*	Characteristics	Ripening Period	Planting**
Jerseymac	Early 'McIntosh' type; crisp red apple of excellent quality; good for eating, sauce, and pies	Late July to early August	A, B
Ginger Gold	New golden-type apple ripening in mid- to late August; high-quality, russet-free fruit; good for eating fresh and pies	Mid-August	C
Gala	New orange-red fruit; sweet and hard with high quality; developed in New Zealand; good for eating fresh	Late August to September	B, C
McIntosh	Old-time favorite; purchase new high-coloring strains; available as a spur type	Early September	A
Spartan	'McIntosh' type but ripens later; small- to medium-sized, red fruit; high-quality dessert apple	Mid-September	B
Delicious	Most popular commercially grown cultivar; available in spur and nonspur strains	Early to mid-October	B
Empire	Dark red; excellent dessert quality; all-purpose apple that keeps well	Mid- to late September	B, C
Golden Delicious	Excellent all-purpose apple; heavy producer; avoid spur strains (tend to russet more than nonspur strains)	October 1 to 15	B, C
Idared	Increasingly popular cultivar; produces large, mildly tart, red fruit; keeps well	October 1 to 15	A, B
Jonagold	Developed in New York as cross between Jonathan and 'Golden Delicious'; high-quality fruit; red blush over yellow skin; triploid; produces sterile pollen (see pollination section)	October 1 to 15	A, B
Stayman	Very popular old standard cultivar; red fruit usually develops some russeting at the stem end; may split on tree; good for fresh eating, pies, sauce; keeps well	October 1 to 15	A
Spigold	Tender-skinned, high-quality, greenish-yellow fruit; triploid; produces sterile pollen (see pollination section)	October 16 to 30	B
Braeburn	Newer apple cultivar; ripens in mid- to late October; red over green fruit; semi-tart but very firm	Mid-October	A, B
Mutsu	Cross between 'Golden Delicious' and 'Indo'; very large, light-green to yellow fruit; triploid; produces sterile pollen	October 16 to 30	B
Fuji	Developed in Japan; one of latest ripening grown in Pennsylvania; may have difficulty maturing fruit each year above Interstate 80; very firm, sweet, red over green fruit; stores extremely well in regular refrigeration	Late October	B

*In order of ripening period.

**To ensure pollination and fruit set, plant cultivars having a common letter.

***Potomac:** Released in 1993, this pear was developed by traditional breeding methods from a cross of 'Moonglow' and 'D'Anjou'. Fruit is light green and glossy with a flesh that is moderately fine and has a flavor similar to that of 'D'Anjou'. Harvest fruit about three weeks after 'Bartlett'.

Seckel: This tree is small, very productive, and fairly blight resistant. It has small, sweet fruit that ripens to deep yellowish brown and is excellent for canning and fresh use. This cultivar is a poor pollen producer. Harvest fruit approximately three weeks after 'Bartlett'.

***Magness:** Developed from a cross of 'Seckel' and 'Comice', this medium-sized pear has a greenish-yellow and slightly russeted color. The flesh is sweet and juicy with few grit cells. Fruit matures about September 12 in southcentral Pennsylvania.

'Magness' pear is pollen sterile, so at least two other cultivars must be planted nearby.

D'Anjou: This cultivar has average to large-sized fruit with skin that ripens to a creamy greenish color and occasionally develops a red cheek. Flesh is mild to rather sweet and finely textured. This late pear is excellent for all uses and a fairly good pollenizer. Harvest 3 to 3½ weeks after 'Bartlett'.

Bosc: This pear has large, long-necked fruit that ripens to a greenish-yellow color that is usually completely overlaid with a cinnamon-colored russet. Fruit quality is excellent for all uses. This cultivar is a good pollenizer for 'Bartlett'. Harvest three to four weeks after 'Bartlett'.

***Shenandoah:** This is one of the latest-ripening European pears, maturing about four to five weeks after 'Bartlett'. Its fruit is large with a yellow-green glossy skin. There may be slight russeting on the calyx end. Fruit will keep in refrigerated storage for up to four months.

Asian Pears

These pears have a different eating quality than that of the European types. They are not allowed to soften before eating and have much higher sugar levels. Their eating texture is similar to that of an apple, and they produce very juicy fruit. While Asian pear pollen is compatible with European pears, the two species usually do not have sufficient overlap in bloom to allow for consistent cross-pollination. Cultivars are listed below in order of ripening.

Shinsui: This is the earliest pear to mature, usually at the end of August in central Pennsylvania. The fruit has an orange-brown russet and is very juicy. Tree growth is upright and very vigorous.

Hosui: Ripening about a week after 'Shinsui', fruit is round with a solid russet and should be thinned shortly after bloom to avoid alternate bearing years.

Shinseiki: Sometimes listed under the name 'New Century', this cultivar matures the first week of September. Its medium-sized fruit has yellow skin with some russeting.

Kosui: Small, yellow-brown fruit matures in central Pennsylvania the first week in September.

Olympic: Also known as 'A-Ri-Rang' or 'Korean Giant', this cultivar produces large fruit that weighs nearly a pound, as the latter name indicates. Fruit is round with an attractive golden-russeted skin and stores for several months.

Ya Li: The greenish-yellow fruit of this cultivar has more of a traditional European pear shape and is harvested in mid-October in central Pennsylvania.

Shinko: This is the latest-maturing Asian pear cultivar, ripening the end of October in central Pennsylvania. Its medium-sized fruit has a golden-brown russet. Trees must be thinned shortly after bloom to prevent alternate bearing. Of the Asian pears, this cultivar probably has the most resistance/tolerance to fire blight.

Nursery Stock Selection

The old adage "You get what you pay for" is an important consideration when buying fruit trees. Bargain plants may be unhealthy or of a cultivar that is not adapted to your area. Buy only trees of recommended cultivars from a reliable source. Here are a few points to keep in mind when purchasing fruit trees:

- Apple and pear trees are now available as either one-year-old "whips" (without branches) or one- and two-year-old trees with branches (often referred to as "feathered").
- Feathered trees are preferred because they will produce fruit earlier, but they cost more than one-year-old whips.
- Look for trees that are 5 to 6 feet tall and have a minimum ½-inch caliper, a good root system, and four to six branches

Landscape Design

CHAPTER 15

evergreen material. A seasonally balanced landscape should have a certain percentage of both evergreen and deciduous plants. The exact proportion of each should be governed by the user's interests and needs.

Deciduous shrubs usually tolerate difficult growing conditions better than most other plants. They are suited well to open, exposed locations that can be dry and windy. Many grow rapidly and may require some annual pruning.

Ornamental Vines

Vines serve many useful landscaping purposes. Where space is limited, vines may be used on trellis supports as dividers or barriers. They screen views or provide privacy for the patio or porch. They break the monotony of a long fence or blank wall. They soften harsh structural lines and blend the structure with other buildings. On steep banks and in other areas where grass is difficult to establish and maintain, vines may be used as groundcovers. They can be established against buildings to provide shade, thereby improving energy efficiency for cooling.

Selecting a suitable vine depends on its intended use, location, soil adaptability, and type of support. Dense, coarse foliage is desirable if a screen is needed. A fine-textured, slow-growing vine adds pattern and interest to a stone or brick wall. A decorative vine should possess desirable flowers, fruit, or foliage for seasonal interest. Growth rate should also be an important consideration in vine selection. Rapidly growing plants can quickly escape into the surrounding landscape and become a hard-to-control weed.

Twining and tendril-type vines climb best on wires, trellises, and arbors. They can be grown on solid, vertical surfaces only if they are properly supported. Although clinging vines can be used on brick or masonry walls, they can erode the cement between bricks and weaken the wall. Old brick and mortar is the most susceptible to damage. These vines also should never be used on the walls of frame buildings because their method of climbing can cause damage. They cling so closely to the wall that moisture is likely to collect under them and cause the wood to rot. Grow clinging vines on trellises far enough from the siding of wood structures to allow for free air circulation. The trellis should be movable to permit painting of the siding without damaging the vine. Clinging vines are particularly valuable on concrete exposures such as along highways or commercial buildings.

Vine supports should be constructed with sturdy, durable materials, such as wire, tubing, or wood. Copper or aluminum wire or tubing will not rust and therefore are preferred over other metals. Use pressure-treated wood or treat wood with a preservative that is not toxic to plants to make it last longer.

Groundcovers

Groundcovers are low-growing plants that spread to form a dense cover. They add beauty to the landscape while helping to prevent soil erosion. Grass is the best-known groundcover, but it is not suited to all locations. Other groundcover plants should be used where grass is difficult to grow or maintain. Unlike grass, most groundcovers cannot be continually walked on. They can be used effectively to reduce maintenance work and put the finishing touch on any landscape design.

Groundcovers should not be used among other plants with low spreading growth habits like their own. Like vines, some groundcovers can become invasive and weedy if they are allowed to escape into surrounding plants or beds where they are not wanted.

Groundcovers can be found to fit many conditions, but they are used most frequently for the following locations:

- Steep banks or slopes
- Shady areas under trees and next to buildings

Table 15-2. Area covered by 100 plants at different planting distances.

Planting Distance (inches)	Area Covered (square feet)
4	11
6	25
8	44
10	70
12	100
18	225
24	400
36	900
48	1,600

- Under plantings in shrub borders and beds
- Places where tree roots grow close to the surface and prevent grass from growing
- Very wet or very dry locations

When planted under trees, groundcovers reduce the possibility of mower damage to the base of the tree. Some groundcovers may be used to protect the roots of shallow-rooted trees. They shade the soil and keep it from drying out rapidly. Some groundcovers don't require as much moisture and nutrients as grass. Therefore, they are in less competition with trees and shrubs.

Some groundcovers prefer partial shade, others thrive in deep shade or full sun, and a few grow well in either sun or shade. Some prefer moist soil, while others need dry or well-drained soil for best survival.

Properly establishing any groundcover plant is critical to its success in the landscape. A well-prepared bed is necessary to develop a dense, healthy cover planting. Take care to eliminate perennial weeds and grass that might compete with the groundcover during establishment. Few, if any, herbicides can be applied to kill only the weeds in a groundcover planting. Keep the plants moist and well fertilized to speed the development of a dense cover that will inhibit future weed growth.

The final density and rate of cover will be determined to a large extent on initial plant spacing in the bed. Space plants so they will develop a uniformly covered area in a relatively short time. For faster coverage, plant in staggered rows, not straight lines, in both directions.

Plants that spread rapidly may be spaced much wider than slowly spreading types. Spacing also depends on available funds and how quickly cover is wanted. Spacing from 6 inches to 2 feet is most frequently used. If plants are spaced 4 inches apart, 100 plants will cover about 11 square feet of area (see Table 15-2).

Watering, weeding, mulching, and feeding are the main requirements for rapid establishment of groundcovers.

Ornamental Grasses

With heights ranging from under 1 foot (blue fescue) to over 10 feet (giant reed), ornamental grasses can be chosen to fit any landscape situation. Often used as a groundcover and for erosion control on slopes, ornamental grasses also make outstanding specimen plants when used in the landscape. Many native grasses adapt well to soil moisture and fertility conditions. In addition to a wide range of heights and spread, there is tremendous variation in leaf size and color. Leaf colors range from pale greens to bright powder blues and blood reds, with many types of both vertical and horizontal patterns.

Most ornamental grasses require full sun and provide a wide variety of flowers ranging from small bottlebrush arrangements to large, showy plumes. Flower colors range from pale yellows and pinks to deep maroons. Many of the flower spikes persist well into the winter, giving added landscape interest, although the leaf clumps will generally die to the ground and regrow each spring.

Woody Ornamentals

CHAPTER 16

Fig. 16-3. Bare-root tree.

Schichtel's Nursery, Inc.

Fig. 16-4. Balled-and-burlapped trees.

Nancy Knauss

Nancy Knauss

Fig. 16-5. Container-grown shrubs.

hawthorns, crabapples, and dogwoods, are useful for ornamental purposes but do not give abundant shade.

Finally, consider how much maintenance the plant requires and any possible drawbacks, including susceptibility to diseases and insect pests (e.g., flowering dogwood, paperbark birch); soft or brittle wood that is easily damaged by wind and ice (e.g., poplar and Callery pear); fruits and seeds that are large, messy, smelly, or otherwise obnoxious (e.g., Kentucky coffeetree and ginkgo); and abundant shedding of twigs and small branches (e.g., honeylocust).

Purchasing Plants

Plants can be placed into three groups according to the way they are grown and then harvested from the nursery: bare root, balled and burlapped (B&B), and container grown.

Bare-root plants are harvested from the nursery with no protection over their root system (Fig. 16-3). They are quite vulnerable to the elements, especially loss of moisture (root desiccation). A B&B plant is dug from the field with a protective ball of soil around the root system (Fig. 16-4). The soil ball is held intact with a wrap of burlap or similar support material. Container-grown plants, on the other hand, spend their entire production cycle in a container, either above the ground or in a pot-in-pot production system, with soilless media surrounding the roots (Fig. 16-5). When sold, there is no damage to the root system of containerized plants; however, care should be taken to ensure that the circling roots are disrupted before planting. All three types of plants must be protected from moisture loss during transport and handling and until they are placed in a permanent location in the garden or landscape. To reduce the

Table 16-1. Trees best suited for bare-root production.

Scientific Name	Common Name
Acer × freemanii	Freeman maple
Acer campestre	Hedge maple
Acer miyabei	Trident maple
Acer rubrum	Red maple
Acer saccharum	Sugar maple
Acer truncatum	Shantung maple
Catalpa speciosa	Northern catalpa
Cercidiphyllum japonicum	Katsura tree
Cladrastis kentukea	Yellowwood
Cornus foemina	Gray dogwood
Cornus mas	Cornelian cherry dogwood
Gleditsia triacanthos	Honeylocust
Gymnocladus dioicus	Kentucky coffeetree
Maackia amurensis	Amur maackia
Malus spp.	Crabapple
Parrotia persica	Persian parrotia
Platanus × acerifolia	London planetree
Prunus 'Accolade'	Accolade flowering cherry
Prunus sargentii	Sargent cherry
Prunus serrulata	Japanese flowering cherry
Prunus virginiana 'Canada Red'	Chokecherry
Quercus bicolor	Swamp white oak
Quercus palustris	Pin oak
Quercus rubra	Northern red oak
Robinia pseudoacacia cultivars	Black locust 'Purple Robe', 'Pyramidalis', Globosum', 'Bessoniana', 'Twisty Baby'
Sorbus alnifolia	Korean mountain ash
Syringa reticulata	Japanese tree lilac
Tilia americana	Basswood
Tilia cordata	Littleleaf linden
Tilia euchlora	Crimean linden
Ulmus americana	American elm hybrids (except 'Frontier')

chances for desiccation, be sure to lay large trees and shrubs down in the back of pickup trucks and cover all plants with a secured tarp or protective covering as they are transported down the road.

Depending on the size of the individual plant at the time of sale, many vines, groundcovers, trees, or shrubs can be purchased as bare-root, container-grown, or B&B plants. Vines in most instances are grown in containers, while groundcovers can be sold as smaller plants within pots or production trays containing 36 to 48 plants. To increase storage life in the nursery or garden center, most trees and shrubs are sold in containers or as B&B material.

Bare-root Plants

Bare-root plants are generally available in nurseries in early spring. The plants are harvested in the spring or the previous fall. Those harvested in the fall are stored over winter under cool, humid conditions to retain quality. Bare-root plants are sold with their roots wrapped in a damp sphagnum moss or similar packing material to prevent drying. Not all species are available or amenable to bare-root production due to their root structures and growth rates (see Table 16-1).

Some nurseries dig bare-root trees in the spring and will use a synthetic, nontoxic product called hydrogel to solve the desiccation problem for the critical time between digging and replanting. Hydrogels are polymers that look like table sugar when dry but can hold several hundred times their weight in water. Fine and coarse grades are available, but the fine grades work best to prevent desiccation because they provide much better coverage of the absorbing roots. The tree roots are dipped in a hydrogel slurry and immediately placed in plastic bags to protect the roots from drying out until the tree is planted no more than a week later (Figs. 16-6 and 16-7).

When purchasing these plants, make certain the packing material is damp and the plant has not dried out. Keep the packing around the roots damp until planting time. Never let the roots dry out. This is perhaps the single most important source of failure in planting bare-root material.

Bare-root plants are generally smaller than other types of plants that can be purchased. Store them in cool locations out of the wind and away from the heat of the sun until they are ready to be planted. If planting immediately after purchase is not possible, the plants may be heeled into the ground for several weeks to prevent drying out.

To heel in a plant, open a trench wide enough and deep enough to accommodate the entire root system. Lay the roots of the plant in the trench and cover them with soil. Keep the area adequately watered until the plant can be moved to its permanent location.

Balled-and-burlapped Plants

Balled and burlapped (B&B) trees have their roots surrounded by a ball of soil, which is covered with a burlap-like material and enclosed in a wire basket. These wrappings are useful during transport to the nursery and planting site.

B&B plants have been grown in a nursery for several years before they are harvested for sale. Many nurseries will prune the roots on such plants while they are in the field to help produce a more compact root system when the plants are dug from the field. Evergreens and a great many deciduous trees and shrubs are suitable for this production method. The practice also allows for the sale of larger-sized plants when compared to bare-root and container-grown material.

B&B material can be planted at just about any time of the year—spring or early fall, as well as summer, if plants are available. Nursery stock is not commonly dug during the summer, so availability in a retail nursery will be based on what was dug in the spring during prime digging season. Summer planting requires additional attention to watering during the drier months to ensure that adequate moisture is available to allow for root growth and transpiration by the new plant. Fall planting should be early enough to allow for some root growth before soil temperatures drop. Generally, root growth stops in the fall when soil temperatures drop to 40°F or less.

When selecting B&B plants, make certain the soil ball is solid and has not been broken. The plant should be firmly set in the soil ball, and both the plant and the root ball should move as a single unit. The plant should also be centered in the root ball. The root ball should be moist and the burlap should be in good physical condition. Old

Fig. 16-6. Dipping a bare-root tree in hydrogel.

Schichtel's Nursery, Inc.

Schichtel's Nursery, Inc.

Fig. 16-7. Bagging a bare-root tree.

Herbaceous Plants

CHAPTER 17

Carol Papas

Fig. 17-4. Textural contrasts.

Fig. 17-6. Analogous color grouping.

Fig. 17-5. Textures as visualized in a black-and-white photograph.

Flowers: Shape and Color

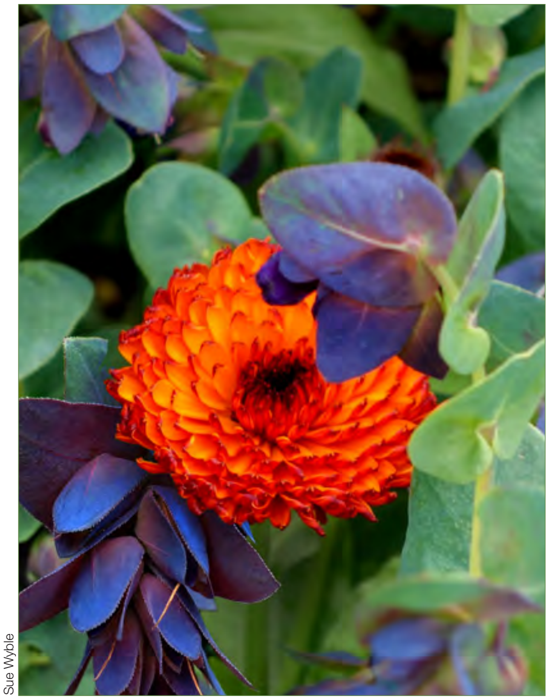
Individual flowers exhibit variation with the solid shapes seen in daisies or daylilies, the flat corymbs of yarrow, and the spiky flowers of veronica and astilbe. A pleasing planting will include contrast in flower shapes, too.

While it is most important to consider plant form and leaf texture when choosing perennials, the reality is that most people hone in on flower color when putting plants together. The color wheel still has many lessons to offer relating to the use of color in the garden. Some gardeners prefer the subtle look of analogous groupings—those that lie side by side on the color wheel, such as a range of pinks and peaches (Fig. 17-6). Others might opt for the simplicity of a monochrome garden composed only of green leaves and white flowers. Another option is the high contrast of classic complementary pairings such as purple and orange, opposites on the color wheel (Fig. 17-7).

Be sure to consider color choices in context. Take a look at the background when selecting plants. A burgundy-leaved canna planted in front of a red-brick home would blend right in with the background, while a variegated cultivar might be a better choice in this context.

Context factors in again when combining plants in a border or even within a contain-

Fig. 17-7. Complementary color grouping.



Sue Wyble

Fig. 17-8. Terra cotta container with 'Henna' coleus.

Carol Papas

Bill Goff

Fig. 17-9. Pastel border.

er. Coleus leaves provide a good example. Each leaf contains colors that can inform the choice of the other plants within the container. Coleus (*Solenostemon* spp.) 'Henna' has rust, lime, and red-orange contained within a single leaf, making it easy to choose a supporting cast of plants. Warm colors such as a sunset-colored lantana or yellow dahlia with dark leaves will complement the coleus, while the addition of a pale-pink petunia would do neither plant justice. Containers are part of the context of a planting; that same coleus will look better in a terra cotta container instead of a gray concrete pot (Fig. 17-8).

Color is very subjective, and the rules of color are not hard and fast. Color combinations seen as discordant or clashing by one person can be seen as exciting and bold by another.

White, cream, and silver flowers and foliage have a light-reflecting quality that adds an extra dimension to the garden. If you work long days, using white in the garden will allow you to see plants well beyond the time the sun has set.

A few classic combinations resonate with most gardeners. Some ideas for combining plants include a monochromatic color scheme, a hot border, or a pastel border composed of pinks, blues, and purples (Fig. 17-9). Color allows gardeners to express their personal style within the garden.

Table 17-3 (continued)

Botanical Name	Common Name	Bloom Color	Height (inches)	Exposure	Soil	Uses
Lupinus hartwegii	Lupine	Blue, rose, yellow	18 to 24	Full sun, cool	Well-drained	Bedding, cutting, fragrance
Mandevilla sanderi	Brazilian jasmine	White, pink, red	vine 36+	Full sun, warm	Moist, well-drained	Containers, trellis
Matthiola incana	Stock	White, pink, violet, red, yellow	12 to 30	Full sun, cool	Well-drained	Bedding, fragrance
Mecardonia 'Gold Dust'	'Gold Dust' mecardonia	Yellow	4 to 6	Full sun	Average	Baskets, containers
Melampodium paludosum	Medallion flower	Yellow	15 to 24	Full sun, heat	Average	Bedding, containers
Mirabilis jalapa	Four o'clock, marvel of Peru	White, pink, yellow	24 to 36	Full sun	Well-drained	Bedding, background, fragrance
Nemesia strumosa	Nemesia	White, pink, blue, purple, orange	12 to 24	Sun/part shade	Average	Bedding, containers, baskets
Nicotiana × sanderae	Hybrid flowering tobacco	White, pink, red, lime-green	12 to 24	Full sun	Average	Bedding, containers
Nierembergia hippomanica	Cupflower	White, blue, purple	9 to 12	Sun/part shade	Well-drained	Baskets, containers, edging, rock garden
Nigella damascena	Love-in-a-mist	White, blue, violet, pink	12 to 24	Sun/part shade	Average	Cutting, drying; re-seeds
Osteospermum hybrids	Cape daisy	White, rose, purple, yellow, orange	12 to 24	Full sun	Well-drained	Bedding, containers
Pelargonium × hortorum	Zonal geranium	White, pink, lavender, salmon, red	12 to 36	Full sun	Well-drained	Bedding, containers, baskets
Pentas lanceolata	Egyptian star cluster	White, pink, lavender, red	12 to 36	Full sun, heat	Well-drained	Bedding, containers, pollinators
Petunia hybrids	Petunia	White, pink, blue, purple, red	6 to 8	Full sun	Well-drained	Bedding, baskets, containers
Phlox drummondii	Annual phlox	White, rose, purple	6 to 15	Sun/part shade	Well-drained	Bedding, containers, rock gardens
Portulaca grandiflora	Moss rose	White, rose, yellow, orange, red	4 to 8	Full sun, heat	Dry, well-drained	Bedding, baskets, containers
Ricinus communis	Castor oil plant	Red flowers, bronze foliage	72 to 96	Full sun	Average	Bedding, background; poisonous
Rudbeckia hirta	Black-eyed Susan	Yellow, orange, maroon	24 to 36	Full sun, dry	Well-drained	Bedding
Salvia coccinea	Hummingbird sage	White, pink, red	12 to 36	Sun/part shade	Well-drained	Bedding, containers, pollinators
Salvia farinacea	Mealycup sage	White, blue, bicolor	12 to 24	Sun/part shade	Well-drained	Bedding, containers

(continued)

Table 17-3 (continued)

Botanical Name	Common Name	Bloom Color	Height (inches)	Exposure	Soil	Uses
Salvia splendens	Scarlet sage	Cream, salmon, burgundy, red	12 to 24	Sun/part shade	Well-drained	Bedding, containers
Sanvitalia procumbens	Creeping zinnia	Yellow, orange	4 to 8	Full sun	Average	Baskets, containers
Scabiosa atropurpurea	Pincushion plant	Purple, crimson	24 to 36	Sun/part shade	Well-drained	Bedding, cutting
Scaevola aemula	Fan flower	White, purple, pink	4 to 9	Full sun, heat	Well-drained	Baskets, containers
Senecio cineraria	Dusty miller	Foliage gray	12 to 24	Sun/part shade	Average	Containers, edging, bedding
Solenostemon varieties	Coleus	Colorful foliage	12 to 48	Sun to shade	Well-drained	Containers, bedding
Strobilanthes dyerianus	Persian shield	Foliage purple/silver	36 to 48	Sun/part shade	Well-drained	Containers, bedding
Sutera grandiflora	Bacopa	White, lavender	trailing 36+	Part shade	Moist, well-drained	Baskets, containers
Tagetes spp.	Marigold	Yellow, orange, red	6 to 48	Full sun	Average	Bedding, containers, edging
Thunbergia alata	Black-eyed Susan vine	Orange, white	vine 48+	Full sun	Moist, well-drained	Baskets, containers, trellis
Torenia fournieri	Wishbone flower	White, blue, violet	6 to 12	Sun/part shade	Well-drained	Bedding, containers
Verbena × hybrida	Bedding verbena	White, pink, blue, peach, red	8 to 15	Full sun	Well-drained	Bedding, baskets, containers
Viola × wittrockiana	Pansy	Blue, purple, white, yellow	4 to 15	Full sun, cool	Average	Bedding, containers
Zinnia spp.	Zinnia	Red, pink, yellow, orange	12 to 48	Full sun	Average	Bedding, cutting

Native Plants

CHAPTER 18

Constance Schmotzer

Table 18-1. Recommended Pennsylvania native plants.

The plants in this table are listed alphabetically by scientific name and sorted by habitat. Some plants are repeated in more than one habitat because they tolerate varied conditions. More extensive lists, propagation techniques, and landscaping recommendations are available on the Internet and in the sources provided in the Bibliography.

Scientific Name	Common Name	Comments
Deciduous Woodlands		
Acer rubrum	Red maple	Canopy tree; adaptable to many sites
Actaea pachypoda (Fig. 18-13)	Doll's eyes, white baneberry	Attractive foliage; white berries
Actaea racemosa	Black cohosh	Nice foliage; white flower spikes in summer
Adiantum pedatum	Maidenhair fern	Delicate fern; lovely foliage
Anemonella thalictroides	Rue anemone	Delicate flowers and foliage
Aquilegia canadensis (Fig. 18-14)	Eastern columbine	Popular spring wildflower; hummingbird food
Arisaema triphyllum	Jack-in-the-pulpit	Interesting flower; red berries in summer
Asarum canadense	Wild ginger	Groundcover
Betula nigra	River birch	Large tree native to floodplains; distinctive bark
Carpinus caroliniana	American hornbeam	Medium-sized tree
Cercis canadensis (Fig. 18-15)	Eastern redbud	Small tree blooms pink in early spring
Claytonia virginica	Springbeauty	Early spring ephemeral with pink flowers
Cornus florida	Flowering dogwood	Tree with large white flowers in spring


Fig. 18-13

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Fig. 18-14

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Fig. 18-15

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Fig. 18-13. *Actaea pachypoda* (doll's eyes).
Fig. 18-14. *Aquilegia canadensis* (eastern columbine).
Fig. 18-15. *Cercis canadensis* (eastern redbud).

Table 18-1 (continued)

Scientific Name	Common Name	Comments
Delphinium exaltatum	Tall larkspur	Blue flowers in late summer
Dicentra cucullaria (Fig. 18-16)	Dutchman's breeches	Fern-like foliage; white flowers; ephemeral
Dicentra eximia	Fringed bleeding heart	Fern-like foliage; pink flowers
Erythronium americanum	Eastern trout lily	Early yellow flower; attractive mottled leaves
Geranium maculatum	Wild geranium	Pink flowers; midspring
Hamamelis virginiana	American witchhazel	Small tree; yellow flowers in fall
Hepatica acutiloba	Sharp-lobe liverleaf	Small plant; white to pink flowers
Heuchera americana	Alumroot	Varieties bred for attractive foliage
Houstonia caerulea	Bluets, Quaker ladies	Tiny plants with blue and yellow flowers
Jeffersonia diphylla	Twinleaf	Interesting foliage; brief flowers in spring
Kalmia latifolia	Mountain laurel	Evergreen shrub; Pennsylvania state flower
Lindera benzoin	Spicebush	Delicate yellow flowers in spring; host for spice-bush swallowtail
Liriodendron tulipifera	Tulip tree	Tall, straight, and stately canopy tree
Mertensia virginica	Virginia bluebells	Spring bloomer; blue flowers
Mitchella repens	Partridgeberry	Delicate evergreen groundcover; red berries
Phlox divaricata	Wild blue phlox	Spring bloomer; likes openings in woods
Phlox stolonifera (Fig. 18-17)	Creeping phlox	Shade-tolerant phlox

(continued)

Fig. 18-16

Fig. 18-17

Fig. 18-16. *Dicentra cucullaria* (Dutchman's breeches).
Fig. 18-17. *Phlox stolonifera* (creeping phlox).

Weeds

CHAPTER 19

NY State IPM Program

Table 19-3 (continued)

Name, Family, and Origin	Description
Phytolacca americana (Fig. 19-32) **Common pokeweed** Pokeweed family (Phytolaccaceae) North America	Large 3- to 8-foot perennial that resembles a small tree. Arising from seeds or large, red-tinged fleshy taproot. Light-green, smooth, lanceolate to egg-shaped alternate leaves, often reddish on undersides. Reddish stems. Small, white flowers in long, purple-stemmed hanging clusters. Berries green at first, turning glossy, dark purple, leaving a purple-red stain. Poisonous.
Plantago lanceolata (Fig. 19-33) **Buckhorn plantain** Plantain family (Plantaginaceae) Europe	Perennial that reproduces by seed. Basal rosette of narrow lanceolate leaves that have nearly parallel veins. Fibrous roots. Small clusters of flowers in tan-green head on erect leafless flower stalks less than 12 inches tall.
Plantago major (Fig. 19-34) **Broadleaf plantain** Plantain family (Plantaginaceae) North America	Perennial similar to buckhorn plantain. Basal rosette of broad, oval leaves with five to seven nearly parallel veins. Small flowers clustered along tan-green, erect, leafless stalks less than 12 inches.
Polygonum cuspidatum **Japanese knotweed*** Buckwheat family (Polygonaceae) Eastern Asia	Shrubby herbaceous perennial to height of 10 feet. Leaves 6 inches long by 3 inches wide, oval, with smooth margins. Stems similar to bamboo, but on newer foliage with a membranous sheath surrounding area where stem and leaf meet. Small, greenish-white flowers in spikes along the stems. Small, greenish, triangular fruits. Reproduces from heavy rhizomes.

(continued)

Fig. 19-32

Fig. 19-33

Fig. 19-34

Fig. 19-32. *Phytolacca americana* (common pokeweed).
Fig. 19-33. *Plantago lanceolata* (buckhorn plantain).
Fig. 19-34. *Plantago major* (broadleaf plantain).

Invasive Species

CHAPTER 20

Nancy Knauss

of their offspring and expand their territory. These methods of survival and spread are common among species and not unique to invasive plants. For example, many species can reproduce through tip layering, resprouting from roots, and producing many viable seeds protected by a thick seed coat to ensure survival in the soil during less-than-optimal growing conditions. Examples of invasive plants with multiple reproductive strategies include multiflora rose (*Rosa multiflora*), which multiplies via seeds contained in rose hips, layering, and resprouting from roots, and garlic mustard, which sets seed even as it continues to produce new flowers.

Below are other common reproduction and survival strategies that focus on specific mechanisms to ensure continuation of the species.

Prolific Seed Production

A purple loosestrife plant can set more than a million seeds in a year. Tree-of-heaven and some Norway maple cultivars are also heavy seed producers. Some plants, such as tree-of-heaven, produce a large quantity of seeds to overcome a reduced germination rate and still ensure the next generation of plants (Fig. 20-4).

High and Rapid Germination Rate

One test of invasiveness is seed germination rate. Some cultivars of Norway maple produce many seeds, which germinate rapidly under the canopy of the tree. Some elms are known for a high germination rate. If allowed to set seed, English ivy (*Hedera helix*) has been shown to have a nearly 100 percent germination rate.

Long Seed Viability

Another test of invasiveness is the viability of the seeds produced. Plants in the bean family with hard seed coats can remain viable for decades until the seed coat is damaged or degraded to allow imbibition of water (e.g., mimosa seeds remain viable for 50 years).

Fig. 20-3. Oriental bittersweet vine girdling a tree.


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Karel Ulizio

Fig. 20-4. Tree-of-heaven seeds.

Long-distance Seed Dispersal

It has long been argued that long-distance seed dispersal is a key to invasiveness of plant species; however, little clear data exists that supports this argument. The long-distance argument theorizes that the spread of windborne seed, such as maple samaras

Fig. 20-5. Suckering growth habit of Canada thistle.

Sandy Feather

Liz West (Wikimedia Commons)

Fig. 20-6. Purple loosestrife colonizing near water.

and tree-of-heaven samaras, to other areas and water sources can move the seed into new areas. Vertebrate feeding, such as deer browsing and songbirds feeding on berries of invasive species, can transport newly scarified seed into a different environment. These are viable methods of seed spread; however, clear data documenting this as a method of invasive plant spread, beyond observation of plants growing in new sites as single stems, is not readily available.

Difficulty in Eradication

Some plant species, such as tree-of-heaven, Canada thistle (Fig. 20-5), and Japanese knotweed, have large, wide-spreading root systems that store energy and support their suckering growth habit. The root systems of such species survive and spread through multiple strategies, such as resprouting when cut down, resprouting from small pieces of root left behind when dug up, sprouting of small pieces of root transported when soil is moved from one site to another, and sprouting at the edges of areas mowed to prevent seed formation and dispersal.

Monoculture

Some invasive plants can seed or spread within an area, outgrowing and often excluding the local native plant populations, thus creating a monoculture. Colonizing species such as tree-of-heaven, Japanese knotweed, Japanese stiltgrass, and purple loosestrife (Fig. 20-6) are examples of plants that can grow into large colonies or monoculture populations to the exclusion of all other plants. Mixed stands of invasive plants can also develop where the invasive species tolerate the environmental conditions created by other invasive species. For example, Japanese stiltgrass survives in low-light, moist sites on edges of woods and can readily be found in mixed stands with other aggressive nonnative species, including Japanese honeysuckle and garlic mustard.

Ecological Change Caused by Invasive Plants

Fire Regimes

Some nonnative prairie grasses burn more easily than native ones, causing wildfires to occur with greater frequency than native plants have evolved to withstand.

Other invasive grasses burn more slowly than natives, exposing native plants to fire for longer periods than they can endure. Invasive vines that burn easily can carry fire to treetops where fire resistance has not developed, killing the tree canopy.

Hydrology Regimes

Invasive plants can greatly affect water resources, reducing the amount of water available to native plants. As an example, Japanese knotweed and purple loosestrife both have water-greedy roots that can deny water to native species.

Geomorphologic Processes

Invasives can change the pattern of erosion and sedimentation in the landscape. As an example of a geomorphological process, some grasses that produce thick stems and have aggressive growth habits produce a large amount of biomass that does not decompose, similar to thatch in a lawn. These grasses (e.g., Japanese stiltgrass and phragmites; Fig. 20-7) can fill in wetlands due to their low decomposition rate.

Reproductive Ecology

Pollinators that visit nonnative and native species can transfer pollen from one to the other. Some research evidence suggests that the transfer of nonnative pollen to the stigma of a native plant can reduce seed set by the native plant. Similarly, European honey bees have been observed preferring nonnative flowers over native flowers. Native pollinator and honey bee pollination behaviors differ because of pollinator life cycle and communication patterns. These different behaviors can lead to some plants not being pollinated and honey bees outcompeting native pollinators for resources, thus potentially reducing native plant pollination and seed set.


Sandy Feather

Fig. 20-7. Phragmites.

Food Nutrition

Native wildlife may eat invasive plant parts that do not provide the most desirable nutrition, such as when birds need fat for migration but eat berries instead. There is evidence that invasive nonnative plants can change the distribution of native butterfly populations due to the reduced availability of native plants as a food source. In addition, invasive plants outcompeting native plants can reduce the availability of preferred food sources, forcing native wildlife populations to either adapt or move to more productive areas.

Soil Ecology

Some invasive plants have been shown to change the microbes and enzymes in the soil through changes in depth of leaf litter, soil pH, soil nutrient balance, and allelopathic modification, affecting either plants directly or the microbes that support them. These soil changes make the soil more suitable to the invasive and less suitable to natives adapted to the original soil.

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Fig. 20-8. Garlic mustard.

Leaf Litter Depth

Invasive plants may decompose so quickly that there is not enough leaf litter to protect tender plant roots (e.g., Chinese tallow tree, *Sapium sebiferum*), or they may decompose very slowly, smothering small plants and preventing native seeds from germinating (e.g., *Melaleuca quinquenervia*, an evergreen tree from Australia that is found in southern Florida).

Soil pH

Plants interact with the soil as they remove nutrients and respire through their roots. In this process, soil pH around a plant can change over time. Research suggests that the soil pH found under Japanese stiltgrass and Japanese barberry was lower than that found under a native blueberry. The hypothesized cause was the change in nitrification and nutrient cycling by the plants. The level of actual change in pH and the length of change in a seasonal cycle relative to barberry is still being debated in the literature.

Available Nitrogen

Research suggests that invasive species (e.g., European buckthorn, Norway maple, Japanese stiltgrass, and Japanese barberry) alter nutrient cycling in soils where they have invaded, increasing the availability of nutrients and thus enhancing invasive plant growth to the detriment of native plants. Studies of soil found under common buckthorn (*Rhamnus cathartica*) suggest that nonnative earthworms are attracted to these sites due to the enhanced nutrient resources. This results in greater soil disturbance and more rapid nutrient cycling by the nonnative earthworms, which may prevent native plant regeneration and seed germination.

Allelopathy

Allelopathy is a biological modification of the environment to enhance the survival and reproduction of the plant modifying the soil while interfering with the success of neighboring plants. While not completely understood, there are many examples of plants that release allelopathic compounds, including black walnut, Japanese knotweed, garlic mustard, tree-of-heaven, sunflower, and black locust. The allelopathic release can be active or passive through the breakdown of leaves and fruit, and it may either directly affect competing plants or target soil microorganisms. For example, garlic mustard allelopathy inhibits native mycorrhizae (Fig. 20-8). Stress often exacerbates the allelopathic effect on surrounding plants (e.g., drought stress worsens the effect on tomatoes growing near a walnut tree root system). Allelopathy is an emerging field as researchers learn more about plant-to-plant-to-soil interactions.

INTEGRATED VEGETATION MANAGEMENT

Integrated vegetation management (IVM) is a subset of integrated pest management (IPM), which can be defined simply as a systematic approach to commonsense pest

Garden Wildlife

CHAPTER 21

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Fig. 21-7. Rabbit damage on tree trunk.

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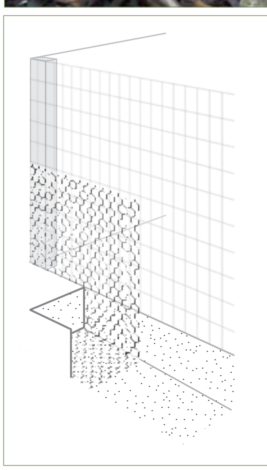


Sue Wyble

Fig. 21-8. Rabbit fence.

slanting cut with no apparent tooth marks. When rabbits gnaw bark, they gnaw in patches. The average width of a cottontail's incisor is 0.1 inch and the average width of the tooth mark is 0.08 inch. Squirrels and voles also gnaw bark, but their tooth marks are much narrower. Distinctive round droppings or rabbit tracks in the immediate area are also a good sign of their presence.

Damage Control

Many control methods can be used to manage cottontail populations. Exclusion techniques, such as fences and tree wraps, are most effective, and they are the only way to control damage in areas where rabbit populations are high. In areas with moderate damage, repellents have been used successfully to reduce damage. Because of the cottontail's high reproductive potential, trapping and other lethal techniques are not effective over long time periods. If property owners feel they cannot properly handle the damage control techniques necessary, many wildlife pest control operators are available to deal with wildlife problems.

Exclusion. One of the best ways to protect a backyard garden or berry patch is to put up a fence (Fig. 21-8). A 2-foot chicken-wire fence with the bottom tight to the ground or buried a few inches is sufficient. Wire mesh that is 1 inch or smaller will keep young rabbits from getting through. A more substantial fence of welded wire, chain link, or hog wire will keep rabbits, pets, and children out of the garden and can be used to trellis vine crops. The lower 1½ to 2 feet should be covered with small-mesh wire. A fence may seem costly, but with proper care, it will last many years and reduce damage caused by rabbits and other animals.

Cylinders of ¼-inch wire hardware cloth will protect young orchard trees or landscape plants. The cylinders should extend higher than a rabbit's reach while standing on the expected snow depth, and 1 to 2 inches out from the tree trunk. Rabbits commonly damage vegetation at a height of 2 to 3 feet, depending on the snow depth in winter. Larger mesh sizes, ½ to ¾ inch, can be used to reduce cost, but be sure the cylinder extends far enough away from the tree trunk so that rabbits cannot reach through the holes to the tree.

Habitat modification. Although frequently overlooked, removing brush piles, weeds, and other debris can be a useful way to manage rabbits. Keeping your grass mowed will remove potential cover that may attract cottontails to your garden. Filling old woodchuck or skunk burrows will remove their potential as rabbit homes. Habitat modification is especially effective in suburban areas where fewer suitable habitats are likely to be available. Habitat modification may remove rabbit habitat, but it will also change the environment around your home, including the habitat for rabbit predators. Cottontails are not the only creatures that inhabit brush piles and weed patches. Always weigh the consequences before carrying out any form of habitat management.

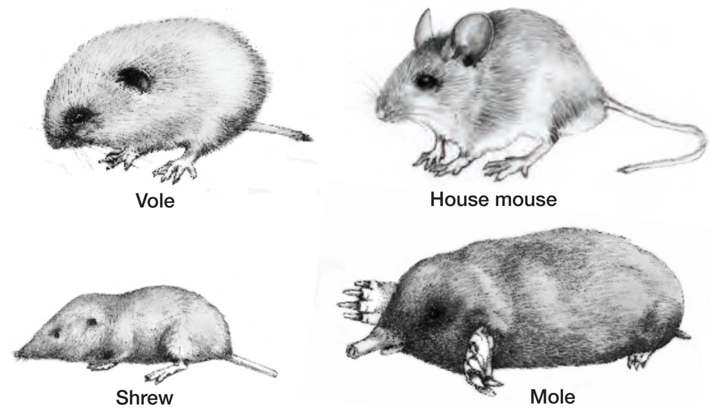
Repellents. Several chemical repellents discourage rabbit browsing. For best results, use repellents and other damage control methods at the first sign of damage. Most rabbit repellents are contact or taste repellents that render the treated plant parts distasteful. Taste repellents protect only the parts of the plant they contact; new growth that emerges after application is not protected and heavy rains may necessitate reapplication.

Odor repellents protect plants within a limited area and do not need to be touching the plant. The degree of efficacy is highly variable depending on the behavior and number of rabbits and alternative food sources that are available to them. When rabbits are abundant, use other control techniques along with chemical repellents.

Meadow Mice (Voles)

Voles are small, chunky, ground-dwelling rodents. Although similar to each other, there are two types of voles: meadow and woodland. Mature voles are 4 to 6 inches long and have stocky bodies, short legs, and short tails. Adults are chestnut brown mixed with black, and their underparts are dark gray. The underfur is generally dense and covered with thicker, longer guard hairs. Their feet are brownish, and the thin hair that covers their tails is dark on the upper surface, gradually changing to a lighter gray beneath. They have small black eyes, and their ears are furred and do not project much above the hair. The young are uniformly gray.

Voles have other common names, including meadow mice, ground moles, field mice, and meadow moles. The use of these terms can cause confusion when identifying rodents. It is important to correctly identify small mammals before starting control activities since materials and methods that are effective against one species may not be useful on another (Fig. 21-9).



Voles (4 to 6 inches in length), often confused with house mice, are rodents with relatively large black eyes, small ears, a blunt face, and prominent orange front teeth for gnawing. Meadow voles, the most common voles in Pennsylvania, are herbivores and eat a variety of grasses, seeds, and roots.

Shrews (3 to 4 inches in length) are insectivores that hunt for insects above the ground and in tunnels made by moles or voles. Shrews are much smaller than moles and mouse-like in appearance with a long, pointed snout, a short dense coat of fur, and small eyes.

Moles (5 to 7 inches in length) are insectivores with small eyes and ear openings that are concealed in fur. Paddle-like forefeet, bent sideways for digging, feature large claws for digging. Mole are specialized for underground life with short, velvety fur that offers no resistance when brushed in either direction, allowing them to travel forward and backward through the soil.

Sue Wyble

Fig. 21-9. Rodents and insectivores.

The meadow vole is most often found in extensive grassy or weedy areas such as old fields and moist hillsides with heavy groundcover. However, stream and pond banks, orchards, pastures, hay fields, and fencerows also provide suitable habitat for meadow and woodland voles. Meadow voles occasionally invade lawns, gardens, and nurseries.

Woodland voles are most abundant in southeastern Pennsylvania, where they are common in old fields, thickets, gardens, orchards, and the edges of agricultural land, particularly where the soil is loose and sandy.

Voles eat a wide variety of plants, most frequently grasses and forbs (herbaceous flowering plants). In late summer and fall, they store seeds, tubers, bulbs, and rhizomes. They eat bark at times, primarily in the fall and winter, and will also eat grain crops, especially when their populations are high. Occasional food items include snails, insects, and animal remains. Voles are active during the day and night, year-round, with peak activity occurring at dawn and dusk. They do not hibernate.

Voles are semi-fossorial and, as such, construct many tunnels and surface runways with numerous burrow entrances. A single burrow system may contain several adults and young. Vole nests are globular structures of dry grass that are about 6 to 8 inches in diameter. Nest cavities are usually located on the surface of the ground or under old boards, discarded metal, logs, or other such cover. In winter, aboveground nests may be made in deep snow, but these are temporary and will be vacated when the snow melts.

Voles may breed throughout the year, most commonly in the spring and summer. In general, they have 1 to 5 litters per year. Litter sizes range from 1 to 11 young and average 3 to 6 young. The gestation period is about 21 days. Young are weaned by the time they are 21 days old, and females are sexually mature in 35 to 40 days. Voles have short life spans that generally range from 2 to 16 months.

Damage

Voles may cause extensive damage to orchards, ornamentals, and tree plantings by gnawing on the bark of seedlings and mature trees (girdling). They eat crops outright and also cause damage by building extensive runway and tunnel systems through crop fields. Underground, woodland voles may consume small roots, girdle large roots, and eat bark from the bases of trees. After the snow has melted in early spring, the runway systems of meadow voles can also create unsightly areas in lawns, golf courses, and groundcovers. However, this is usually only a temporary problem.

The most easily identifiable sign of meadow voles is an extensive surface runway system with numerous burrow openings. Voles keep these runways free of obstructions, and vegetation near well-traveled runways may be clipped close to the ground. Overhanging vegetation provides cover as they travel along runways. Such travel lanes are about 1½ inches wide and serve as reliable indicators of meadow vole activity. Woodland voles do not use surface runways; instead, they build extensive systems of underground tunnels. As they build tunnels, they push out dirt, producing small, conical piles of soil on the ground surface—an indicator of woodland vole activity.

Bits of freshly cut vegetation and accumulations of vole droppings (brown or green in color and shaped like rice grains) in surface runways are positive evidence that the runways are being used. Vegetation, small roots, or mold in the paths indicate that voles no longer use them. Meadow voles may also build and use underground tunnels, and they will often use underground tunnels made by moles or woodland voles.

Homeowners often notice meadow vole damage in the spring when melting snow reveals the crisscross network of runways voles used to travel under the snow. Under the cover of snow, meadow voles may travel safely into areas they would not normally venture, such as open lawns or grassy areas. The voles usually leave with the melting snow, and the lawn quickly recovers.

Glossary

A

Abiotic: nonliving entities that can affect an ecosystem. These entities do not grow, reproduce, or spread from plant to plant.

Abscisic acid: a plant hormone that promotes leaf detachment, induces seed and bud dormancy, and inhibits germination.

Abscission: the natural detachment of plant parts, typically dead leaves and ripe fruit.

Acaricide: pesticide that controls mites, ticks, and spiders.

Acclimatization: the process of adapting to new environmental conditions (e.g., reducing or increasing the amount of light levels that a plant is exposed to in order to avoid shocking the plant).

Acidic: containing or having the properties of an acid with a pH below 7.0.

Active ingredient: a substance in a pesticide that is biologically active.

Adjuvants: any substance added to the spray tank to modify a pesticide's performance, the physical properties of the spray, or both.

Adsorption: the adhesion of ions, atoms, or molecules from a gas or liquid to a surface.

Adventitious: plant structures, such as buds, shoots, or roots, developing from an unusual position (i.e., other than from a terminal or axillary position).

Aeration: a method for removing plugs of soil in the turf, creating a system of large pores to increase permeability of water and air.

Aerobic: living or occurring in the presence of free oxygen.

Aerosols: low-concentrate solutions that are usually applied as a fine spray or mist.

Aggregate (soil): mass of soil particles, such as a clod, crumb, block, or prism.

Aggregate fruit: develops from a single flower that had several ovaries (e.g., raspberry).

Alien: with respect to a particular ecosystem, any species that is not native to that ecosystem; alien species may or may not be invasive; also called nonnative or exotic.

Alkaline: containing or having the properties of an alkali with a pH above 7.0.

Allelopathy: a biological modification of the environment to enhance the survival and reproduction of the plant modifying the soil while interfering with the success of neighboring plants.

Amendment: any material added to soil that improves its physical or chemical condition.

Ametabolous: no metamorphosis.

Anaerobic: living or occurring in the absence of free oxygen.

Andromonoecious: having perfect and staminate flowers on the same plant.

Angiosperms: a flowering plant whose seeds are enclosed within an ovary (fruit).

Annual: plant that lives for only one growing season, during which time it grows, flowers, and produces seed, and dies.

Anther: the pollen-producing tip of the male reproductive organ (stamen).

Anvil pruner: pruner with a top cutting blade that presses against a bottom, noncutting, flat blade, resulting in some crushing of living plant tissue; best suited for dead plant material.

Apical dominance: the influence exerted by a terminal bud in suppressing the growth of lateral buds.

Apical (terminal) bud: a bud located at the apex of a stem that exerts a strong chemical control over the lateral buds lower on the stem.

Artificial classification: classification of plants that is based on habitat, flower color, or growth pattern.

Asexual (vegetative) propagation: production of a new plant by using a part of a parent plant via budding, grafting, cuttings, or division. Reproduction of a plant without the use of a seed.

Auxin: a hormone created in the terminal bud that flows down the stem and suppresses the growth of other buds and keeps them dormant.

Avicide: chemical for controlling pest birds.

Axil: the angle formed between a leaf stalk and the stem to which it is attached. In flowering plants, buds develop in the axils of leaves.

Axillary bud: an embryonic shoot that lies at the junction of the stem and petiole of a plant; most lateral buds arise in the axis of a leaf.

B

Bacterium: a single-celled, microscopic organism having a cell wall but no chlorophyll; reproduces by cell division.

Baits: a formulation made by adding the active ingredient to an edible or attractive substance; often used to control slugs, snails, or small ground insects and rodents.

Band: application of fertilizer or pesticide to a strip over or along each crop row.

Bark: outermost tissue of a woody stem that usually includes phloem and xylem.

Berry: a simple fruit that is derived from one flower and contains one ovary.

Biennial: a flowering plant that takes two years to complete its biological life cycle; vegetative growth develops the first year; flowering and fruiting occur in the second year.

Binomial system of nomenclature: classification system developed by Carl Linnaeus in which the scientific name for an organism is composed of two Latin terms that designate the genus and specific epithet.

Bioaccumulate: the gradual building up of pesticide residue in the bodies of animals and humans.

Biological control: involves the use of a living organism (insects, beneficial nematodes, or pathogens) to reduce insect populations.

Biotic disease: caused by living entities such as a bacterium, fungus, mycoplasma, or virus, and can spread easily from one plant to another.

Black water: any water that is run through the toilet.

Blade: the expanded, thin structure on either side of the midrib of a leaf; usually the largest and most conspicuous leaf part.

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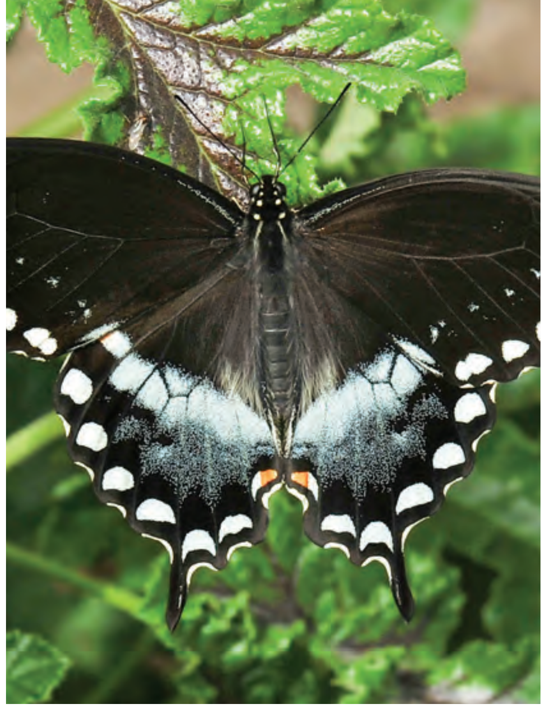


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