The Kentucky Extension Master Gardener Program

University of Kentucky
Cooperative Extension
University of Kentucky and Kentucky State University

The Kentucky Extension Master Gardener Program manual (ID-1) is also available as an online publication.

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Cooperative Extension Service

The Kentucky Extension Master Gardener Program

Introduction

The Kentucky Extension Master Gardener Program

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In this chapter:

In the mid-19th century, there was a political movement calling for the creation of agriculture colleges. The movement was led by Jonathan Turner, a professor at Illinois College.

In 1853, the Illinois Legislature adopted a resolution calling for the Illinois congressional delegation to work toward enacting a bill that would create the land-grant system. They thought a congressman from the eastern part of the country would have better luck getting this type of legislation through Congress, so Rep. Justin Smith Morrill of Vermont was recruited to introduce the bill.

Unlike the original proposal, the Morrill bill allocated land based on the number of senators and representatives each state had in Congress. Under the act each eligible state would receive 30,000 acres of federal land—either within or contiguous to its boundaries—for each member of Congress the state had according to the census of 1860. The land was to provide a financial base for the funding of these schools.

The original bill passed in 1859, but was vetoed by President James Buchanan. In 1861, the bill was resubmitted with an amendment that included military tactics as well as engineering and agriculture. Many of the Southern states did not support this type of legislation, but because they began to secede from the United States, the bill was passed and signed into law by President Abraham Lincoln in July of 1862. The Southern states that seceded were not given access to the federal land.

The purpose of the land-grant colleges was, "without excluding other scientific and classical studies and including military tactic, to teach such branches of learning as are related to agriculture and the mechanic arts, in such manner as the legislatures of the States may respectively prescribe, in order to promote the liberal and practical education of the industrial classes in the several pursuits and profession in life."

After the Civil War, this land-grant opportunity was extended to the former Confederate states and to states created after 1862. If a state did not have enough federal land to meet the requirement for funding, the state was issued "script," which meant that the state could select federal lands in other states to create funding for these schools.

The Morrill Act of 1862 authorized "separate but equal" facilities for African-Americans. Mississippi and Kentucky were the only two states to provide this type of education. The proposed second Morrill Act was aimed at the former Confederate states. It required each state to show proof that race was not a requirement for admission or to create a separate land-grant institution that would admit African-Americans. This bill was passed in 1890. Although cash was granted for these institutions instead of land, they have the same legal standing as the 1862 land-grant schools. Sixteen African-American land-grant colleges were established throughout the South and are known as 1890 land-grant institutions. In Kentucky, the University of Kentucky is the 1862 land-grant school and Kentucky State University is the 1890 land-grant school.

Congress soon realized that to be effective, the educational function of land-grant universities must be supplemented with research capability. Consequently, it passed the Hatch Act in 1887. This act provided for the establishment of facilities where colleges could conduct research into agricultural, mechanical, and related problems faced by rural citizenry. Congress also saw a need to disseminate the knowledge gained at the land-grant colleges to the general public, farmers and homemakers being the initial focus.

The Start of Extension

Extension had its beginnings in the movement to improve agricultural production. Seaman Knapp's successful use of the demonstration method on Louisiana farms in the fight against the cotton boll weevil served as the model for legislation. The Cooperative Extension Service was created by the federal government in 1914 by the passage of the Smith-Lever Act. Section 2 of that Act, which was in effect as of June 23, 1972 (U.S.C. 341 et seq.), says:

"Cooperative Agricultural Extension work shall consist of the giving of instruction and practical demonstrations in agriculture and home economics and subjects relating thereto to persons not

attending or resident in said colleges in the several communities, and imparting information on said subjects through demonstrations, publications, and otherwise and for the necessary printing and distribution of information in connection with the foregoing, and this work shall be carried on in such manner as may be mutually agreed upon by the Secretary of Agriculture and the State agricultural college or colleges or Territory or possession receiving the benefits of this Act."

The 1940s and 1950s began a period of rapid technological advancement in American agriculture. Farmers improved their competitive position primarily through the adoption of improved management practices, the expansion of their resource base, and increased efficiency. This led to production surpluses and a heavy reliance upon agricultural production in international trade and development assistance. With an abundance of reasonably priced food supply pretty much assured, national attention, and to some extent the concern of Extension, in the 1960s shifted to the problems of urban, low-income, and minority residents.

At the same time, there was a substantial reduction in the size of the farm and rural population. In 1910, approximately 35 percent of the U.S. population were classified as farmers, and until 1940, almost one-quarter of the population were farmers. Since that time, the farm population has declined to less than three percent of the population. A similar decline occurred in the rural portion of the population. At the turn of the century, more than 50 percent of the nation's population lived in a location defined as rural. In 1980, less than 30 percent did. As these rural and farm residents relocated in metropolitan centers, they carried with them an awareness of what Extension did for them in rural areas, setting the stage for an urban clientele.

The Cooperative Extension Service takes information generated by research scientists and presents it to the public in layman's terms. This concept is called technology transfer and it is what Cooperative Extension is all about—providing up-to-date, unbiased, scientifically based information to the public in a manner they can understand.

How does the system work?

The Cooperative Extension Service is a partnership between the United States Department of Agriculture (USDA), State Cooperative Extension Services, land-grant universities, 1890 institutions and county government. Funding for Cooperative Extension Service is provided by federal, state, and local governments. Policy considerations, program development and program emphasis are developed through cooperative efforts. In fact, the Extension Service is very much a grass-roots organization, often focused on local issues.

The components of Cooperative Extension include organizations and personnel at the federal, state and local levels.

Federal

- United States Department of Agriculture
- Secretary of Agriculture

At the federal level, agencies support Cooperative Extension through research grants and cooperate in setting policy and focusing issues to guide its mission.

State

Land-Grant Institutions

University of Kentucky—University supervises the Extension program throughout the state.

1890 Institutions

Kentucky State University—Extension efforts are focused on the urban environment and small farms.

State Extension Specialists

Extension specialists exist from most academic disciplines, including agricultural economics, communications, biosystems and agricultural engineering, plant and soil sciences, animal and food sciences, entomology, forestry, 4-H youth development, human environmental sciences, horticulture, plant pathology, community and leadership development, and rural and economic development. Within the Department of Horticulture, there are state specialists or Extension associates for youth programming, consumer horticulture, woody plants, fruits, greenhouse crops, vegetables, annuals, and perennial flowers. Specialists take research information and provide it to county agents, growers, consumers, youth, policy makers, and other clients.

Local

County Agents

The county staff (usually agriculture and natural resources, family and consumer sciences, 4-H youth development agents, and in some cases, horticulture agents with support staff) develop their own programs and, when necessary, rely on state specialists to provide them with specific content information for their educational programming needs. A local Extension council is formed for each county. These councils are made up of local citizens who determine program priorities. They then support the county staff in their efforts to deliver relevant, high-quality programs to people of the county.

Volunteers

For strategic planning to be successful and for there to be a unified approach to societal concerns or issues, volunteers serving on planning and advisory councils help to focus programming on the needs of traditional and new clients and concentrate resources in a few areas of major concern. When there is adequate volunteer commitment and support, large numbers of impactful programs can be supported by a small team of Extension agents. This is where volunteers such as Extension Master Gardeners can serve a critical role in extending Extension programming to a wider audience.

Program Planning

The Secretary of Agriculture has delegated responsibility for program planning to the Extension staff within the Department of Agriculture. General boundaries of programs that were expected over the past 20 years have been periodically defined by "scope" reports developed by a committee established by the USDA Extension administrator and directors of Extension. Such reports usually are published every 10 years or so. They provide historical evidence of how policy changes relate to what is appropriate for federal funding under the Smith-Lever Act.

The law also requires that "before the funds herein provided shall become available to any college for any fiscal year, plans for the work to be carried on under this Act shall be submitted by the proper officials of each college and approved by the Secretary of Agriculture."

Each state must provide one statewide plan with various specific research and program directives, and those plans must be agreed to by the USDA Extension Service before a state can receive federal funding.

Idea Sources for Programs

Three main sources of Extension programs have emerged.

Research/academic disciplines—The campus department and the USDA research branch were historically a main source of what would be emphasized in the Extension programs. Early specialists were guided by what departments viewed as important information for farm families. In the 1930s and 1940s, for example, there was considerable concentration across the United States in introducing farmers to hybrid seed corn and in improved seed/cuttings for other crops that were developed through Experiment Station Research.

The first state plans of work were primarily developed within departments based upon the best judgment of the research, resident, and instruction faculty as to what areas should be emphasized.

Researchers and administrators at land-grant universities and the USDA have continued to view disseminating research findings and encouraging their use as a main role of the Extension system.

Grass-roots planning—However, as the Extension service moved to county locations, leaders became much more aware of the vast differences among counties across the country and even within a given state. The people in some counties were much farther ahead in relation to knowing and following recommended practices. Some were much farther behind. Before the advent of television, communities and counties were fairly isolated. As the academic field of adult education developed in the 1940s and 1950s, one of the cardinal principles was that education was much more likely to be successful if programs were based upon needs.

In many states, during the 1950s and 1960s emphasis was placed on each county Extension Service developing an individual county plan—in consultation with local people—based on identifying the greatest needs.

State plans of work often were a composite of individual county plans. Campus departments assisted counties by providing information to Extension agents and leaders about areas where they saw developing needs. USDA held annual Outlook Conferences that briefed state staff on emerging problems and economic changes. But the county plan was sacrosanct in many states. Each county, in consultation with local people, established what Extension agents in that county would focus upon for the next year.

Community development became an important fourth program area with Extension Services in Kentucky and several other states, adding county positions or encouraging other agents to increase programming in such areas.

Because needs among clientele differ, Extension programs at the local level have become more diverse. In Kentucky, projects available to 4-H members went from about 20 projects focused on farming and homemaking to more than 250 that included any area that would help a young person learn and develop life skills.

With the help of media and volunteers, county Extension agents and state Extension specialists stretched their resources to cover a multitude of subjects each year. Although several states encouraged agents to focus on at least one intensive project that concentrated resources on a specific area for several months, most agents preferred to take the cumulative route. They found themselves acting as generalists, responding to a host of local questions and needs. They preferred to cover all areas a little bit each year with the expectation that over a five- or six-year period substantial practice changes would occur in all areas.

Societal Needs—Societal needs have always been present as one source of programming but have not always been recognized as a dominant influence. Research often has been stimulated by major social problems, such as scarcity of food or the need to conserve soil. Grass-roots planning often yielded programs that not only met individual needs of clients but were directed toward common needs that were held by a larger group. Many counties were fortunate enough to have wise leaders who could influence others on planning committees to see beyond their own immediate needs and to encourage programs like land-use planning and zoning.

Thus, over the years, Extension programs carried on in any county or state have been influenced to different degrees by research, individual client needs, and the needs of society.

Current Conditions

Two major factors affect the nature of Extension programs and the way those programs are decided.

- Rural families not only make up a smaller percentage of the U.S. population, but because a greater share of the nation's

food supply comes from other countries, the broader population is no longer dependent upon the American farmer. Rather than dominating American society, as was the case when Extension was started in 1914, farmers and rural communities have become a small minority struggling to maintain programs established by Congress and state legislatures.
- The pool of tax dollars has diminished at national, state, and local levels; and competition for those dollars is vastly increased.

There is continuing pressure on Extension to:
- Show that its programs are important to American society as a whole and benefit people beyond its direct clientele
- Show substantial impact from money invested
- Show substantial efforts on major problem areas nationwide

For example, water purity is of keen importance to all Americans. Our health and safety from major illness and disease depend upon the quality of water. The agricultural industry (farming, processing, and packaging) is one source of pollutants. Because of Extension's direct focus on farming, the Cooperative Extension Service puts considerable emphasis on those practices that increase the purity of water. Extension administrators are encouraging counties and states to concentrate some of their programming resources on water quality and other areas that are of major concern to society in general.

Cooperative Extension is constantly challenged to be a dynamic educational organization. This challenge forces Extension to be contemporary, progressive, and visionary.

What Can You Do for the Cooperative Extension Service?

Volunteer workers are one of the most important and unique aspects of the Cooperative Extension Service. This is in keeping with Extension's philosophy that active citizen participation in planning and implementation insures program success. As an Extension Master Gardener, you will join this family of volunteers.

The Extension Master Gardener Program

The Extension Master Gardener Program was created to meet an increase in requests from home gardeners for horticultural information. This increase derives primarily from the urban and transient nature of modern American life. Fifty years ago, an Extension agent dealt with the questions of a few hundred farm families. In many regions, however, land that once constituted a single farm now encompasses several subdivisions, increasing the number of families an Extension office must serve. In addition, many of these families are unfamiliar with the grasses, shrubs, trees, and diseases that comprise the microenvironment of their new home. They often will call their local Extension office for advice on what to plant and how to care for it.

Consequently, the Extension Master Gardener Program was created in 1973 in the state of Washington. Since then it has spread nationwide. Master Gardeners have become a vital part of Extension's ability to provide consumers with up-to-date, reliable knowledge so they can enjoy and protect the plantings around their homes. Master Gardening also has become a fun and useful volunteer activity that has given its participants a sense of community spirit, accomplishment, and intellectual stimulation.

Today, nearly 100,000 Extension Master Gardener volunteers are active in all 50 states and the District of Columbia. These programs seek to engage diverse audiences both as volunteers and through outreach efforts. Local agents, advisory councils and volunteer leaders are committed to offering programs that serve all people regardless of race, color, age, sex, religion, disability, or national origin.

Your Responsibility as an Extension Master Gardener

When you enter the Extension Master Gardener Program, you are entering into a contract. In essence, you agree that in return for the training you receive, you will volunteer a predetermined number of hours back to Extension. Failure to complete this obligation means you are not entitled to wear a Master Gardener badge, nor participate in Master Gardener activities.

Upon completion of your training, you have one year to complete the agreed-upon volunteer service commitment, also called payback time. This time requirement varies from one Extension unit to another.

After you complete your payback time, you may choose to continue with the Extension Master Gardener Program. Numerous people have worked as Master Gardeners for years and contributed substantial amounts of time to Extension. To be considered an active Master Gardener, however, you must agree to volunteer a minimum number of hours annually. In Kentucky the current requirement for new trainees is 40 hours of volunteer service to obtain their initial certification as a Master Gardener. To renew certification, Master Gardener volunteers must complete 20 hours of volunteer service and 10 hours of continuing education credit each year. The county agent in charge of the local program determines what activities count toward volunteer service and continuing education credits.

Report Volunteer Time—Time sheets were historically used to keep track of the hours of time you volunteer as a Master Gardener and some programs continue to use this method. Some programs may appoint a Master Gardener to keep track of this information. Other programs use on-line methods of reporting volunteer hours. Whatever the method of reporting your time, don't be lax; the reported hours are used in county progress reports, and you deserve recognition for your efforts.

Use of the Title "Extension Master Gardener"—The title "Extension Master Gardener" should be used only by individuals trained in a Cooperative Extension Service program. The title is valid only when used by an active Extension Master Gardener who is participating in a program approved by an Extension agent. When an individual ceases to be active in the Extension Master Gardener program, their designation as an Extension Master Gardener ceases.

Extension Master Gardeners should not display credentials or give the appearance of being an Extension Master Gardener at a place of business unless that place is designated by the county office as a place where an Extension educational program is taking place. The title "Extension Master Gardener" should not be used in a manner which implies Cooperative Extension Service endorsement of any product or place of business.

The title "Extension Master Gardener" should be used only when doing unpaid volunteer work for Extension. When experienced Extension Master Gardeners speak before groups on horticultural subjects, they may accept unsolicited reimbursements (such as reimbursements for expenses) or gifts. It is inappropriate, however, to seek speaking engagements for pay while participating in an authorized Extension activity and using the title "Extension Master Gardener."

A Word of Caution—When you work as an Extension Master Gardener, you are acting as a representative of the Cooperative Extension Service. While Master Gardeners are covered by Extension's liability insurance when performing their volunteer duties in regard to sharing horticultural information, the Master Gardener needs to be concerned that any information given to the general public should be factual and based on Cooperative Extension recommendations. Do not be afraid to say, "I do not know the answer to that question."

One particular area of concern is pesticide recommendations. Master Gardeners know that the use of chemicals in the garden is usually a last resort. Under the amended Federal Insecticide, Fungicide, and Rodenticide Act (Federal Environmental Control Act of 1972), it is illegal to use a pesticide on a crop unless the crop is listed on the label. The given rate of application on the label may not be exceeded. Fines and other penalties vary according to the laws broken. Please refer all pesticide questions to the county agent unless you have been specifically told by the county agent that a certain recommendation can be made.

Master Gardener Curriculum

The focus of local Extension programs can be diverse. As such, the Extension Master Gardener training program must maintain some flexibility and allow the county agent to determine where emphasis should be placed. Although flexibility is desirable, it has been determined that all Master Gardener candidates must complete a minimum of training in certain core subjects (Table 1).

In addition to the core requirement material, the agent will require additional hours of training to address specific subjects such as propagation, woody plant material, or vegetables. The additional training hours and subject matter will be determined by the agent's program and need for volunteer assistance.

Upon completion of the training program, a candidate must pass a written final examination before they can be designated a Master Gardener. The final exam will consist of 100 total points possible. Seventy-five percent of the possible points will come from questions on material covered in the core curriculum. The remaining 25 percent of the points will come from questions developed by the county agent and based on material covered in the additional training.

After the candidate has passed the written exam, they will receive a Kentucky Extension Master Gardener certificate and a Master Gardener name badge. They also will be asked to choose which volunteer activities they would like to perform in order to fulfill their commitment to the Master Gardener program. Volunteer activities often include unsupervised work with vulnerable audiences, and background checks are required prior to commencing training.

Transfer of Certification from Other States

Master Gardener certification from other states will be honored at the discretion of the county agent in charge of the program. The agent may accept the transfer of certification outright or may require the Master Gardener to participate in one or more of the Master Gardener training sessions that may contain information of a state-specific nature. Kentucky certification will be granted once the Master Gardener has completed any needed training and performed 20 hours of volunteer service.

What Does a Master Gardener Do?

The local Extension agent will supply the Master Gardeners with a list of volunteer job descriptions (see the Sample Job Description). These jobs will be focused on the needs of that particular agent as well as the needs of the county. No volunteer will be asked to participate in an activity they do not feel comfortable doing or are not physically able to do. The variety of jobs available should enable any volunteer to find an area in which to perform their payback time.

Table 1. Master Gardener Training

Core Subjects	Number of Hours Training Required
Cooperative Extension/ Volunteerism	2 hours
Botany	6 hours with lab
Soils and Fertility	4 hours with lab
Plant Pathology	4 hours with lab
Entomology	4 hours with lab
Pesticides/Pesticide Safety/ Environmental Issues	4 hours
Total	**24 core hours of training**

Sample Job Description*

Job Title: Senior Citizen Community Garden

Volunteers Needed: Two

Major Objectives: To be event coordinator for the operation of the community garden

Responsibilities:
- Arrange weekly garden work sessions and assist members in running the sessions
- Help plan garden meetings, programs and events
- Help procure supplies and plant material for the garden
- Coordinate the planting and maintenance of the garden
- Generate publicity for garden activities

Training:
- One two-hour training
- Update meetings as necessary

Time Involved:
- Day time meetings
- Approximately 8 hours per month including meetings, garden visits and preparation
- 64 hours per volunteer

Length of Commitment: 8 months

Program Contact: County Agent

** This job in no way implies employment with the University.*

The Extension agent is responsible for providing a number of job possibilities that can utilize the talents and expertise of the Master Gardener. In recent years, creative Master Gardeners and Extension agents have recognized that talents which citizens bring to the Master Gardener program can be utilized in a variety of horticultural activities. Sometimes it just takes a suggestion to create a new area of Master Gardener activity. Don't be afraid to make suggestions.

Can a Volunteer be Fired?

Well, maybe reassigned would be a better term. For example, a particular Master Gardener may agree to fill the job as a tour guide for a demonstration garden. The tours are supposed to be conducted at 2:00 p.m. on Tuesdays and Thursdays. The particular Master Gardener turns out to be one of those people who always is running 15 minutes behind schedule. It is then the Extension agent's responsibility to discuss the matter with the Master Gardener and if necessary reassign the Master Gardener to a job that does not have such time constraints.

Expectations for Extension Master Gardener Volunteers

Kentucky residents place trust in the Kentucky Cooperative Extension Service to provide quality leadership and reliable, unbiased information. The opportunity to represent the Kentucky Cooperative Extension Service is a privileged position of trust that should be held only by those who are willing to demonstrate behaviors that fulfill this trust.

The primary purpose of these expectations for volunteers is to ensure the safety and well-being of all participants. Kentucky Cooperative Extension Service volunteers are expected to function within the guidelines of the Kentucky Cooperative Extension Service and its various organizations.

The following statements relate to the role of a volunteer with the Kentucky Cooperative Extension Service:

- I will represent the Kentucky Cooperative Extension Service by conducting myself with courteous manners and language, serving as a positive role model, and demonstrating reasonable conflict-resolution skills.
- I will abide by all applicable laws and Cooperative Extension Service rules, policies, and guidelines. This includes, but is not limited to, child abuse, fiscal management procedures, and substance abuse.
- I will accept supervision and support from salaried Extension staff or designated management volunteers.
- I will make all reasonable efforts to ensure that programs are accessible to all individuals regardless of race, color, age, sex, religion, disability, or national origin.
- I will participate in orientation and training related to the Extension Master Gardener Program, sponsored by the Kentucky Cooperative Extension Service.
- I will not consume or allow others to use alcohol or illegal drugs while involved in any Kentucky Cooperative Extension Service-sponsored program.
- I will, when engaged in Kentucky Cooperative Extension Service activities, operate motor vehicles and other equipment in a safe and reliable manner and only with a valid operator's license. I will comply with all motor vehicle-related state regulations and laws, including those regulating the proper use of seat belts for adults and youth.
- I will accept the responsibility to promote and support the vision, mission, and values of the Kentucky Cooperative Extension Service.
- I will conduct myself in a manner that is in the best interest of the Kentucky Cooperative Extension Service and will not use the volunteer position for purposes of private or personal gain.
- I will use technology in an appropriate manner that reflects the best practice in volunteer service to the Kentucky Cooperative Extension Service.

These expectations represent a contractual agreement between volunteers and the Kentucky Cooperative Extension Service. By continuing with the Master Gardener training and becoming a certified Kentucky Extension Master Gardener, you agree to adhere to these expectations.

Chapter 01

Basic Botany

By Ann Marie VanDerZanden, former Extension Master Gardener state coordinator, Oregon State University. Adapted for Kentucky by Richard Durham, consumer horticulture Extension specialist and state Master Gardener coordinator, University of Kentucky.

In this chapter:

Plants are essential to life on earth. Either directly or indirectly, they are the primary food source for humans and other animals. Additionally, they provide fuel, replenish the earth's oxygen supply, prevent soil erosion, slow down wind movement, cool the atmosphere, provide wildlife habitat, supply medicinal compounds, and beautify our surroundings.

Many plants are familiar to us, and we can identify and appreciate them based on their external structure. However, their internal structure and function often are overlooked. Understanding how plants grow and develop helps us capitalize on their usefulness and make them part of our everyday lives.

This chapter focuses on *vascular* plants—those that contain water-, nutrient-, and food-conducting tissues called "xylem" and "phloem." Ferns and seed-producing plants fall into this category.

In several cases, we will distinguish between *monocotyledonous* and *dicotyledonous* plants. Sometimes called "monocots" and "dicots" for short, these plants have several important distinguishing characteristics. For example, monocots (e.g., grasses) produce only one seed leaf, while dicots (broadleaf plants) have two. The vascular systems, flowers, and leaves of the two types of plants also differ (Table 1.1). These differences will be important in our discussion of plant growth and development.

Plant Life Cycles

Based on its life cycle, a plant is classified as either an annual, biennial, or perennial.

An *annual,* such as a zinnia, completes its life cycle in one year. Annuals are said to go from seed to seed in one year or growing season. During this period, they germinate, grow, mature, bloom, produce seeds, and die. Summer annuals complete their life cycle during spring and summer; most winter annuals complete their growing season during fall and winter. There are both winter and summer annual weeds, and understanding a weed's life cycle is important to controlling it.

A *biennial* requires all or part of two growing seasons to complete its life cycle. During the first season, it produces vegetative structures (leaves) and food storage organs. The plant overwinters and then produces flowers, fruit, and seeds during its second season. Swiss chard, carrots, beets, sweet William, and parsley are examples of biennials.

Sometimes biennials go from seed germination to seed production in only one growing season. This situation occurs when extreme environmental conditions, such as drought or temperature variation, cause the plant to pass rapidly through the equivalent of two growing seasons. This phenomenon is referred to as *bolting.* Sometimes bolting occurs when biennial plant starts are exposed to a cold spell before being planted in the garden.

Perennial plants live more than two years and are grouped into two categories: herbaceous perennials and woody perennials. *Herbaceous perennials* have soft, nonwoody stems that

Table 1.1. Comparison of monocots and dicots.

Structure	Monocots	Dicots
Seed leaves (cotyledons)	one	two
Vascular system	Xylem and phloem are paired in bundles, which are dispersed throughout the stem.	Xylem and phloem form rings inside the stem. The phloem forms an outer ring, the xylem an inner ring. In long-lived woody perennials, yearly concentric rings are produced.
Floral parts	Usually in threes or multiples of three.	Usually in multiples of four or five.
Leaves	Often parallel-veined.	Generally net-veined.

generally die back to the ground each winter. New stems grow from the plant's crown each spring. Trees and shrubs, on the other hand, have woody stems that withstand cold winter temperatures. They are referred to as *woody perennials*.

Internal Plant Parts

Cells are the basic structural and physiological units of plants. Most plant reactions (cell division, photosynthesis, respiration, etc.) occur at the cellular level. Plant *tissues* (meristems, xylem, phloem, etc.) are large, organized groups of similar cells that work together to perform a specific function.

A unique feature of plant cells is that they are readily *totipotent*. In other words, almost all plant cells retain all of the genetic information (encoded in DNA) necessary to develop into a complete plant. This characteristic is the main reason that vegetative (asexual) reproduction works. E.g., the cells of a small leaf cutting from an African violet have all of the genetic information necessary to generate a root system, stems, more leaves, and ultimately flowers.

Specialized groups of cells called *meristems* are a plant's growing points. Meristems are the site of rapid, almost continuous cell division. These cells either continue to divide or begin to differentiate into other tissues and organs. How they divide and whether they ultimately become a tissue or an organ are controlled by a complex array of internal plant hormones but also can be influenced by environmental conditions. In many cases, you can manipulate meristems to make a plant do something you want, such as change its growth pattern, flower, alter its branching habit, or produce vegetative growth.

External Plant Parts

External plant structures such as leaves, stems, roots, flowers, fruits, and seeds are known as plant *organs*. Each organ is an organized group of tissues that work together to perform a specific function. These structures can be divided into two groups: sexual (reproductive) and vegetative. *Sexual* or *reproductive* parts produce seed; they include flower buds, flowers, fruit, and seeds. *Vegetative* parts (Figure 1.1) include roots, stems, shoot buds, and leaves; they are not directly involved in sexual reproduction. Vegetative parts often are used in asexual forms of reproduction such as cuttings, budding, or grafting.

Roots

Often roots are overlooked, probably because they are less visible than the rest of the plant. However, it's important to understand plant root systems because they have a pronounced effect on a plant's size and vigor, method of propagation, adaptation to soil types, and response to cultural practices and irrigation.

Botany Terminology

Anther—The pollen sac on a male flower.

Apex—The tip of a shoot or root.

Apical dominance—The tendency of an apical bud to produce hormones that suppress growth of buds below it on the stem.

Axil—The location where a leaf joins a stem.

Cambium—A layer of growing tissue (meristem) that separates the xylem and phloem and produces new xylem and phloem cells.

Chlorophyll—The green pigment in leaves that is responsible for capturing light energy from the sun.

Chloroplast—A specialized component (organelle) of certain cells; contains chlorophyll and is responsible for photosynthesis.

Cortex—Cells that make up the primary tissue of the root and stem.

Cotyledon—The first leaf that appears on a seedling. Also called a seed leaf.

Cuticle—A relatively impermeable surface layer on the epidermis of leaves and fruits.

Dicot—Having two cotyledons or seed leaves.

Epidermis—The outermost layer of plant cells.

Guard cell—Epidermal cells that open and close to let water, oxygen, and carbon dioxide pass through the stomata.

Internode—The space between nodes on a stem.

Meristem—Specialized groups of cells that undergo cell division and are a plant's growing points.

Mesophyll—A leaf's inner tissue, located between the upper and lower epidermis; contains the chloroplasts and other specialized cellular parts (organelles).

Monocot—Having one cotyledon or seed leaf.

Node—An area on a stem where a leaf, stem, or flower bud is located.

Ovary—The part of a female flower where eggs are located. Also, the base of the pistil.

Petiole—The stalk that attaches a leaf to a stem.

Phloem—Photosynthate-conducting tissue.

Photosynthate—A food product (sugar or starch) created through photosynthesis.

Photosynthesis—The process in green plants of converting carbon dioxide and water into food (sugars and starches) using energy from sunlight.

Pistil—The female flower part; consists of a stigma, style, and ovary.

Respiration—The process of converting sugars and starches into energy.

Stamen—The male flower part; consists of an anther and a supporting filament.

Stigma—The top of a female flower (pistil) part; collects pollen.

Stoma (pl. stomates, stomata)—Tiny openings in the epidermis that allow water, oxygen, and carbon dioxide to pass into and out of a plant.

Style—The part of the female flower (pistil) that connects the stigma to the ovary. Pollen travels down the style to reach the ovary, where fertilization occurs.

Transpiration—The process of losing water (in the form of vapor) through stomata.

Turgor—Cellular water pressure; responsible for keeping cells firm.

Vascular tissue—Water-, nutrient-, and photosynthate-conducting tissue (xylem and phloem).

Xylem—Water- and nutrient-conducting tissue.

Roots typically originate from the lower portion of a plant or cutting. They have a root cap but lack nodes and never bear leaves or flowers directly. Their principal functions are to absorb nutrients and moisture, anchor the plant in the soil, support the stem, and store food. In some plants, they can be used for propagation.

Structure

Internally, there are three major parts of a root (Figure 1.2):

- The *meristematic zone* is at the tip and produces new cells; it is an area of cell division and growth.
- Behind the meristem is the *zone of elongation*. In this area, cells increase in size through food and water absorption. As they grow, they push the root through the soil.

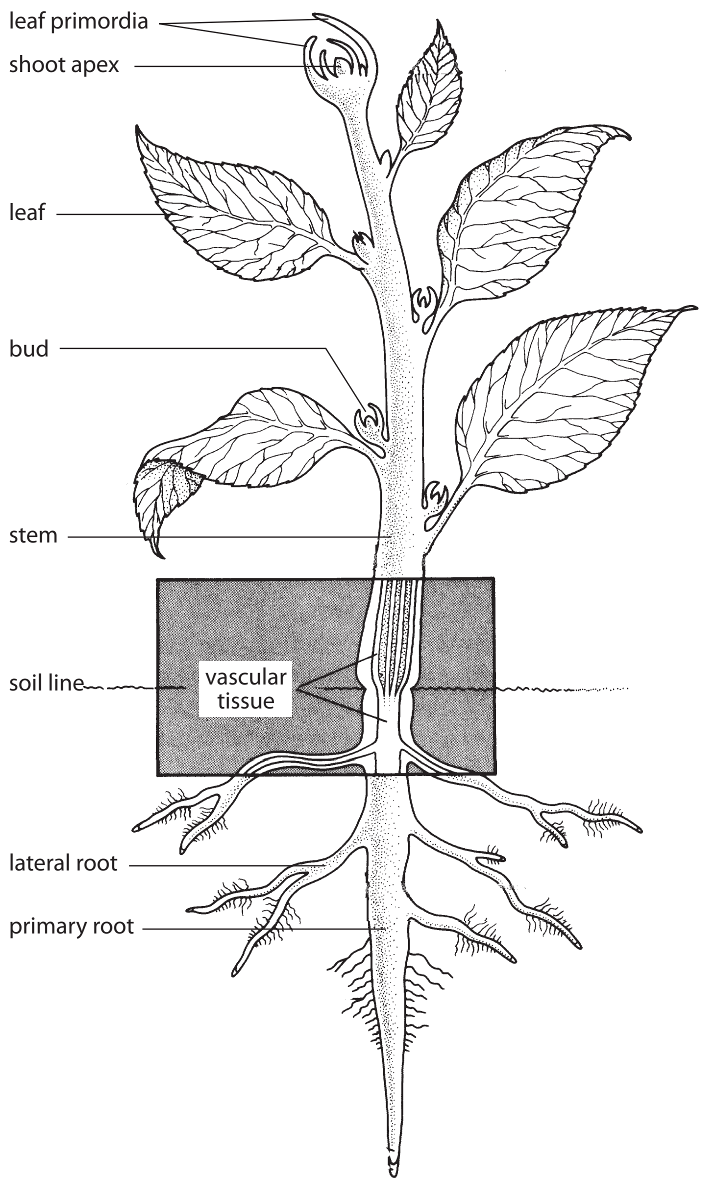


Figure 1.1. Principal parts of a vascular plant. (Adapted with permission from *Plant Physiology,* The Benjamin/Cummings Publishing Company, Inc., 1991.)

- The *zone of maturation* is directly beneath the stem. Here, cells become specific tissues such as epidermis, cortex, or vascular tissue.

A root's *epidermis* is its outermost layer of cells (Figure 1.3). These cells are responsible for absorbing water and minerals dissolved in water. *Cortex* cells are involved in moving water from the epidermis to the *vascular tissue* (xylem and phloem) and in storing food. Vascular tissue is located in the center of the root and conducts food and water.

Externally, there are two areas of importance: the root cap and the root hairs (Figure 1.2). The *root cap* is the root's outermost tip. It consists of cells that are sloughed off as the root grows through the soil. Its function is to protect the root meristem.

Root hairs are delicate, elongated epidermal cells that occur in a small zone just behind the root's growing tip. They generally appear as fine down to the naked eye. Their function is to increase the root's surface area and absorptive capacity. Root hairs usually live one or two days. When a plant is transplanted, they are easily torn off or may dry out.

Many roots have a naturally occurring *symbiotic* (mutually beneficial) relationship with *mycorrhizae* fungi, which improves the plant's ability to absorb water and nutrients.

Types of Roots

There are two major types of roots: primary and lateral roots.

A *primary* root originates at the lower end of a seedling's embryo (Figure 1.2). If the primary root continues to elongate downward, becomes the central feature of the root system, and has limited secondary branching, it is called a *taproot* (Figure 1.4a). Hickory and pecan trees, as well as carrots, have taproots.

A *lateral*, or secondary, root is a side or branch root that arises from another root. If the primary root ceases to elongate, and numerous lateral roots develop, a *fibrous* root system is formed (Figure 1.4b). These lateral roots branch repeatedly to form the network of feeding roots found on most plants.

Some plants, such as grasses, naturally produce a fibrous root system. In other cases, severing a plant's taproot by undercutting it can encourage the plant to produce a fibrous root system. Nurseries use this technique with trees that naturally produce a taproot, because trees with a compact, fibrous root system are transplanted more successfully.

How Roots Grow

During early development, a seedling absorbs nutrients and moisture from the soil around the sprouting seed. A band of fertilizer several inches to each side and slightly below newly planted seeds helps early growth of most row crops.

As a plant becomes well established, the quantity and distribution of its roots strongly influence its ability to absorb moisture and nutrients. For most plants, the majority of the absorbing (feeder) roots are located in the top 12 inches of soil. The soil environment in this region generally is best for root growth, with a good balance of fertility, moisture, and air spaces.

The following factors are important in root growth:

- Roots in water-saturated soil do not grow well and ultimately may die due to lack of oxygen.
- Roots penetrate much deeper in loose, well-drained soil than in heavy, poorly drained soil.
- A dense, compacted soil layer can restrict or terminate root growth.
- Container plants not only have a restricted area for root growth, but they are susceptible to cold damage because the limited amount of soil surrounding their roots may not provide adequate insulation. Dark-colored containers may also absorb solar radiation in summer, and the heat generated may also damage root systems.
- In addition to growing downward, roots grow laterally and often extend well beyond a plant's drip line (edge of foliage or canopy). Keep this extensive root system in mind when disturbing the soil around existing trees and shrubs.

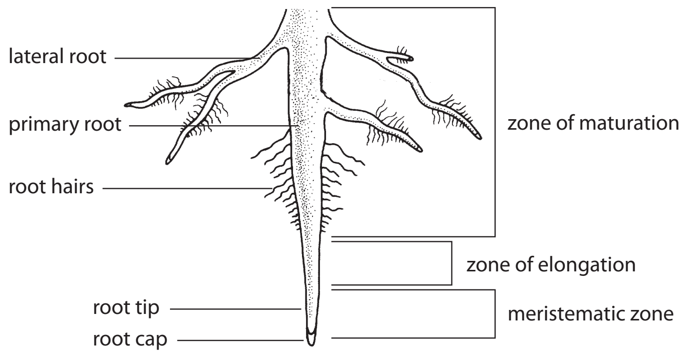


Figure 1.2. Root structure. (Adapted with permission from *Plant Physiology,* The Benjamin/Cummings Publishing Company, Inc., 1991.)

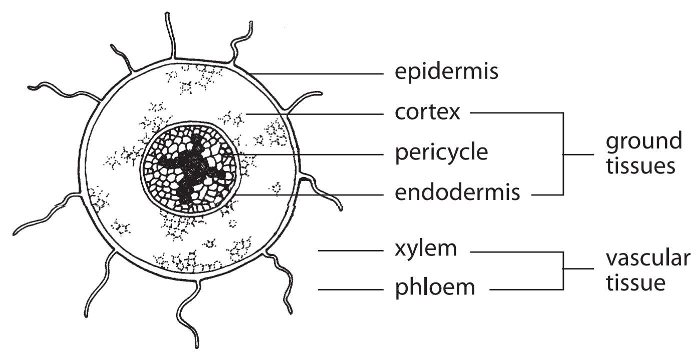


Figure 1.3. Cross section of a root. (Adapted with permission from *Plant Physiology,* The Benjamin/Cummings Publishing Company, Inc., 1991.)

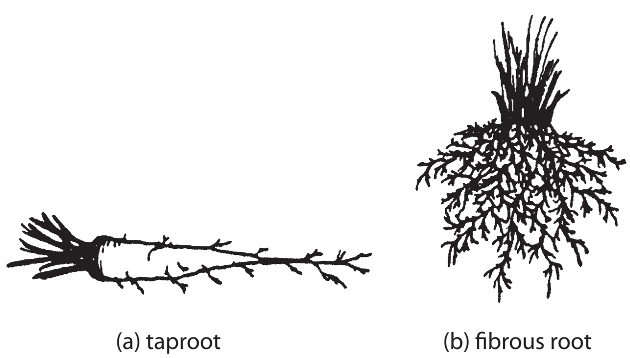


Figure 1.4. Taproot of a carrot (a) and fibrous root of grass (b).

Roots as Food

An enlarged root is the edible portion of several vegetable crops. Sweet potatoes are a swollen tuberous root; and carrots, parsnips, salsify, and radishes are elongated taproots.

Stems

Stems support buds and leaves and serve as conduits for carrying water, minerals, and food (*photosynthates*). The vascular system inside the stem forms a continuous pathway from the root, through the stem, and finally to the leaves. It is through this system that water and food products move.

Structure

Vascular system—This system consists of xylem, phloem, and vascular cambium. It can be thought of as a plant's plumbing. *Xylem* tubes conduct water and dissolved minerals; *phloem* tubes carry food such as sugars. The *cambium* is a layer of meristematic tissue that separates the xylem and phloem and produces new xylem and phloem cells. This new tissue is responsible for a stem's increase in girth.

The vascular cambium is important to gardeners. E.g., the cambial tissues on a grafted scion and rootstock need to line up. In addition, careless weed trimming can strip the bark off a tree, thus injuring the cambium and causing the tree to die.

The vascular systems of monocots and dicots differ (Figure 1.5). Although both contain xylem and phloem, these structures are arranged differently in each. In a monocot, the xylem and phloem are paired in bundles, which are dispersed throughout the stem. In a dicot, the vascular system is said to be continuous because it forms rings inside the stem. The phloem forms the outer ring just under the bark in mature woody stems. The xylem forms the inner ring and may be divided into the sapwood and heartwood. Individual rings may be evident in the xylem that correspond to growth events. In temperate zones or climates with pronounced wet and dry seasons, these individual rings can be used to discern the plant's age and the environmental conditions that may have caused differing rates of yearly growth.

Nodes—A node is an area on a stem where buds are located (Figure 1.6). It is a site of great cellular activity and growth where small buds develop into leaves, stems, or flowers. When pruning, it is important to locate a plant's nodes. Generally, you want to make a pruning cut just above, but not too close to, a node. Pruning in this manner encourages the buds at that node to begin development and ultimately form new stems or leaves.

The area between two nodes is called an *internode*. Its length depends on many factors, including genetics. Several other factors also can influence internode length:

- Reduced soil fertility decreases internode length, while an application of high-nitrogen fertilizer can greatly increase it.
- Lack of light increases internode length and causes spindly stems. This situation is known as stretch, or *etiolation*, and often occurs in seedlings started indoors and in houseplants that do not get enough sunlight.
- Internode length also varies with the season. Early-season growth has long internodes, while late-season growth generally has much shorter internodes.
- If a stem's energy is divided among three or four side stems or is diverted into fruit growth and development, internode length is shortened.
- Plant growth regulator substances and herbicides also can influence internode length.

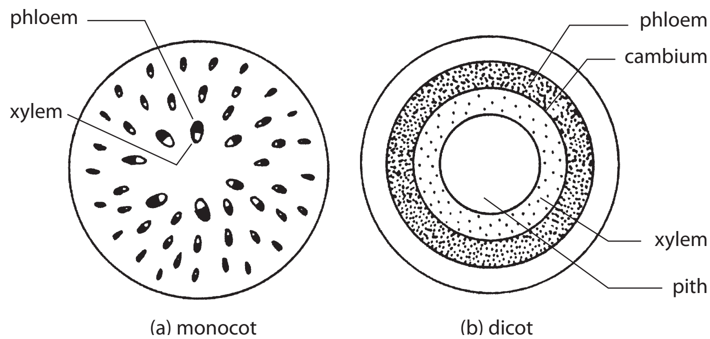


Figure 1.5. Cross sections of stems: (a) discontinuous vascular system of a monocot stem and (b) continuous vascular system of a woody dicot stem.

Types of Stems

Stems may be long, with great distances between the leaves and buds (e.g., branches of trees, runners on strawberries) or compressed, with short distances between buds or leaves (e.g., crowns of strawberry plants, fruit spurs, and African violets). Although stems commonly grow aboveground, they sometimes grow belowground in the form of rhizomes, tubers, corms, or bulbs. All stems must have buds or leaves to be classified as stem tissue.

Specialized aboveground stems—Some plants have specialized aboveground stems known as crowns, spurs, or stolons (Figure 1.7). *Crowns* (on strawberries, dandelions, and African violets) are compressed stems with leaves and flowers on short internodes.

Spurs are short, stubby side stems that arise from a main stem. They are the fruit-bearing stems on pear, apple, and cherry trees. If severe pruning is done too close to fruit-bearing spurs, they can revert to nonfruiting stems, thus eliminating the year's potential fruit crop.

Stolons are fleshy or semiwoody, elongated, horizontal stems that often lie along the soil surface. Strawberry runners are stolons that have small leaves at the nodes. Roots develop from these nodes, and a daughter plant is formed. This type of vegetative reproduction is an easy way to increase the size of a strawberry patch.

Spider plants also produce stolons, which ultimately can become entirely new plants.

Specialized belowground stems—Potato tubers, iris rhizomes, and tulip bulbs are underground stems that store food for the plant (Figure 1.8). It sometimes is difficult to distinguish between roots and stems, but one sure way is to look for nodes. Stems have nodes; roots do not.

In potato *tubers*, for example, the "eyes" are actually the stem's nodes, and each eye contains a cluster of buds. When growing potatoes from "seed" pieces (cut potatoes), it is important that each piece contains at least one eye and be about the size of a golf ball so there will be enough energy for early growth of shoots and roots.

Stem Terminology

Shoot—A young stem (one year old or less) with leaves.

Twig—A young stem (one year old or less) that is in the dormant winter stage (has no leaves).

Branch—A stem that is more than one year old, typically with lateral stems radiating from it.

Trunk—A woody plant's main stem.

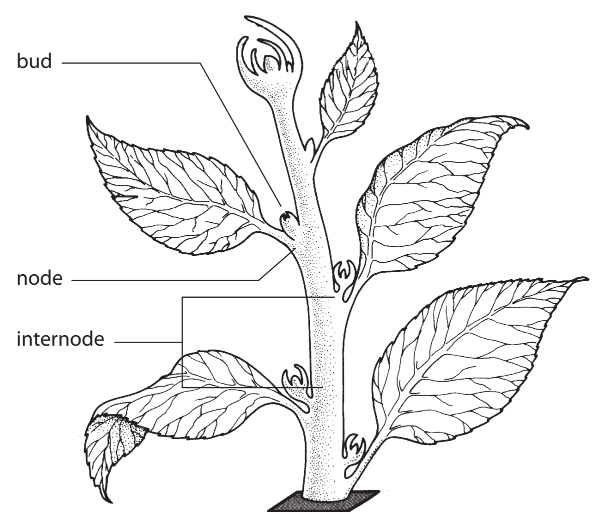


Figure 1.6. Stem structure. (Adapted with permission from *Plant Physiology,* The Benjamin/Cummings Publishing Company, Inc., 1991.)

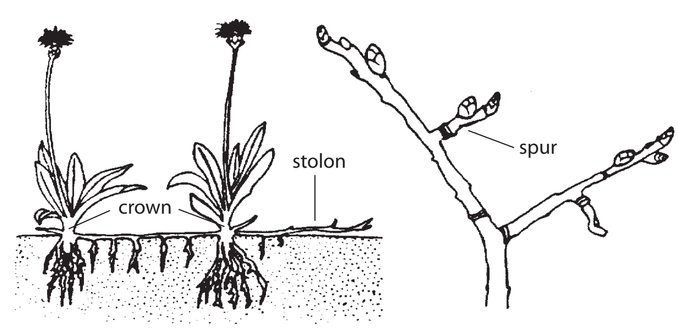


Figure 1.7. Diversified aboveground stem development.

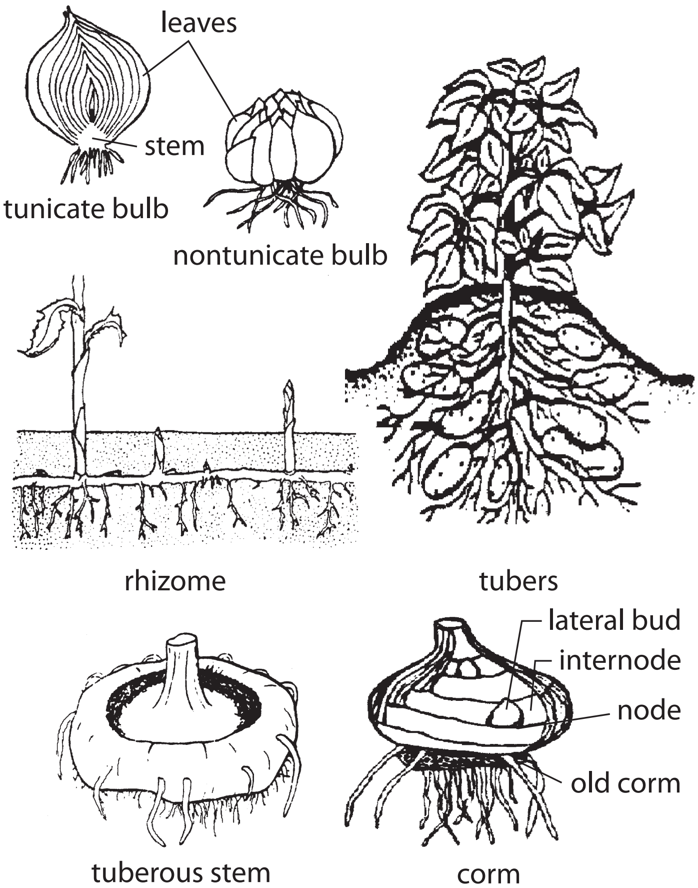


Figure 1.8. Diversified belowground stem development.

Rhizomes resemble stolons because they grow horizontally from plant to plant. Some rhizomes are compressed and fleshy (e.g., iris), while others are slender and have elongated internodes (e.g., bentgrass). Johnsongrass is an insidious weed principally because of the spreading capability of its rhizomes.

Tulips, lilies, daffodils, and onions produce *bulbs*, which are shortened, compressed underground stems surrounded by fleshy scales (leaves) that envelop a central bud at the tip of the stem. In November, you can cut a tulip or daffodil bulb in half and see all of the flower parts in miniature.

After a bulb-producing plant flowers, its phloem transports food reserves from its leaves to the bulb's scales. When the bulb begins growing in the spring, it uses the stored food. For this reason, it is important not to remove the leaves from daffodils, tulips, and other bulb-producing plants until after they have turned yellow and withered. At that time, these plants have finished producing the food that will be used for next year's flowering.

There are two types of bulbs: tunicate and nontunicate (Figure 1.8). *Tunicate* bulbs (e.g., daffodils, tulips, and onions) have concentric scales, actually modified leaves. It helps protect the bulb from damage during digging and from drying out once it is out of the soil. *Nontunicate,* or scaly, bulbs (e.g., lilies) have individual scalelike modified leaves. They are very susceptible to damage and drying out, so handle them very carefully.

Corms are another kind of belowground stem. Although both bulbs and corms are composed of stem tissue, they are not the same. Corms are shaped like bulbs, but do not contain fleshy scales. A corm is a solid, swollen stem with dry, scalelike leaves. Gladiolus and crocuses produce corms.

Other plants (e.g., dahlias and sweet potatoes) produce underground storage organs called *tuberous roots*, which often are confused with bulbs and tubers. However, these are root tissue, not stem tissue, and have neither nodes nor internodes.

Stems and Propagation

Stems often are used for vegetative plant propagation. Using sections of aboveground stems that contain nodes and internodes is an effective way to propagate many ornamental plants. These stem cuttings produce roots and eventually new plants.

Belowground stems also are good propagative tissues. You can divide rhizomes into pieces, remove small bulblets or cormels from the parent, and cut tubers into pieces containing eyes and nodes. All of these tissues will produce new plants.

Types of Plants and Their Stems

Trees generally have one, but occasionally several, main trunks, which usually are more than 12 feet tall when mature. In contrast, shrubs generally have several main stems, which usually are less than 12 feet tall when mature.

Most fruit trees, ornamental trees, and shrubs have woody stems. These stems contain relatively large amounts of hardened xylem tissue in the central core (heartwood or sapwood).

Herbaceous or succulent stems contain only a little xylem tissue and usually live for only one growing season. In perennial plants, new herbaceous stems develop from the crown (root–stem interface) each year.

Canes are stems with relatively large *pith*. They usually live only one or two years.

Examples of plants with canes include roses, grapes, blackberries, and raspberries. For fruit production, it is important to know which canes to prune, how to prune them, and when to prune them.

A *vine* is a plant with long, trailing stems. Some vines grow along the ground, while others must be supported by another plant or structure. Twining vines circle a structure for support. Some circle clockwise (e.g., hops and honeysuckle), while others circle counterclockwise (e.g., pole beans and Dutchman's pipe vine). Climbing vines are supported either by aerial roots (e.g., English ivy and poison ivy), by slender tendrils that encircle a supporting object (e.g., cucumbers, gourds, grapes, and passionflowers), or by tendrils with adhesive tips (e.g., Virginia and Japanese creeper). In temperate areas both woody and herbaceous trailing plants are called vines, but in the tropics, woody trailing plants are called "lianas."

Stems as Food

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

Buds

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

Buds of many plants require exposure to a certain number of days below a critical temperature before resuming growth in the spring. This period, often referred to as rest or chilling requirement, varies for different plants. Forsythia, for example, requires a relatively short rest period and grows at the first sign of warm weather. Many peach varieties, on the other hand, require 700 to 1,000 hours of temperatures below 45°F. During rest, dormant buds can withstand very low temperatures, but after the rest period is satisfied, they are more susceptible to damage by cold temperatures or frost.

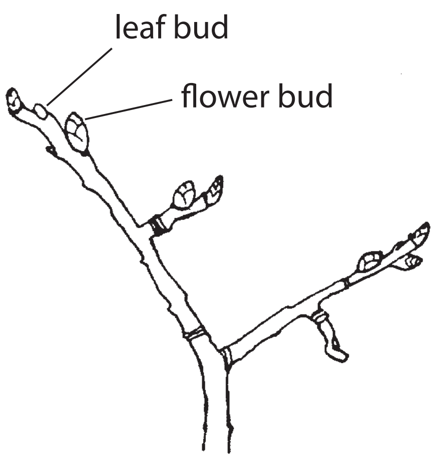


Figure 1.9. Elm leaf and flower buds.

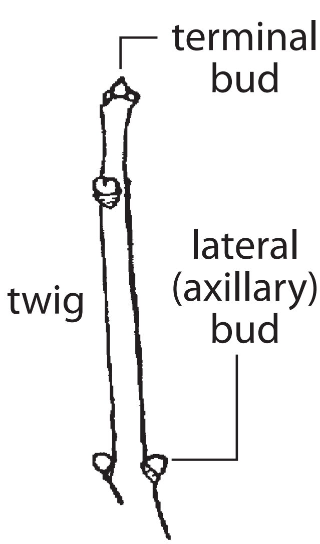


Figure 1.10. Bud location.

A leaf bud is composed of a short stem with embryonic leaves. Leaf buds often are less plump and more pointed than flower buds (Figure 1.9).

A flower bud is composed of a short stem with embryonic flower parts. In the case of fruit crops, flower buds sometimes are called fruit buds. This terminology is inaccurate, however; although flowers have the potential to develop into fruits, they may not do so because of adverse weather conditions, lack of pollination, or other unfavorable circumstances.

Location

Buds are named for their location on the stem (Figure 1.10). *Terminal* buds are located at the apex (tip) of a stem. Lateral (*axillary*) buds are located on the sides of a stem and usually arise where a leaf meets a stem (an *axil*). In some instances, an axil contains more than one bud.

Adventitious buds arise at sites other than the terminal or axillary position. They may develop from roots, a stem internode, the edge of a leaf blade, or callus tissue at the cut end of a stem or root. Adventitious buds allow stem, leaf, and root cuttings to develop into entirely new plants.

Buds as Food

Enlarged buds or parts of buds form the edible portion of some horticultural crops. Cabbage and head lettuce are examples of unusually large terminal buds. Succulent axillary buds are the edible part of Brussels sprouts. In the case of globe artichoke, the fleshy basal portion of the flower bud's bracts is eaten, along with its solid stem. Broccoli is the most important horticultural plant with edible flower buds. In this case, portions of the stem, as well as small leaves associated with the flower buds, are eaten.

Leaves

Function and Structure

The principal function of leaves is to absorb sunlight to manufacture plant sugars through a process called *photosynthesis*. Leaf surfaces are flattened to present a large area for efficient light absorption. The blade, or lamina, is the expanded thin structure on either side of the midrib and usually is the largest, most conspicuous part of a leaf (Figure 1.11).

A leaf is held away from its stem by a stemlike appendage called a *petiole*, and the base of the petiole is attached to the stem at a node. Petioles vary in length or may be lacking entirely, in which case the leaf blade is described as *sessile,* or stalkless.

The node where a petiole meets a stem is called a *leaf axil*. The axil contains single buds or bud clusters, referred to as axillary buds. They may be either active or dormant; under the right conditions, they will develop into stems or leaves.

A leaf blade is composed of several layers (Figure 1.12). On the top and bottom is a layer of thick, tough cells called the *epidermis*. Its primary function is to protect the other layers of leaf tissue. The arrangement of epidermal cells determines the leaf's surface texture. Some leaves, such as those of African violets, have hairs (*pubescence*), which are extensions of epidermal cells that make the leaves feel like velvet.

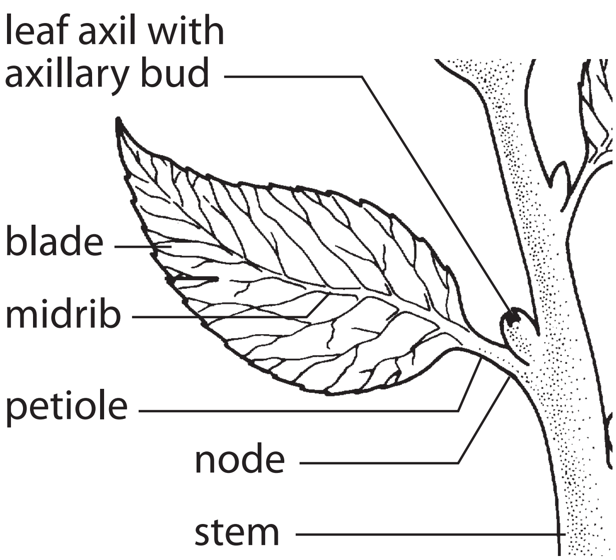


Figure 1.11. Leaf parts. (Adapted with permission from *Plant Physiology,* The Benjamin/Cummings Publishing Company, Inc., 1991.)

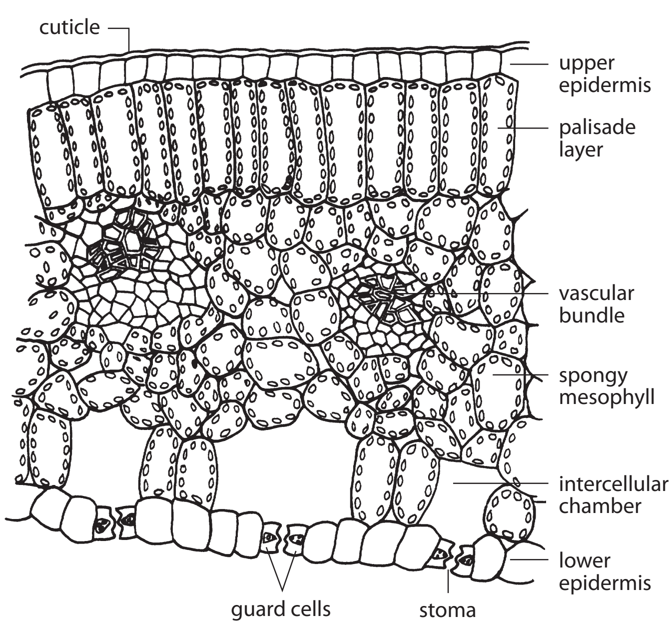


Figure 1.12. Leaf cross section. (Reprinted with permission from *Plant Science: Growth, Development, and Utilization of Cultivated Plants,* Prentice Hall, 1988.)

The *cuticle* is part of the epidermis. It produces a waxy layer called *cutin*, which protects the leaf from dehydration and disease. The amount of cutin on a leaf increases with increasing light intensity. For this reason, when moving plants from shade into full sunlight, do so gradually over a period of a few weeks. This gradual exposure to sunlight allows the cutin layer to build up and protect the leaves from rapid water loss or sunscald.

The waxy cutin also repels water. For this reason, many pesticides contain a spray additive to help the product adhere to, or penetrate, the cutin layer.

Special epidermal cells called *guard cells* open and close in response to environmental stimuli such as changes in weather and light. They regulate the passage of water, oxygen, and carbon dioxide into and out of the leaf through tiny openings called *stomata*. In most species, the majority of the stomata are located on the underside of leaves.

Conditions that would cause plants to lose a lot of water (high temperature, low humidity) stimulate guard cells to close. In mild weather, they remain open. Guard cells also close in the absence of light.

Located between the upper and lower epidermis is the *mesophyll*. It is divided into a dense upper layer (*palisade mesophyll*) and a lower layer that contains lots of air space (*spongy mesophyll*). Located within the mesophyll cells are *chloroplasts*, where photosynthesis takes place.

Types of Leaves

There are many kinds of plant leaves. The most common and conspicuous leaves are referred to as foliage and are the primary location of photosynthesis. However, there are many other types of modified leaves:

- *Scale leaves* (cataphylls) are found on rhizomes and buds, which they enclose and protect.
- *Seed leaves* (cotyledons) are found on embryonic plants. They store food for the developing seedling.
- *Spines* and *tendrils*, such as those on barberry and pea plants, protect a plant or help support its stems.
- *Storage leaves*, such as those on bulbous plants and succulents, store food.
- *Bracts* often are brightly colored. For example, the showy structures on dogwoods and poinsettias are bracts, not petals.

Venation

The vascular bundles of xylem and phloem extend from the stem, through the petiole, and into the leaf blade as veins.

The term *venation* refers to how veins are distributed in the blade. There are two principal types of venation: parallel-veined and net-veined (Figure 1.13).

In *parallel-veined* leaves, numerous veins run essentially parallel to each other and are connected laterally by minute, straight veinlets. Parallel-veined leaves occur most often on monocotyledonous plants. The most common type of parallel veining is found in plants of the grass family, whose veins run from the leaf's base to its apex.

In *net-veined* leaves (also called *reticulate-veined*), veins branch from the main rib or ribs and subdivide into finer veinlets. These veinlets then unite in a complicated network. This system of enmeshed veins makes the leaf more resistant to tearing than does a parallel vein structure. Net-veined leaves occur on dicotyledonous plants.

Net venation may be either pinnate or palmate. In *pinnate* (featherlike) venation, the veins extend laterally from the midrib to the edge (e.g., apples, cherries, and peaches). In *palmate* venation, the principal veins extend outward, like the ribs of a fan, from the base of the leaf blade (e.g., grapes and maples).

Leaves as Plant Identifiers

Leaves are useful for plant identification. A leaf's shape, base, apex, and margin can be important identifying characteristics (Figures 1.14–1.16).

Leaf type (Figure 1.17) also is important for identification. There are two types of leaves: simple and compound. In *simple* leaves, the leaf blade is a single, continuous unit. *Compound* leaves are composed of several separate leaflets arising from the same petiole. Some leaves are doubly compound. Leaf type can be confusing because a deeply lobed simple leaf may look like a compound leaf.

Leaf arrangement along a stem also is used in plant identification (Figure 1.18). There are four types of leaf arrangement:

- *Opposite* leaves are positioned across the stem from each other, with two leaves at each node.
- *Alternate* (spiral) leaves are arranged in alternate steps along the stem, with only one leaf at each node.
- *Whorled* leaves are arranged in circles along the stem.

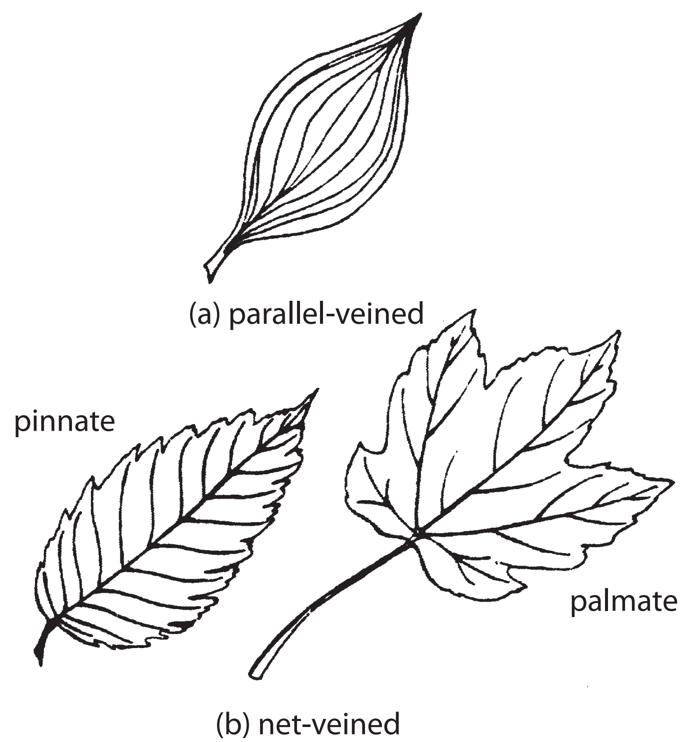


Figure 1.13. Types of venation: (a) parallel-veined; (b) net-veined.

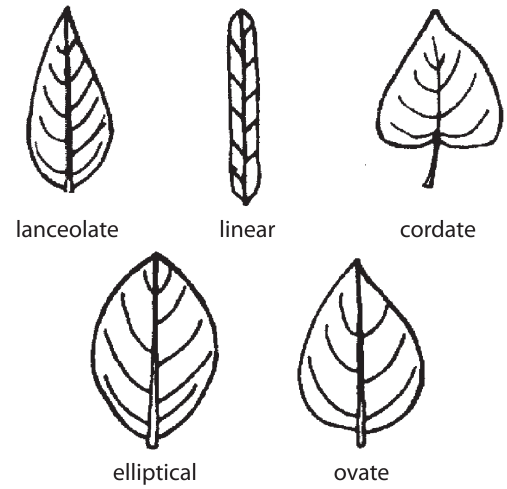


Figure 1.14. Common leaf blade shapes.

Lanceolate—Longer than wide and tapering toward the apex and base.

Linear—Narrow, several times longer than wide and of approximately the same width throughout.

Cordate (heart-shaped)—Broadly ovate, tapering to an acute apex, with the base turning in and forming a notch where the petiole is attached.

Elliptical—About two or three times as long as wide, tapering to an acute or rounded apex and base.

Ovate—Egg-shaped, basal portion wide, tapering toward the apex.

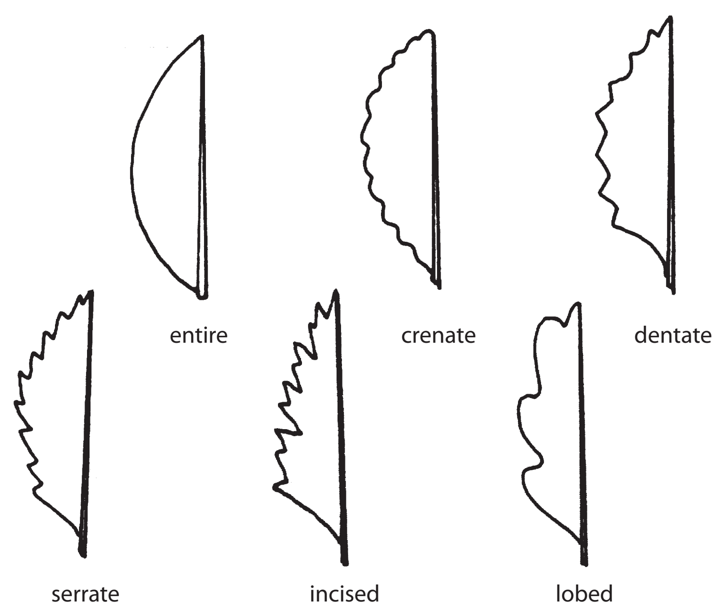


Figure 1.15. Common leaf margin shapes.

Entire—Having a smooth edge with no teeth or notches.

Crenate—Having rounded teeth.

Dentate—Having teeth ending in an acute angle pointing outward.

Serrate—Having small, sharp teeth pointing toward the apex.

Incised—Having a margin cut into sharp, deep, irregular teeth or incisions.

Lobed—Having incisions that extend less than halfway to the midrib.

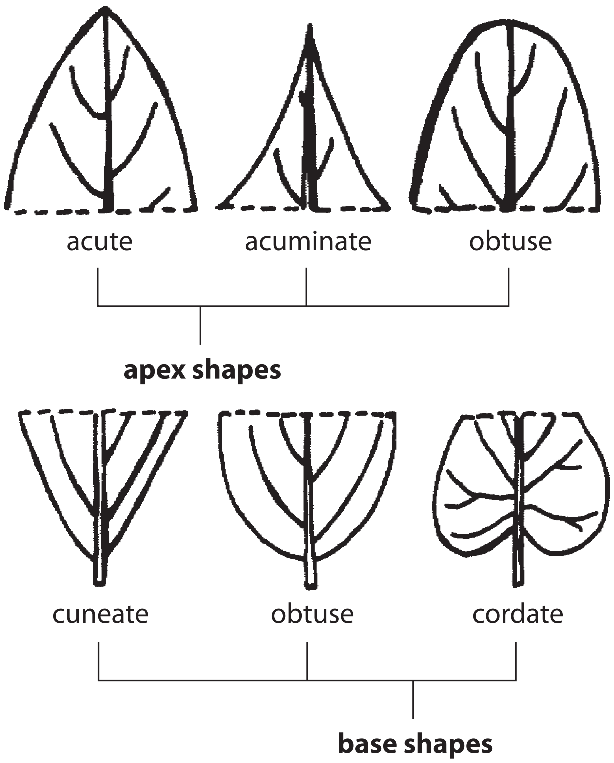


Figure 1.16. Common leaf apex and base shapes.

Acute—Ending in an acute angle, with a sharp, but not acuminate, point.

Acuminate—Tapering to a long, narrow point.

Obtuse—Tapering to a rounded edge.

Cuneate—Wedge-shaped; triangular with the narrow end at the point of attachment.

Cordate (heart-shaped)—Turning in and forming a notch.

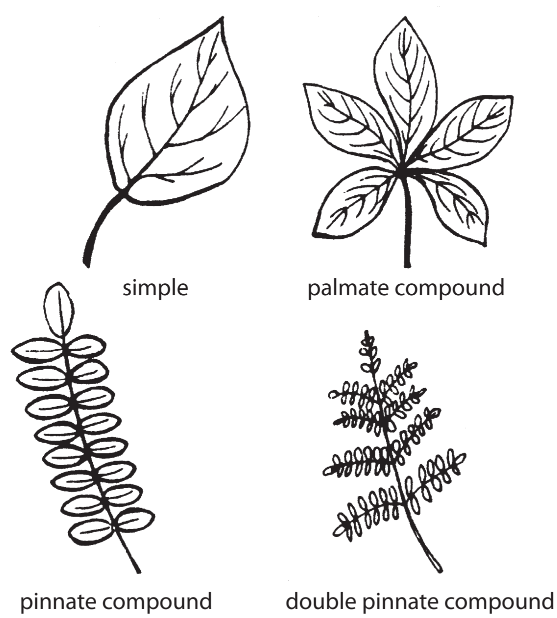


Figure 1.17. Leaf types.

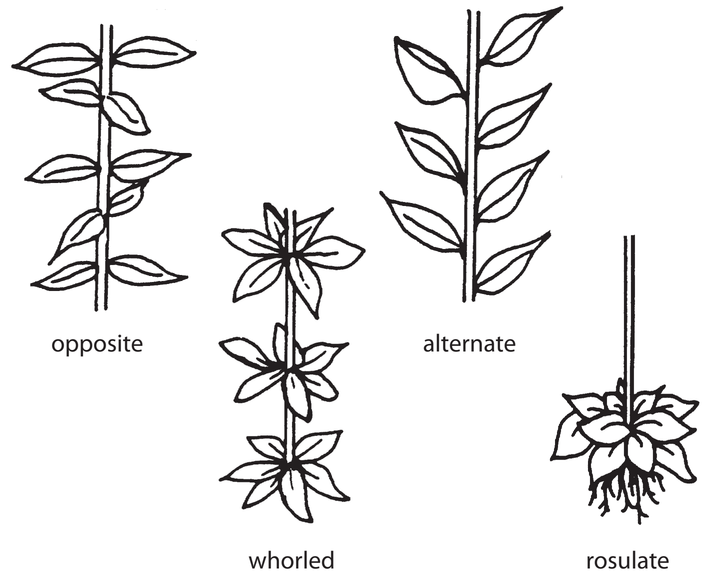


Figure 1.18. Leaf arrangement.

- *Rosulate* leaves are arranged in a rosette around a stem with extremely short nodes.

Leaves as Food

The leaf blade is the principal edible part of several horticultural crops, including chives, collards, endive, kale, leaf lettuce, mustard, parsley, spinach, Swiss chard, and other greens. The edible part of leeks, onions, and Florence fennel is a cluster of fleshy leaf bases. The petiole is the edible product in celery and rhubarb.

Flowers

Flowers, which generally are the showiest part of a plant, have sexual reproduction as their sole function. Their beauty and fragrance have evolved not to please humans but to ensure continuance of the species. Fragrance and color attract pollinators (insects, birds, or other animals), which play an important role in the reproductive process.

Flowers are important for plant classification. The system of plant nomenclature we use today was developed by Carl von Linné (Linnaeus) and is based on flowers and/or reproductive parts of plants. One reason his system is successful is because flowers are the plant part least influenced by environmental changes. Thus, knowledge of flowers and their parts is essential for anyone interested in plant identification.

Structure

As a plant's reproductive part, a flower contains a stamen (male flower part) and/or pistil (female flower part), plus accessory parts such as sepals, petals, and nectar glands (Figure 1.19).

The *stamen* is the male reproductive organ. It consists of a pollen sac (*anther*) and a long supporting filament. This filament holds the anther in position, making the pollen available for dispersal by wind, insects, birds, or other animals.

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

Sepals are small, green, leaf-like structures located at the base of a flower. They protect the flower bud. Collectively, the sepals are called a *calyx*.

Petals generally are the highly colored portions of a flower. Like nectar glands, petals may produce fragrance. Collectively, the petals are called a *corolla*. The number of petals on a flower often is used to help identify plant families and genera. Flowers of dicots typically have four or five sepals and/or petals or multiples thereof. In monocots, these floral parts typically come in threes or multiples of three.

Types of Flowers

If a flower has a stamen, pistil, petals, and sepals, it is called a *complete* flower (Figure 1.19). Roses are an example. If one of these parts is missing, the flower is called *incomplete*.

The stamen and pistil are the essential parts of a flower and are involved in seed production. If a flower contains both functional stamens and pistils, it is called a *perfect* flower, even if it does not contain petals and sepals. If either stamens or pistils are lacking, the flower is called *imperfect* (Figure 1.20). *Pistillate* (female) flowers possess a functional pistil or pistils but lack stamens. *Staminate* (male) flowers contain stamens but no pistils.

Plants with imperfect flowers are further classified as monoecious or dioecious. *Monoecious* plants have perfect flowers of separate male and female flowers on the same plant (e.g., corn and pecans). Some monoecious plants bear only male flowers at the beginning of the growing season but later develop both sexes (e.g., cucumbers and squash).

Dioecious species have separate male and female plants. Examples include holly, ginkgo, and pistachio. In order to set fruit, male and female plants must be planted close enough together for pollination to occur. In some instances (e.g., holly), the fruit is desirable. In the case of ginkgo, however, the fruit generally is not desirable due to its putrid smell when ripe. Kiwis are complicated because they may have one plant with bisexual flowers and another plant with only male flowers. The plant world isn't all absolutes!

Types of Inflorescences

Some plants bear only one flower per stem, which is called a *solitary* flower. Other plants produce an *inflorescence*—a cluster of flowers. Each flower in an inflorescence is called a *floret*.

Most inflorescences belong to one of two groups: racemes and cymes. In the *racemose* group, the florets start blooming from the bottom of the stem and progress toward the top. In a *cyme*, the top floret opens first and blooms progress downward along the stem. Detailed discussions of flower types are found in many botany textbooks. (See "For More Information" at the end of this chapter.)

How Seeds Form

Pollination is the transfer of pollen from an anther to a stigma, either by wind or by pollinators. Species pollinated by insects, animals, or birds often have brightly colored or patterned flowers that contain fragrance or nectar. While searching for nectar, pollinators transfer pollen from flower to flower, either on the same plant or on different plants. Plants evolved this ingenious mechanism in order to ensure their species' survival. Wind-pollinated flowers often lack showy floral parts and nectar because they don't need to attract pollinators.

A chemical in the stigma stimulates pollen to grow a long tube down the style to the ovules inside the ovary. When pollen reaches the ovules, it releases sperm, and fertilization typically occurs. *Fertilization* is the union of a male sperm nucleus from a pollen grain with a female egg. If fertilization is successful, the ovule develops into a seed. It is important to remember that pollination is no guarantee that fertilization will occur.

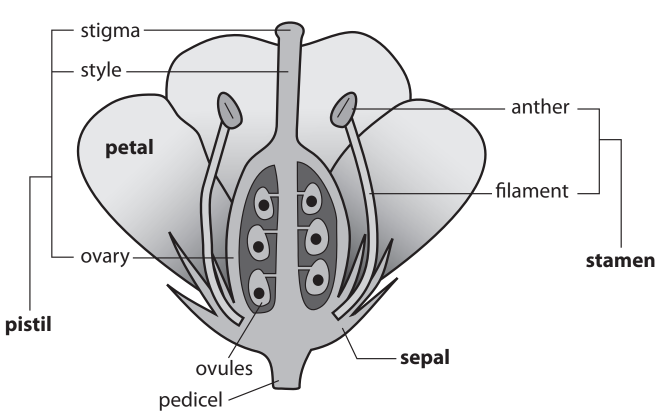


Figure 1.19. Complete flower structure.

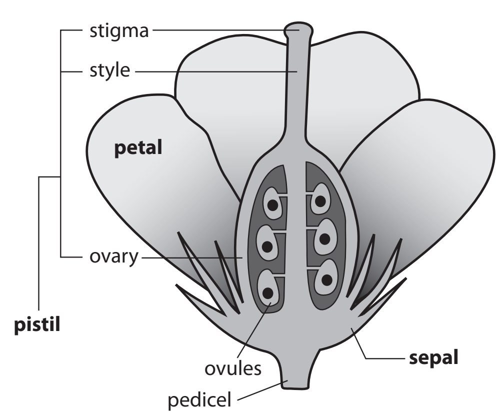


Figure 1.20. Imperfect (pistillate) flower structure.

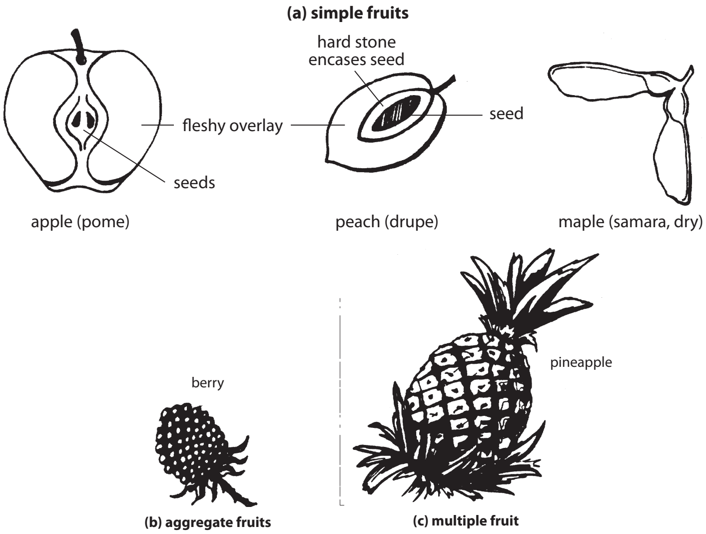


Figure 1.21. Types of fruit: (a) Simple fruits (apple, peach, and maple) and (b) aggregate fruits (berry and cone) and (c) multiple fruit (pineapple).

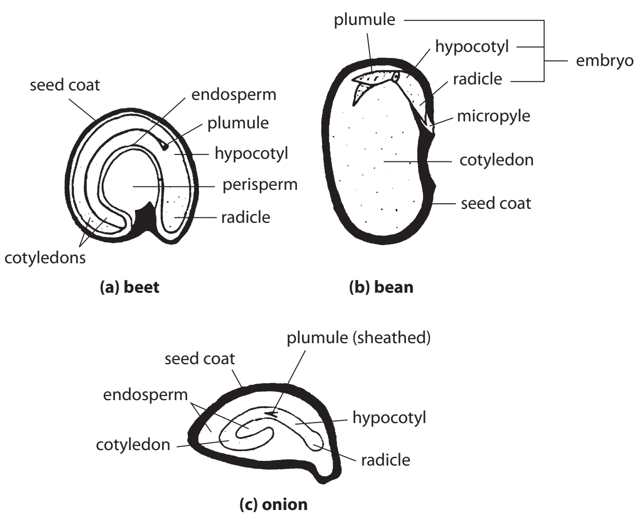


Figure 1.22. Parts of a seed: (a) beet; (b) bean; (c) onion. In bean, the cotyledons replace the endosperm in providing food for the germinating embryo.

Cross-fertilization combines genetic material from two parent plants. The resulting seed has a broader genetic base, which may enable the population to survive under a wider range of environmental conditions.

Fruit

Structure

Fruit consists of fertilized, mature ovules (seeds) plus the ovary wall, which may be fleshy, as in a peach.

The only part of the fruit that contains genes from both the male and female flowers is the seed. The rest of the fruit arises from the maternal plant and is genetically identical to it.

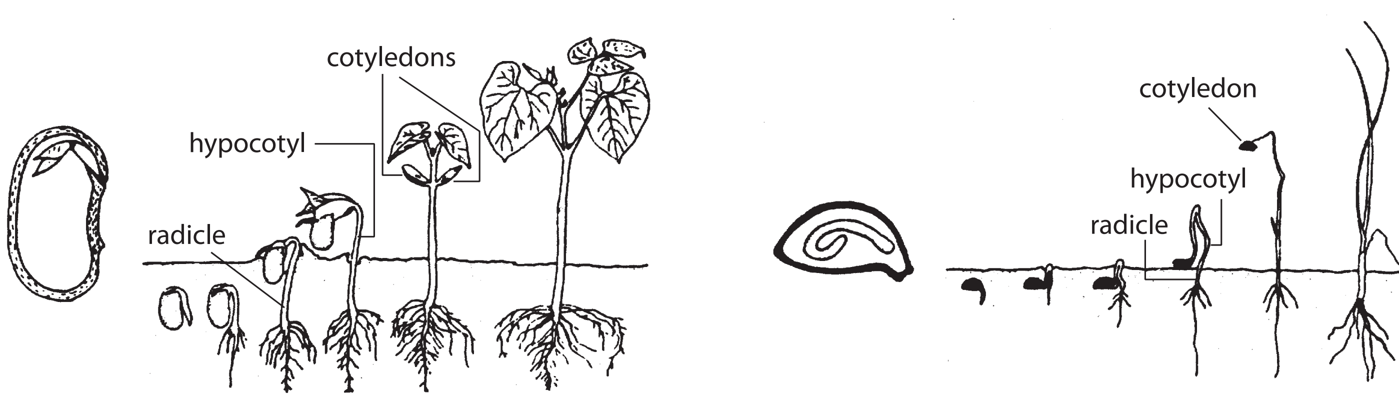
Types of Fruit

Fruits are classified as simple, aggregate, or multiple (Figure 1.21). *Simple* fruits develop from a single flower and a single ovary. They include fleshy fruits such as cherries and peaches (drupe), pears and apples (pome), and tomatoes (berries). Although generally referred to as a vegetable, tomato is technically a fruit because it develops from a flower. Squash, cucumbers, and eggplants also develop from a single ovary and are classified botanically as fruits.

Other types of simple fruit are dry. Their wall is either papery or leathery and hard, as opposed to the fleshy examples just mentioned. Examples are peanuts (legume), poppies (capsule), maples (samara), and walnuts (nut).

An *aggregate* fruit develops from a single flower with many ovaries. Examples are strawberries, raspberries, and blackberries. The flower has one corolla, one calyx, and one stem, but it has many pistils and ovaries. Each ovary is fertilized separately. If some ovules are not pollinated successfully, the fruit will be misshapen.

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



(a) germination of a bean (dicot) **(b) germination of an onion (monocot)**

Figure 1.23. Germination of a dicot (a) and a monocot (b).

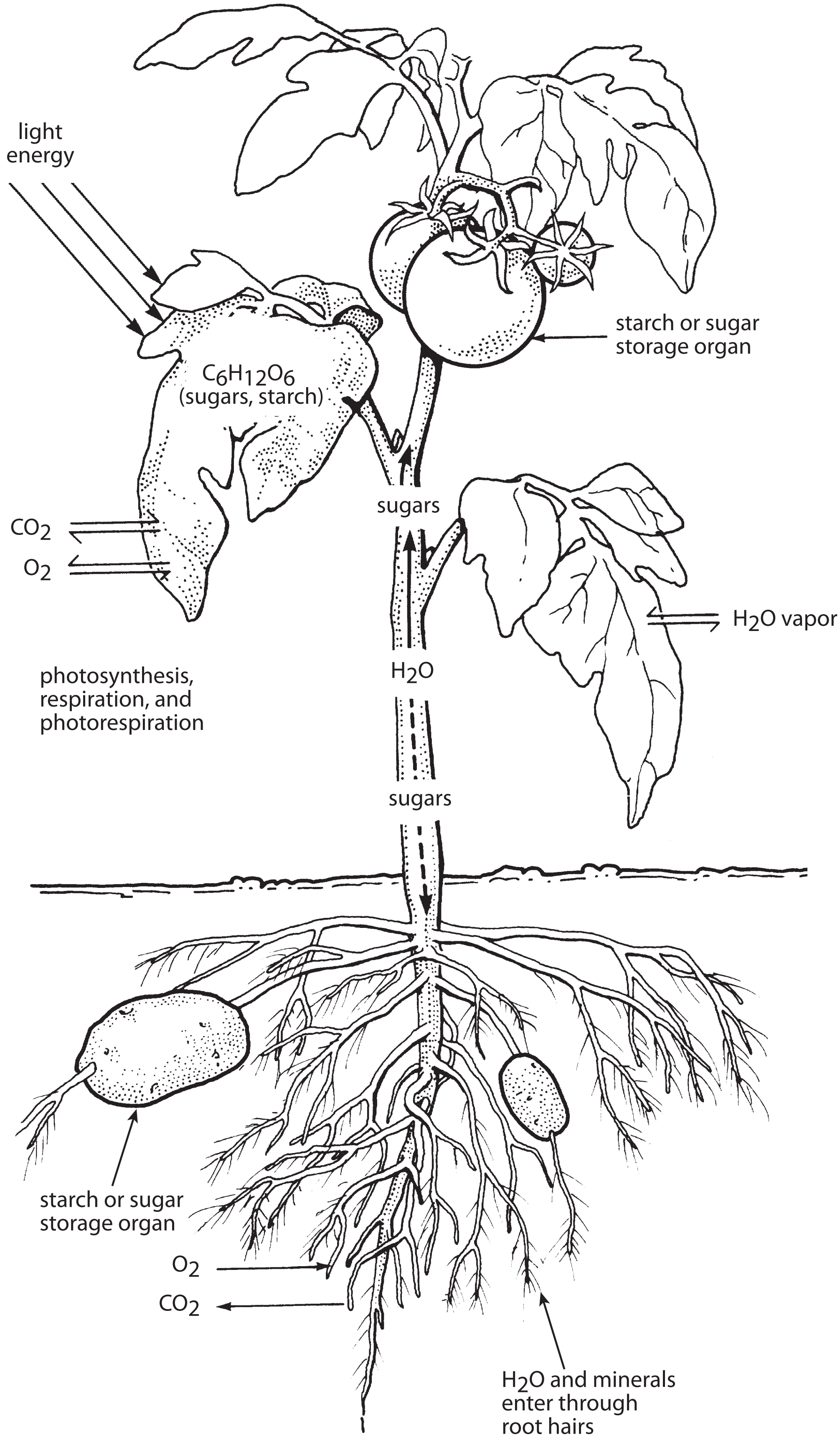


Figure 1.24. Schematic representation of photosynthesis, respiration, leaf water exchange, and translocation of sugar (photosynthate) in a plant. (Reprinted with permission from *Plant Science: Growth, Development, and Utilization of Cultivated Plants,* Prentice Hall, 1988.)

Seeds

A seed contains all of the genetic information needed to develop into an entire plant. As shown in Figure 1.22, it is made up of three parts:

- The *embryo* is a miniature plant in an arrested state of development. It will begin to grow when conditions are favorable.
- The *endosperm* (and in some species the cotyledons) is a built-in food supply (although orchids are an exception where the seed contains no endosperm), which can be made up of proteins, carbohydrates, or fats.
- The *seed coat*, a hard outer covering, protects the seed from disease and insects. It may also prevent water from entering the seed and initiating germination before the proper time.

Germination

Germination is a complex process whereby a seed embryo goes from a dormant state to an active, growing state (Figure 1.23). Before any visible signs of germination appear, the seed must absorb water through its seed coat. It also must have enough oxygen and a favorable temperature. Some species, such as celery, also require light. Others require darkness.

If these requirements are met, the *radicle* is the first part of the seedling to emerge from the seed. It develops into the primary root and grows downward in response to gravity. From this primary root, root hairs and lateral roots develop. Between the radicle and the first leaflike structure is the *hypocotyl*, which grows upward in response to light.

The seed leaves, or *cotyledons*, encase the embryo. They usually are shaped differently than the leaves produced by the mature plant. Monocots produce one cotyledon, while dicots produce two.

Because seeds are reproductive structures and thus important to a species' survival, plants have evolved many mechanisms to ensure seed survival. One such mechanism is seed dormancy. Dormancy comes in two forms: seed coat dormancy and embryo dormancy.

In *seed coat dormancy*, a hard seed coat does not allow water to penetrate. Redbud, locust, and many other ornamental trees and shrubs exhibit this type of dormancy.

A process called *scarification* is used to break or soften the seed coat. In nature, scarification is accomplished by means such as the heat of a forest fire, digestion of the seed by a bird or mammal, or partial breakdown of the seed coat by fungi or insects. The breakdown can be done mechanically by nicking the seed coat with a file or chemically by softening the seed coat with sulfuric acid. In either instance, it is important to not damage the embryo.

Embryo dormancy is common in ornamental plants, including elm and witch hazel. These seeds must go through a chilling period before germinating. To break this type of dormancy, *stratification* is used. This process involves storing seeds in a moist medium (potting soil or paper towels) at temperatures between 32°F and 50°F. The length of time required varies by species.

Even when environmental requirements for seed germination are met and dormancy is broken, other factors also affect germination:

- The seed's age greatly affects its *viability* (ability to germinate). Older seed generally is less viable than young seed, and if older seed does germinate, the seedlings are less vigorous and grow more slowly.
- The seedbed must be properly prepared and made up of loose, fine-textured soil.

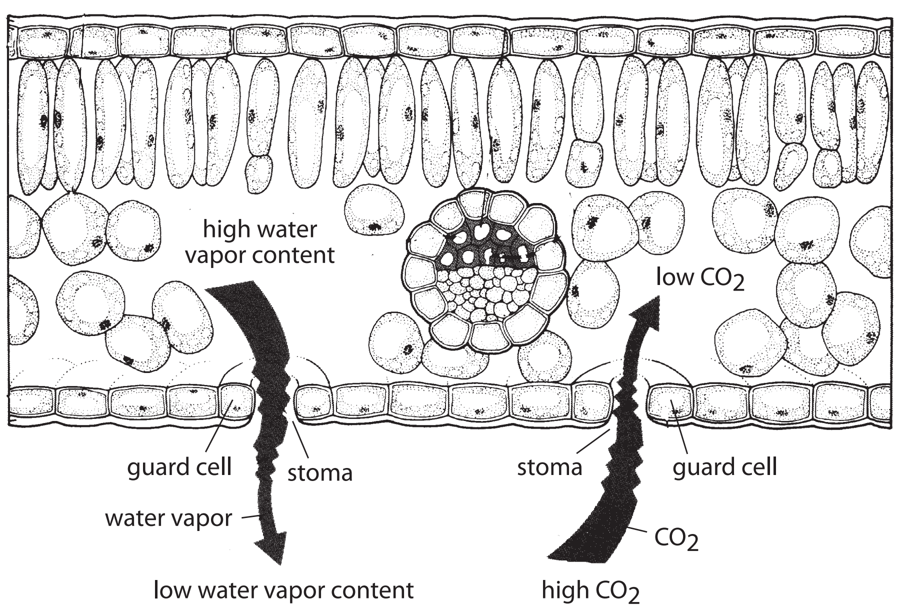


Figure 1.25. Stomata open to allow carbon dioxide (CO_2) to enter a leaf and water vapor to leave. (Reprinted with permission from *Plant Physiology,* The Benjamin/Cummings Publishing Company, Inc., 1991.)

- Seeds must be planted at the proper depth. If they are too shallow, they may wash away with rain or watering; if they are too deep, they won't be able to push through the soil.
- Seeds must have a continual supply of moisture; however, if overwatered, they will rot.

Many weed seeds are able to germinate quickly and under less-than-optimal conditions. This is one reason they make such formidable opponents in the garden.

Plant Growth and Development

Photosynthesis, respiration, and transpiration are the three major functions that drive plant growth and development (Figure 1.24). All three are essential to a plant's survival. How well a plant is able to regulate these functions greatly affects its ability to compete and reproduce.

Photosynthesis

One of the major differences between plants and animals is plants' ability to manufacture their own food. This process is called *photosynthesis*, which literally means "to put together with light." To produce food, a plant requires energy from the sun, carbon dioxide from the air, and water from the soil. The formula for photosynthesis can be written as follows:

carbon dioxide + water + sunlight
= sugar + oxygen

or

$$6CO_2 + 6H_20 > C_6H_{12}0_6 + 60_2$$

After producing carbohydrates, a plant either uses them as energy, stores them as starch, or builds them into complex energy compounds such as oils and proteins. All of these food products are called *photosynthates*. The plant uses them to build complex structures or transports them to its roots or developing fruits.

Photosynthesis occurs only in the *mesophyll* layers of plant leaves and, in some instances, in mesophyll cells in the stem. Mesophyll cells are sandwiched between the leaf's upper and lower epidermis (Figure 1.12) and contain numerous *chloroplasts*, where photosynthesis takes place. Chloroplasts are incredibly small. One square millimeter, about the size of a period on a page, would contain 400,000 chloroplasts.

Chlorophyll, the pigment that makes leaves green, is found in the chloroplasts. It is responsible for trapping light energy from the sun. Often chloroplasts are arranged perpendicular to incoming sun rays so they can absorb maximum sunlight.

If any of the ingredients for photosynthesis—light, water, and carbon dioxide—is lacking, photosynthesis stops. If any factor is absent for a long period of time, a plant will die. Each of these factors is described below.

Light

Photosynthesis depends on the availability of light. Generally, as sunlight intensity increases, so does photosynthesis. However, for each plant species, there is a maximum level of light intensity above which photosynthesis does not increase. Many garden crops, such as tomatoes, respond best to maximum sunlight. Tomato production decreases drastically as light intensity drops, and few tomato varieties produce any fruit under minimal sunlight conditions.

Water

Water is one of the raw materials for photosynthesis. It is taken up into the plant by the roots and moved upward through the xylem. Anything that hinders water movement in the plant, such as physical injury or insect/disease damage, will impact photosynthesis. Drought conditions that limit water availability may also cause stomata guard cells to close, limiting CO_2 uptake and slowing photosynthesis.

Carbon dioxide

Photosynthesis also requires carbon dioxide (CO_2), which enters a plant through its stomata (Figure 1.25). In most plants, photosynthesis fluctuates throughout the day as stomata open and close. Typically, they open in the morning, close down at midday, reopen in late afternoon, and shut down again in the evening.

Carbon dioxide is plentiful in the air, so it is not a limiting factor in plant growth. However, it is consumed rapidly during photosynthesis and is replenished very slowly in the atmosphere. Tightly sealed greenhouses may not allow enough outside air to enter and thus may lack adequate carbon dioxide for plant growth. Carbon dioxide generators are used to replenish or supplement CO_2 in commercial greenhouses for crops such as roses, carnations, and tomatoes. In smaller home greenhouses, dry ice is an effective source of CO_2.

Temperature

Although not a direct component in photosynthesis, temperature is important. Photosynthesis occurs at its highest rate between 65°F and 85°F and decreases at higher or lower temperatures.

Table 1.2. Photosynthesis and respiration.

Photosynthesis	Respiration
Produces food	Uses food
Stores energy	Releases energy
Uses water	Produces water
Uses carbon dioxide	Produces carbon dioxide
Releases oxygen	Uses oxygen
Occurs in sunlight	Occurs in darkness as well as in light

Respiration

Carbohydrates made during photosynthesis are of value to a plant when they are converted to energy. This energy is used for cell growth and building new tissues. The chemical process by which sugars and starches are converted to energy is called *oxidation* and is similar to the burning of wood or coal to produce heat. Controlled oxidation in a living cell is called *respiration* and is shown by this equation:

sugar + oxygen = carbon dioxide + water+ energy

or

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

This equation is essentially the opposite of photosynthesis. Photosynthesis is a building process, while respiration is a breaking-down process (Table 1.2). Unlike photosynthesis, respiration does not depend on light, so it occurs at night as well as during the day. Respiration occurs in all life forms and in all cells.

Transpiration

When a leaf's guard cells shrink, its stomata open, and water vapor is lost. This process is called *transpiration*. In turn, more water is pulled through the plant from the roots. The rate of transpiration is directly related to whether stomata are open or closed. Stomata account for only 1 percent of a leaf's surface, but 90 percent of the water transpired is released through stomata.

Transpiration is a necessary process and uses about 90 percent of the water that enters a plant's roots. The other 10 percent is used in chemical reactions and in plant tissues. Water moving via the transpiration stream is responsible for several functions:

- Transporting minerals from the soil throughout the plant.
- Cooling the plant through evaporation.
- Maintaining cell firmness.

The amount and rate of water loss depends on factors such as temperature, humidity, and wind or air movement. Transpiration often is greatest in hot, dry (low relative humidity), windy weather. However, transpiration may decrease during drought conditions when a limited water supply will cause stomata to close.

Environmental Factors Affecting Growth

Plant growth and geographic distribution are greatly affected by the environment. If any environmental factor is less than ideal, it limits a plant's growth and/or distribution. For example, only plants adapted to limited amounts of water can live in deserts.

Either directly or indirectly, most plant problems are caused by environmental stress. In some cases, poor environmental conditions (e.g., too little water) damage a plant directly. In other cases, environmental stress weakens a plant and makes it more susceptible to disease or insect attack.

Environmental factors that affect plant growth include light, temperature, water, humidity, and nutrition. It is important to understand how these factors affect plant growth and development. With a basic understanding of these factors, you may be able to manipulate plants to meet your needs, whether for increased leaf, flower, or fruit production. By recognizing the roles of these factors, you also will be better able to diagnose plant problems caused by environmental stress.

Light

Three principal characteristics of light affect plant growth: quantity, quality, and duration.

Quantity

Light quantity refers to the intensity, or concentration, of sunlight. It varies with the seasons. The maximum amount of light is present in summer, the minimum in winter. Up to a point, the more sunlight a plant receives, the greater its capacity for producing food via photosynthesis.

You can manipulate light quantity to achieve different plant growth patterns. Increase light by surrounding plants with reflective materials, a white background, or supplemental lights. Decrease it by shading plants with cheesecloth or woven shade cloth.

Quality

Light quality refers to the color (wavelength) of light. Sunlight supplies the complete range of wavelengths and can be broken up by a prism into bands of red, orange, yellow, green, blue, indigo, and violet.

Blue and red light, which plants absorb, have the greatest effect on plant growth. Blue light is responsible primarily for vegetative (leaf) growth. Red light, when combined with blue light, encourages flowering. Plants look green to us because they reflect, rather than absorb, green light.

Knowing which light source to use is important for manipulating plant growth. For example, fluorescent (cool white) light is high in the blue wavelength. It encourages leafy growth and is excellent for starting seedlings. Incandescent light is high in the red or orange range, but generally produces too much heat to be a valuable light source for plants. Fluorescent grow-lights attempt to imitate sunlight with a mixture of red and blue wavelengths, but they are costly and generally no better than regular fluorescent lights.

Duration

Duration, or *photoperiod*, refers to the amount of time a plant is exposed to light. Photoperiod controls flowering in many plants (Figure 1.26). Scientists initially thought the length of light period triggered flowering and other responses within plants, so they describe plants as short-day or long-day, depending on the plants' flowering conditions. We now know

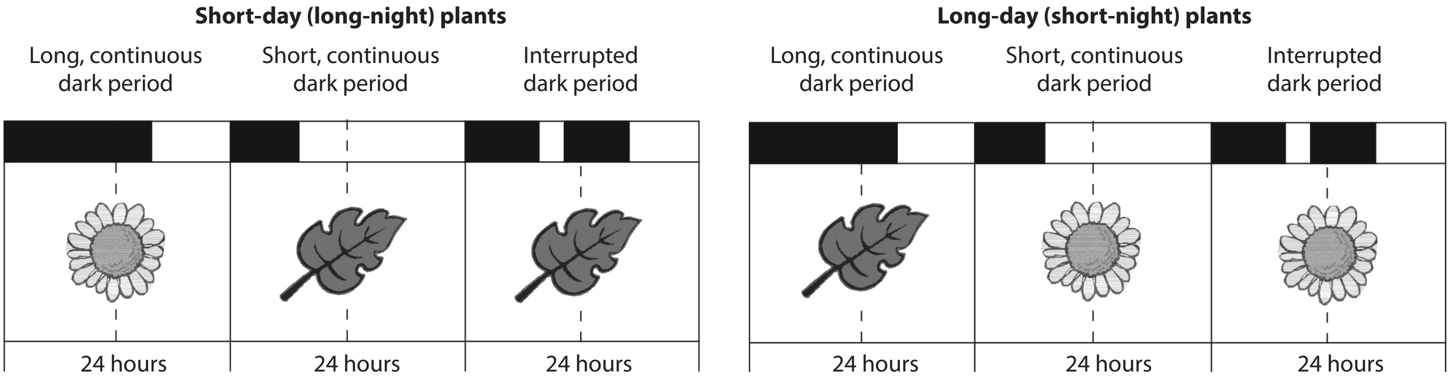


Figure 1.26. Periodicity of plants. Short-day (long-night) plants require a long period of uninterrupted darkness to flower. Long-day (short-night) plants require a short period of uninterrupted darkness to flower.

that it is not the length of the light period but rather the length of uninterrupted darkness that is critical to floral development.

Plants are classified into three categories: short day (long night), long day (short night), or day neutral, depending on their response to the duration of light or darkness. *Short-day* plants form flowers only when day length is less than a critical photoperiod required—for example, 13 hours. Many spring and fall-flowering plants, such as chrysanthemums, poinsettias, and Christmas cactus, are in this category.

In contrast, *long-day* plants form flowers only when day length exceeds a critical photoperiod. Most summer-flowering plants (e.g., rudbeckia, California poppies, and asters), as well as many vegetables (beets, radishes, lettuce, spinach, and potatoes), are in this category.

Day-neutral plants form flowers regardless of day length. Examples are tomatoes, corn, cucumbers, and some strawberry cultivars. Some plants do not fit into any category, but may respond to combinations of day lengths. Petunias, for example, flower regardless of day length, but flower earlier and more profusely with long days.

You can easily manipulate photoperiod to stimulate flowering. For example, chrysanthemums normally flower in the short days of spring or fall, but you can get them to bloom in midsummer by covering them with a cloth that completely blocks out light for longer than the critical photoperiod each day. After several weeks of this treatment, the artificial dark period no longer is needed, and the plants will bloom as if it were spring or fall. This method also is used to make poinsettias flower in time for Christmas.

To bring a long-day plant into flower when day length is less than the critical photoperiod, expose the plant to supplemental light. After a few weeks, flower buds will form. Incandescent rather than fluorescent light is most often used to control photoperiod.

Temperature

Temperature influences most plant processes, including photosynthesis, transpiration, respiration, germination, and flowering. As temperature increases (up to a point), photosynthesis, transpiration, and respiration increase. When combined with day length, temperature also affects the change from vegetative (leafy) to reproductive (flowering) growth. Depending on the situation and the specific plant, the effect of temperature can either speed up or slow down this transition.

Germination

The temperature required for germination varies by species. Generally, cool-season crops (e.g., spinach, radishes, and lettuce) germinate best at 55°F to 65°F, while warm-season crops (e.g., tomatoes, petunias, and lobelias) germinate best at 65°F to 75°F.

Flowering

Sometimes horticulturists use temperature in combination with day length to manipulate flowering. For example, a Christmas cactus forms flowers as a result of short days and low temperatures (Figure 1.26). To encourage a Christmas cactus to bloom, place it in a room with long-night conditions each day and a temperature of 50°F to 55°F until flower buds form.

If temperatures are high and days are long, cool-season crops such as spinach will flower (bolt). However, if temperatures are too cool, fruit will not set on warm-season crops such as tomatoes.

Crop quality

Low temperatures reduce energy use and increase sugar storage. Thus, leaving crops such as ripe winter squash on the vine during cool, fall nights increases their sweetness.

Adverse temperatures, however, cause stunted growth and poor-quality vegetables. For example, high temperatures cause bitter lettuce.

Photosynthesis and Respiration

Thermoperiod refers to daily temperature change. Plants grow best when daytime temperature is about 10° to 15° higher than nighttime temperature. Under these conditions, plants photosynthesize (build up) and respire (break down) during optimum daytime temperatures and then curtail respiration at night. However, not all plants grow best under the same nighttime and daytime temperatures. For example, snapdragons grow best at nighttime temperatures of 55°F; poinsettias, at 62°F.

Temperatures higher than needed increase respiration, sometimes above the rate of photosynthesis. Thus, photosynthates are used faster than they are produced. For growth to occur, photosynthesis must be greater than respiration.

Daytime temperatures that are too low often produce poor growth by slowing down photosynthesis. The result is reduced yield (e.g., fruit or grain production).

Breaking Dormancy

Some plants that grow in cold regions need a certain number of days of low temperature (dormancy). Knowing the period of low temperature required by a plant, if any, is essential in getting it to grow to its potential.

Peaches are a prime example; most varieties require 700 to 1,000 hours between 32°F and 45°F before breaking their rest period and beginning growth. Lilies need six weeks of temperatures at or slightly below 33°F before blooming.

Hardiness

Plants are classified as hardy or nonhardy depending on their ability to withstand cold temperatures. *Hardy* plants are those that are adapted to the cold temperatures of their growing environment.

Woody plants in the temperate zone have very sophisticated means for sensing the progression from fall to winter. Decreasing day length and temperature trigger hormonal changes that cause leaves to stop photosynthesizing and to ship nutrients to twigs, buds, stems, and roots. An *abscission* layer forms where each petiole joins a stem, and the leaves eventually fall off. Changes within the trunk and stem tissues over a relatively short period of time "freeze-proof" the plant.

Winter injury to hardy plants may occur when temperatures drop too quickly in the fall before a plant has progressed to full dormancy. In other cases, a plant may break dormancy in mid- or late winter if the weather is unseasonably warm. If a sudden, severe cold snap follows the warm spell, otherwise hardy plants can be seriously damaged.

It is worth noting that the tops of hardy plants are much more cold-tolerant than the roots. Plants that normally are hardy to 10°F may be killed if they are in containers and the roots are exposed to 20°F. Many nurseries overwinter hardy plants in protective structures or protect plant roots by sinking pots in the ground or insulating pots with sawdust or mulch.

Winter injury also may occur because of *desiccation* (drying out) of plant tissues. People often forget that plants need water even during winter. When the soil is frozen, water movement into a plant is severely restricted. On a windy winter day, broadleaf evergreens can become water-deficient in a few minutes, and the leaves or needles will then turn brown. To minimize the risk of this type of injury, make sure your plants go into the winter well watered.

Water and Humidity

Most growing plants contain about 90 percent water, playing many roles in plants. It is:

- A primary component in photosynthesis and respiration
- The source of *turgor pressure* in cells (Like air in an inflated balloon, water is responsible for the fullness and firmness of plant tissue. Turgor is needed to maintain cell shape and ensure cell growth.)
- A solvent for minerals and carbohydrates moving through the plant
- A means for cooling leaves as it evaporates from leaf tissue during transpiration
- A regulator of stomatal opening and closing, thus controlling transpiration and, to some degree, photosynthesis
- The source of pressure to move roots through the soil
- The medium in which most biochemical reactions take place

Relative humidity is the ratio of water vapor in the air to the amount of water the air could hold at the current temperature and pressure. Warm air can hold more water vapor than cold air. Relative humidity (RH) is expressed by the following equation:

RH = water in air ÷ water air could hold
(at constant temperature and pressure)

Relative humidity is given as a percent. For example, if a pound of air at 75°F could hold four grams of water vapor and there are only three grams of water in the air, then the relative humidity (RH) is

$$3 \div 4 = 0.75 = 75\%$$

Water vapor moves from an area of high relative humidity to one of low relative humidity. The greater the difference in humidity, the faster water moves. This factor is important because the rate of water movement directly affects a plant's transpiration rate.

The relative humidity in the air spaces between leaf cells approaches 100 percent. When a stoma opens, water vapor inside the leaf rushes out into the surrounding air (Figure 1.25), and a bubble of high humidity forms around the stoma. By saturating this small area of air, the bubble reduces the difference in relative humidity between the air spaces within the leaf and the air adjacent to the leaf. As a result, transpiration slows down.

If wind blows the humidity bubble away, however, transpiration increases. Thus, transpiration usually is at its peak on hot, dry, windy days. On the other hand, transpiration generally is quite slow when temperatures are cool, humidity is high, and there is no wind.

Hot, dry conditions generally occur during the summer, which partially explains why plants wilt quickly in the summer. If a constant supply of water is not available to be absorbed by the roots and moved to the leaves, turgor pressure is lost and leaves go limp.

Table 1. 3. Plant macronutrients.

Element	Absorbed forms	Mobility in plants	Signs of excess	Signs of deficiency	Notes
Nitrogen (N)	NO_3- (nitrate) NH_4+ (ammonium)	Leachable, especially NO_3-. Mobile in plants.	Succulent growth; dark-green color; weak, spindly growth; few fruits. May cause brittle growth, especially under high temperatures.	Reduced growth, yellowing (chlorosis). Reds and purples may intensify in some plants. Reduced lateral bud breaks. Symptoms appear first on older growth.	In general, the best NH_4+:NO_3- ratio is 1:1. Under low-sugar conditions (low light), high NH_4+ can cause leaf curl. Uptake is inhibited by high P levels. The N:K ratio is extremely important. Indoors, the best N:K ratio is 1:1 unless light is extremely high. In soils with a high C:N ratio, more N should be supplied.
Phosphorus (P)	H_2PO_4- HPO_4- (phosphate)	Normally not leachable, but may leach from soil high in bark or peat. Not readily mobile in plants.	Shows up as micronutrient deficiency of Zn, Fe, or Co.	Reduced growth. Color may intensify. Browning or purpling of foliage in some plants. Thin stems, reduced lateral bud breaks, loss of lower leaves, reduced flowering.	Rapidly bound (fixed) on soil particles. Under acid conditions, fixed with Fe, Mg, and Al (aluminum). Under alkaline conditions, fixed with Ca. Important for young plant and seedling growth. High P interferes with micronutrient absorption and N absorption. Used in relatively small amounts compared to N and K.
Potassium (K)	K+	Can leach in sandy soils. Mobile in plants.	Causes N deficiency in plant and may affect the uptake of other positive ions.	Reduced growth, shortened internodes. Marginal burn or scorch (brown leaf edges), necrotic (dead) spots in leaves. Reduction of lateral bud breaks, tendency to wilt readily.	N:K balance is important. High N:low K favors vegetative growth; low N:high K promotes reproductive growth (flowers, fruit).
Magnesium (Mg)	Mg++	Leachable. Mobile in plants.	Interferes with Ca uptake.	Reduction in growth. Marginal chlorosis, interveinal chlorosis (yellow between the veins) in some species (may occur on middle or lower leaves). Reduction in seed production, cupped leaves.	Mg commonly is deficient in foliage plants because it is leached and not replaced. Epsom salts at a rate of 1 teaspoon per gallon may be used two times per year. Mg also can be absorbed by leaves if sprayed in a weak solution. Dolomitic limestone can be applied in outdoor situations to correct a deficiency.
Calcium (Ca)	Ca++	Normally not leachable. Moderately limited mobility in plants. Interferes with Mg absorption.	High Ca usually causes high pH, which then precipitates many micronutrients so that they become unavailable to plants.	Inhibition of bud growth, death of root tips. Cupping of maturing leaves, weak growth. Blossom-end rot of many fruits, pits on root vegetables.	Ca is important to pH control and rarely is deficient if the correct pH is maintained. Water stress (too much or too little) can affect Ca relations within plants, causing deficiency in the location where Ca was needed at the time of stress.
Sulfur (S)	SO_4- (sulfate)	Leachable. Not mobile in plants.	Sulfur excess usually is in the form of air pollution.	General yellowing of affected leaves or the entire plant.	S often is a carrier or impurity in fertilizers and rarely is deficient. It also may be absorbed from the air and is a by-product of combustion.

Table 1.4. Plant micronutrients.

Element	Absorbed forms	Signs of excess	Signs of deficiency	Notes
Iron (Fe)	Fe++, Fe+++	Rare except on flooded soils. Interveinal chlorosis, primarily on young tissue, which eventually may turn white.	Soil high in Ca, Mn, P, or heavy metals (Cu, Zn); high pH; poorly drained soil; oxygen-deficient soil; nematode attack on roots.	Add Fe in the chelate form. The type of chelate needed depends on soil pH.
Boron (B)	BO_3-(borate)	Blackening or death of tissue between veins.	Failure to set seed, internal breakdown, death of apical buds.	
Zinc (Zn)	Zn++	Shows up as Fe deficiency. Also interferes with Mg absorption.	"Little leaf" (reduction in leaf size), short internodes, distorted or puckered leaf margins, interveinal chlorosis.	
Copper (Cu)	Cu++, Cu+	Can occur at low pH. Shows up as Fe deficiency.	New growth small, misshapen, wilted.	May be found in some peat soils.
Manganese (Mn)	Mn++	Reduction in growth, brown spotting on leaves. Shows up as Fe deficiency.	Interveinal chlorosis of leaves followed by brown spots, producing a checkered effect.	Found under acid conditions.
Molybdenum (Mo)	MoO_4-(molybdate)		Interveinal chlorosis on older or midstem leaves, twisted leaves (whiptail).	
Chlorine (Cl)	Cl-	Salt injury, leaf burn. May increase succulence.	Leaves wilt, then become bronze, then chlorotic, then die; club roots.	

Plant Nutrition

Plant nutrition often is confused with fertilization. *Plant nutrition* refers to a plant's need for and use of basic chemical elements. *Fertilization* is the term used when these materials are added to the environment around a plant. A lot must happen before a chemical element in a fertilizer can be used by a plant.

Plants need 16 elements for normal growth. Three of them—carbon, hydrogen, and oxygen—are found in air and water. The rest are found in the soil.

Three soil elements are called *primary nutrients* because they are used in relatively large amounts by plants. They are nitrogen, phosphorus, and potassium. Calcium, magnesium, and sulfur are called *secondary nutrients* because they are used in moderate amounts. Often, primary and secondary nutrients are collectively called *macronutrients* (Table 1.3).

Seven other soil elements are used in much smaller amounts and are called *micronutrients*, or trace elements (Table 1.4). They are iron, boron, zinc, copper, manganese, molybdenum, and chlorine.

Most of the nutrients a plant needs are dissolved in water and then absorbed by its roots. In fact, 98 percent are absorbed from the soil-water solution, and only about 2 percent are actually extracted from soil particles.

Fertilizers

Fertilizers are materials containing plant nutrients that are added to the environment around a plant. Generally, they are added to the water or soil, but some can be sprayed on leaves. This method is called *foliar fertilization*. It should be done carefully with a dilute solution, because a high fertilizer concentration can injure leaf cells. The nutrient, however, does need to pass through the thin layer of wax (cutin) on the leaf surface.

Fertilizers are not plant food! Plants produce their own food from water, carbon dioxide, and solar energy through photosynthesis. This food (sugars and carbohydrates) is combined with plant nutrients to produce proteins, enzymes, vitamins, and other elements essential to growth.

Nutrient Absorption

Anything that reduces or stops sugar production in leaves can lower nutrient absorption. Thus, if a plant is under stress because of low light or extreme temperatures, nutrient deficiency may develop.

A plant's developmental stage or rate of growth also may affect the amount of nutrients absorbed. Many plants have a rest (dormant) period during part of the year. During this time, few nutrients are absorbed. As flower buds begin to develop, plants also may absorb different nutrients than they absorb during periods of rapid vegetative growth.

Plants in Communities

The preceding discussion focused on the structure and physiology of individual plants. Interactions among plants also are important for gardeners. The study of these interactions is called plant or landscape *ecology*.

In ornamental gardens, we generally aim to develop a stable community of plants that complement each other in form, color, leaf characteristics, and bloom. We must pay attention to the differing requirements of plants within this community.

A garden's framework often is defined by large shrubs or trees, which cast differing amounts of shade over the course of the year. When choosing plants to grow under or near large framework specimens, be sure their needs match the available light and moisture.

As trees and shrubs grow and mature, you may need to manipulate them, either by removing those that have outgrown their space or by selective pruning and thinning. Often, understory plants that did well when the landscape was young

Table 1.5. Common growth-affecting materials.

Compound	**Effect/Use**
Hormones	
Gibberellic acid (GA)	Stimulates cell division and elongation, breaks dormancy, speeds germination.
Ethylene gas (CH_2)	Ripening agent; stimulates leaf and fruit abscission.
Indoleacetic acid (IAA)	Stimulates apical dominance, rooting, and leaf abscission.
Plant growth regulators	
Indolebutyric acid (IBA)	Stimulates root growth.
Naphthalene acetic acid (NAA)	Stimulates root growth, slows respiration (used as a dip on holly).
Growth retardants (Alar, B-Nine, Cycocel, A-Rest)	Prevent stem elongation in selected crops (e.g., chrysanthemums, poinsettias, and lilies).
Herbicides (2,4-D, etc.)	Distort plant growth; selective and nonselective materials used for killing unwanted plants.

must be replaced with plants that are more shade tolerant. This process is a kind of plant *succession*, dictated by the changing light and moisture environment and carried out by the owner.

A lawn also is a changing landscape. It starts out as a mix of several adapted grass species on bare ground. Other plants (which we often call weeds) sprout from seed reserves in the soil. Additional seeds and plants move in and grow if conditions are right. Broadleaf weeds may find niches in bare areas or areas with compacted soil, or their low growth habit (dandelion) may escape mowing. Moss begins to take over where the lawn is thin, a common problem in semishaded areas. These changes are another example of plant succession.

To manage invasive plants, keep your lawn grasses competitive by using proper cultural practices, periodically overseeding, and using herbicides in certain situations. In spite of your best efforts, however, plant succession may occur.

Gardeners who plant wildflower mixtures often discover that there is much more variety in flowers the first year than in succeeding years. Some species do very well, and others simply cannot compete. Again, plant succession occurs.

The most short-term assemblage of plants in a garden occurs in annual vegetable and flower beds. Here there is no attempt to create a community that will last more than one season.

Since many of the most competitive weeds thrive in recently disturbed soil, it is a challenge to give desired annual crop plants an advantage. The plant that captures light first will grow and suppress plants beneath it. Early weed competition can have a devastating impact on crop growth. Consistent weeding, mulching, and the use of transplants improve the odds for annual vegetable and flower crops.

Another type of relationship between plants is called *allelopathy*. In this phenomenon, some plants produce compounds in their leaves, roots, or both that inhibit the growth of other plants. Black walnut is the most notorious example. Its roots can suppress many common vegetable plants, and its leaves, if mulched on a vegetable garden over the winter, can affect many annual crops as does an herbicide the following spring. Some of the worst weeds show allelopathic traits and prevent desired ornamental or vegetable species from growing.

Finally, there are relationships between plants that involve pollinators, animals, birds, pests, predators, and even nutrient transport between species through symbiotic fungi called *mycorrhizae*. These relationships are quite complex, and many are not well understood. They are the subject of active research and offer much to think about for thoughtful gardeners.

Plant Hormones and Growth Regulators

Plant hormones and growth regulators are chemicals that affect flowering; aging; root growth; distortion and killing of leaves, stems, and other parts; prevention or promotion of stem elongation; color enhancement of fruit; prevention of leafing and/or leaf fall; and many other conditions (Table 1.5). Very small concentrations of these substances produce major growth changes.

Hormones are produced naturally by plants, while *plant growth regulators* are applied to plants by humans. Plant growth regulators may be synthetic compounds (e.g., IBA and Cycocel) that mimic naturally occurring plant hormones or natural hormones that were extracted from plant tissue (e.g., IAA).

Applied concentrations of these substances usually are measured in parts per million (ppm) and in some cases parts per billion (ppb). These growth-regulating substances most often are applied as a spray to foliage or as a liquid drench to soil around a plant's base. Generally, their effects are short lived, and they may need to be reapplied in order to achieve the desired effect.

There are five groups of plant growth-regulating compounds: auxin, gibberellin (GA), cytokinin, ethylene, and abscisic acid (ABA). For the most part, each group contains both naturally occurring hormones and synthetic substances.

Auxin causes several responses in plants:

- Bending toward a light source (*phototropism*)
- Downward root growth in response to gravity (*geotropism*)
- Promotion of apical dominance
- Flower formation
- Fruit set and growth
- Formation of adventitious roots

Auxin is the active ingredient in most rooting compounds in which cuttings are dipped during vegetative propagation.

Gibberellins stimulate cell division and elongation, break seed dormancy, and speed germination. The seeds of some species are difficult to germinate; you can soak them in a GA solution to get them started.

Unlike other hormones, *cytokinins* are found in both plants and animals. They stimulate cell division and often are included in the sterile media used for growing plants from tissue culture. If a medium's mix of growth-regulating compounds is high in cytokinins and low in auxin, the tissue culture explant (small plant part) will produce numerous shoots. On the other hand, if the mix has a high ratio of auxin to cytokinin, the explant will produce more roots. Cytokinins also are used to delay plant aging and death (*senescence*).

Ethylene is unique in that it is found only in the gaseous form. It induces ripening, causes leaves to droop (*epinasty*) and drop (abscission), and promotes senescence. Plants often increase ethylene production in response to stress, and ethylene often is found in high concentrations within cells at the end of a plant's life. The increased ethylene in leaf tissue in the fall is part of the reason leaves fall off of trees. Ethylene also is used to ripen fruit (e.g., green bananas).

Abscisic acid (ABA) is a general plant growth inhibitor. It induces dormancy; prevents seeds from germinating; causes abscission of leaves, fruits, and flowers; and causes stomata to close. High concentrations of ABA in guard cells during periods of drought stress probably play a role in stomatal closure.

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Chapter 02

Plant Identification

By Marty Wingate, Master Gardener, King County, Washington State University. Adapted for use in Kentucky by Richard Durham, consumer horticulture Extension specialist and state Master Gardener coordinator, University of Kentucky.

In this chapter:

Learning about new plants is an exciting venture. Sometimes you are looking for a plant to fill a certain spot in your garden. At other times, you want to complete a particular color scheme, or your attention is caught by a magnificent tree, shrub, or perennial in a public or private garden. When you come across an unfamiliar plant, it can be frustrating to try to figure out what it is without knowing some of the botanical principles of plant identification.

The rules of plant identification and nomenclature (naming) may seem complex and more trouble than they are worth, but knowing the basic rules and applying them to everyday gardening leads to a better understanding of plants and how they are classified. Identification may be as simple as knowing that members of the mint family (*Lamiaceae*) have square stems. (Rub a stem of oregano or dead nettle between your fingers as a test.) Or identification may be as complicated as deciding among a series of choices that eventually lead to identification of the plant's genus and species. (This process is called "keying out," and it will be explained in more detail later.)

You'll be able to dazzle your family and friends by rattling off names such as *Liriodendron tulipfera* (commonly known as the tulip tree or tulip poplar and the current state tree of Kentucky) by learning about plant identification. You'll also be able to determine a plant's cultural requirements, ultimate size, flowering and fruiting habits, propagation methods, and common problems. Many insects and diseases are fairly host-specific; that is, they attack only certain species (and sometimes only certain varieties within a species) or certain genera. When you know a plant's genus and species, you can identify problems and make a diagnosis more easily, efficiently, and with more certainty. In fact, the first step in diagnosing a sick plant is to identify the plant.

Plant Names

Plants follow the same kind of classification system as do animals: kingdom, division, class, order, family, genus, and species. As gardeners, we are mostly concerned with the last three categories:

Family—A broad group of plants with common characteristics. The family name is written in plain text, its first letter is capitalized, and it ends in "aceae." For example, the nightshade family is Solanaceae. Common plants in this family include tomato, potato, pepper, eggplant, and tobacco. Some families may be listed using an older style; you may find the daisy family written as either Compositae or Asteraceae, for example. That's because sometimes taxonomists (people who make decisions about plant names) don't agree.

Genus (plural genera)—A category within a family that contains related species. Families may contain a few genera or many. For example, the monkey puzzle tree, *Araucaria araucana*, is one of only two genera in the family Auricaceae. The rose family (Rosaceae), on the other hand, includes more than 100 genera—everything from apples to spirea. Genus names are written in italics or are underlined, and the first letter is capitalized. For example, *Picea* is the genus for spruce.

Species—A population of individual plants within a genus that are capable of interbreeding freely with one another. For example, *Picea abies* is the species for Norway spruce.

Other terms also are important in plant identification:

Specific epithet—The second word in a plant name. (The word "species" refers to the plant, but the term "specific epithet" refers to the actual word in the name.) It is italicized, and the first letter is not capitalized.

Variety—A subset of a species. Varieties are populations of plants divided by geography and some significantly different characteristic. For example, *Rudbeckia fulgida,* the orange coneflower native to North America, is a desirable perennial that, compared to many *Rudbeckias,* is less susceptible to powdery mildew. The variety *sullivantii* has exceptional three- to four-inch, bright yellow flowers. The popular cultivar 'Goldsturm' is a more compact form of this variety. The word "variety" can be abbreviated as "var."; it is not italicized. Subspecies (ssp.) often is used in Britain with the same meaning.

Form—A naturally occurring characteristic that makes the plant different from other plants in the same population. For example, the pink-flowering dogwood, *Cornus florida* f. *rubra,* occurs naturally in its native habitat in the eastern United States, where it grows among the white-flowered form, which is more prominent.

Hybrids

A hybrid is a cross between two varieties or species, whether of the same genus or two different genera. F1 hybrids, common among annual vegetables and flowers, are highly controlled and manipulated. They are a cross between two lines within a species, each of which has been selected and repeatedly inbred for specific traits.

Hybrid names are written with an × between the genus and specific epithet. The latter word is made up, and often "media" is used.

Some hybrids occur in nature, such as *Arctostaphylos* × *media*, which is a cross between kinnikinnick (*A. uva-ursi*) and the taller growing *A. columbiana* and is found where the two parents grow in close proximity.

Hybridization is common in cultivation, as breeders look for better plants for our gardens. Sometimes, cultivated plants grow close enough together to cross on their own. 'Eddie's White Wonder' is a cross between two native dogwood species: *Cornus nuttallii* and *Cornus florida*. 'Arthur Menzies,' an impressive winter-blooming evergreen shrub, was an accidental cross between *Mahonia bealei* and *Mahonia lomariifolia*.

Occasionally, an intergeneric hybrid occurs. The commonly planted Leyland cypress was an accidental cross between two species found at a nursery in England. The parents are the Monterey cypress, *Cupressus macrocarpa*, and the Alaskan cedar, *Chamaecyparis nootkatensis*. The correct way to write an intergeneric hybrid is to put the × before the genus. Leyland cypress is written as × *Cupressocyparis leylandii*. (The two generic names were combined.)

Cultivars

The term cultivar is short for "cultivated variety." These are plants within a species that have been selected especially for a particular characteristic and propagated—usually asexually—to continue this characteristic. Bigger blooms, better color, larger fruits, and more compact growth are a few reasons a plant may be selected. The cultivar name is written in plain text and set off by single quotes.

Gardeners are familiar with cultivar names and often refer to plants by only the genus and cultivar, especially if the cultivar is the result of a hybrid cross. Thus we see *Penstemon* 'Apple Blossom,' *Fuchsia* 'Santa Claus,' and *Rhododendron* 'PJM.'

Cultivars may arise from chance seedlings, selective breeding, or a sport (a spontaneous genetic change). The continuously blooming climbing rose 'New Dawn' was found as a sport of an old once-blooming climber, 'Dr. W. van Fleet.'

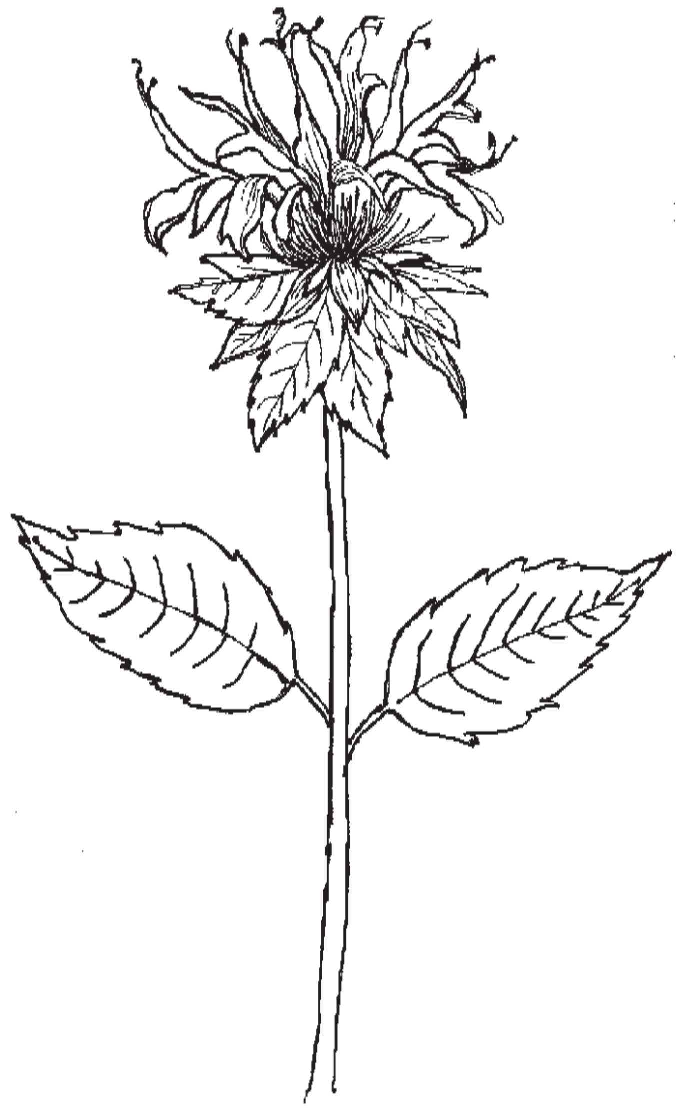
Before 1959, cultivar names could be Latin or at least sound like it. *Viburnum opulus* 'Roseum,' the snowball viburnum, was named before 1959. After that, cultivars were named in modern languages, so you will find cultivars with Japanese, German, Dutch, or English names.

For a while, the practice was to anglicize cultivar names that English speakers found difficult to pronounce (or that were difficult to market to English speakers). This practice not only was unfair to breeders but caused a great deal of confusion. Now, growers and nurseries are encouraged to use the correct names, whatever the language. Thus, for example, the well-known *Penstemon* 'Garnet' should be listed as *Penstemon* 'Andenken an Freidrich Hahn.'

Keys are tools for classification and identification. When using a key, you move from general to more and more specific descriptions (and eventually to identification) by choosing among linked statements. These statements have descriptions, such as "leaves hairy" and "leaves smooth." Choosing the statement that more correctly describes a specific plant leads to a progressive narrowing of choices until you arrive at the name of the plant.

Keys are found in many plant identification books and on the Internet. Some include the whole range of flowering plant families; others cover only one genus, such as roses.

The paired statements in a key may be lettered or numbered. Sometimes the two statements are separated by a lot of space, since there are even more choices below each statement. See Table 2.1 for a brief example of a key.



Practicing Plant Identification

Practice—as always—makes perfect. The more you use botanical names for plants, the more quickly you will remember them and the less self-conscious you'll be when you say them. Here are some ways to learn and remember plant names:

- Say the names over and over, using any opportunity that comes along. Repeat the names of plants in your own garden, even when you are alone. Say aloud the names of plants you recognize in other gardens.
- Spend a little time each day on plant names. The names and characteristics of plants should become almost second nature.

Table 2.1. Example of a key.

I. Leaves opposite	1a. Leaves mostly less than 4 cm (1 5/8")	2a. Leaf margins toothed	3a. Leaf margins spiny-toothed	*Osmanthus delavayi*
			3b. Leaf margins crenate*	*Euonymus fortunei*
		2b. Leaf margins entire		*Buxus sempervirens*
	1b. Leaves more than 4 cm			*Viburnum davidii*
II. Leaves alternate	1a. Leaves mostly less than 6 cm (2 3/8")	2a. Stems armed (thorny)		*Pyracantha* species
		2b. Stems not armed	3a. Leaves oblanceolate*	*Pieris japonica*
			3b. Leaves ovate*	*Vaccinium ovatum*
	1b. Leaves greater than 6 cm		4a. Leaves ovate*	*Prunus lusitanica*
			4b. Leaves obovate*	*Prunus laurocerasus*

* Key: crenate = rounded scallops, oblanceolate = broad tip and tapering base, ovate = oval-shaped, obovate = oval-shaped with broadest part of leaf at the tip.

- Try to learn the meaning of the names so they make more sense to you. For example, *Acer macrophyllum* is the bigleaf maple (*macro* meaning "large" and *phyllum* meaning "leaf"). Color also plays an important part in plant names. A few examples are *Acer rubrum*, or red maple, which incorporates the Latin "rub" for red; *Symphoricarpos alba*, or snowberry, which uses the Latin "alba" for white; and *Ribes sanguineum*, or red-flowering currant, which uses the Latin"sanguin" for blood.
- When you look at plants, note identifying features such as leaf shape and arrangement, growth habit, and flower or fruit appearance. All these aspects help in correct identification. Refer to Chapter 1 for illustrations.
- Practice plant identification while visiting arboretums, nurseries, and public gardens (enjoyable in itself). These places often have plant tags or lists of plants.
- Practice using keys such as the one in *Dichotomous Keys for the Arboretum Walk* (https://www.uky.edu/hort/sites/www.uky.edu.hort/files/pages-attachments/treekeys.pdf)

Chapter 03

Plant Propagation

Adapted from the Virginia Master Gardener Handbook. Edited by Ray McNeilan, Extension agent emeritus, Multnomah County, Oregon State University. Edited for Kentucky by Richard Durham, consumer horticulture Extension specialist and state Master Gardener coordinator, University of Kentucky.

In this chapter:

Sexual Propagation

Sexual propagation involves the union of the pollen (male) with the egg (female) to produce a seed. The seed is made up of three parts: the outer seed coat, which protects the seed; the endosperm, which is a food reserve; and the embryo, which is the young plant itself. When a seed is mature and put in a favorable environment, it will germinate, or begin active growth. In this section, seed germination and transplanting of seeds are discussed.

Seed

To obtain quality plants, start with good quality seed from a reliable dealer. Select varieties that will provide the size, color, and habit of growth desired. Choose varieties adapted to your area that will reach maturity before an early frost. Many new vegetable and flower varieties are hybrids, which cost a little more than open pollinated types. However, hybrid plants usually have more vigor and uniformity and better production than nonhybrids and sometimes have specific disease resistance or other unique cultural characteristics.

Although some seeds will keep for several years if stored properly, it is advisable to purchase only enough seed for the current year's use. Good seed will not contain seed of any other crop or debris. Printing on the seed packet usually indicates essential information about the variety, the year for which the seeds were packaged, germination percentage you may typically expect, and notes of any chemical seed treatment. If seeds are obtained well in advance of the actual sowing date or are stored surplus seeds, keep them in a cool, dry place. Laminated foil packets help ensure dry storage. Paper packets are best kept in tightly closed containers and maintained around 40°F in low humidity.

Some gardeners save seed from their own gardens; however, such seed is the result of random pollination by insects or other natural agents and may not produce plants typical of the parents, which is especially true of the many hybrid varieties. (See Chapter 20, Vegetable Gardening, for information on saving vegetable seed.) Most seed companies take great care in handling seeds properly. Generally, do not expect more than 65 percent to 80 percent of the seeds to germinate. From those germinating, expect about 60 percent to 75 percent to produce satisfactory, vigorous, sturdy seedlings.

Germination

There are four environmental factors that affect germination: water, oxygen, light, and heat.

Water

The first step in the germination process is imbibition, or absorption of water. Even though seeds have great absorbent power due to the nature of the seed coat, the amount of available water in the germination medium affects the uptake of water. An adequate, continuous supply of water is important to ensure germination. Once germination has begun, a dry period will cause death of the embryo.

Light

Light is known to stimulate or to inhibit germination of some seed. The light reaction involved here is a complex process. Examples of crops that need light to assist seed germination are ageratum, begonia, browallia, impatiens, lettuce, and petunia. Conversely, calendula, centaurea, annual phlox, verbena, and vinca will germinate best in the dark. Other plants are not specific at all. Seed catalogs and seed packets often list germination or cultural tips for individual varieties. When sowing light-requiring seed, do as nature does, and leave them on the soil surface. If they are to be covered at all, cover them lightly with fine peat moss or fine vermiculite. These two materials, if not applied too heavily, will permit some light to reach the seed and will not limit germination. When starting seed in the home, supplemental light can be provided by fluorescent fixtures suspended 6 to 12 inches above the seeds for 16 hours a day.

Oxygen

In all viable seed, respiration takes place. Respiration in dormant seed is low, but some oxygen is required. The respiration rate increases during germination; therefore, the medium in which the seeds are placed should be loose and well aerated. If the oxygen supply during germination is limited or reduced, germination can be severely retarded or inhibited.

Heat

A favorable temperature is another important requirement of germination. It affects the rate of germination as well as germination percentage. Some seeds will germinate over a wide range of temperatures, while others require a narrow range. Many seed have minimum, maximum, and optimum temperatures at which they germinate. For example, tomato seed has a minimum germination temperature of 50°F and a maximum temperature of 95°F but an optimum germination temperature of about 80°F. When germination temperatures are listed, usually the optimum temperatures are given unless otherwise specified. Generally, 65° to 75°F is best for most plants. This range means germination flats often have to be placed in special chambers or on radiators, heating cables, or heating mats to maintain optimum temperature. The importance of maintaining proper medium temperature to achieve maximum germination percentages cannot be overemphasized.

Germination will begin when certain internal requirements have been met. A seed must have a mature embryo, contain an endosperm large enough to sustain the embryo during germination, and contain sufficient hormones to initiate the process.

Methods of Breaking Dormancy

One of the functions of dormancy is to prevent a seed from germinating before it is surrounded by a favorable environment. In some trees and shrubs, seed dormancy is difficult to break, even when the environment is ideal. The seed can be treated in various ways to break dormancy and cause it to begin germinating.

Seed Scarification

Seed scarification involves breaking, scratching, or softening the seed coat so that water can enter and begin the germination process. There are several methods of scarifying seeds. In acid scarification, seeds are put in a glass container and covered with concentrated sulfuric acid. The seeds are gently stirred and allowed to soak from 10 minutes to several hours, depending on the hardness of the seed coat. When the seed coat has become thin, seeds can be removed, washed, and planted. Another scarification method is mechanical. Seeds are filed with a metal file, rubbed with sandpaper, or cracked with a hammer to weaken the seed coat. Hot water scarification involves putting the seed into water that is 170° to 212°F. The seeds are allowed to soak in the water as it cools for 12 to 24 hours and then planted. A fourth method is one of warm, moist scarification. In this case, seeds are stored in nonsterile, warm, damp containers, where the seed coat will be broken down by decay over several months.

Seed Stratification

Seeds of some fall-ripening trees and shrubs of the temperate zone will not germinate unless chilled underground as they overwinter. This so-called "afterripening" can be accomplished artificially by a practice called "stratification."

The following stratification procedure is usually successful. Put sand or vermiculite in a clay pot to about one inch from the top. Place the seeds on top of the medium and cover with one-half inch of sand or vermiculite. Wet the medium thoroughly and allow excess water to drain through the hole in the pot. Place the pot containing the moist medium and seeds in a plastic bag and seal. Place the bag in a refrigerator. Periodically check to see that the medium is moist but not wet. Additional water will probably not be necessary. After 10 to 12 weeks, remove the bag from the refrigerator, take the pot out and set it in a warm place in the house, and water often enough to keep the medium moist. Soon the seedlings should emerge. When the young plants are about three inches tall, transplant them into pots to grow until time for setting outside.

Another procedure that is usually successful uses sphagnum moss or peat moss. Wet the moss thoroughly, then squeeze out excess water with your hands. Mix seed with the sphagnum or peat and place in a plastic bag. Seal the bag and put it in a refrigerator. Check it periodically. If there is condensation on the inside of the bag, the process will probably be successful. After 10 to 12 weeks, remove the bag from the refrigerator and plant the seeds in pots to germinate and grow. Handle seeds carefully, because often the small roots and shoots are emerging at the end of the stratification period and care must be taken not to break these off. Temperatures in the range of 35° to 45°F (2° to 7°C) are effective, and most refrigerators operate in this range. Seeds of most fruit and nut trees can be successfully germinated by these procedures. Seeds of peaches should be removed from the hard pit. Care must be taken when cracking pits, because any injury to the seed itself can be an entry path for disease organisms.

Starting Seeds

Media

A wide range of materials can be used to start seeds, from plain vermiculite or mixtures of soilless media to various amended soil mixes. With experience, you will learn what works best under your conditions. However, keep in mind that germinating medium should be rather fine and uniform, but also well aerated and loose. It also should be free of insects, disease organisms, and weed seeds; of low fertility (indicated by low total soluble salts); and capable of holding and moving moisture by capillary action.

The importance of using a sterile medium and container cannot be overemphasized (Figure 3.1). The home gardener can treat a small quantity of soil mixture in an oven to make it sterile. Place slightly moist soil in a heat-resistant container in an oven set at about 250°F. Use a candy or meat thermometer

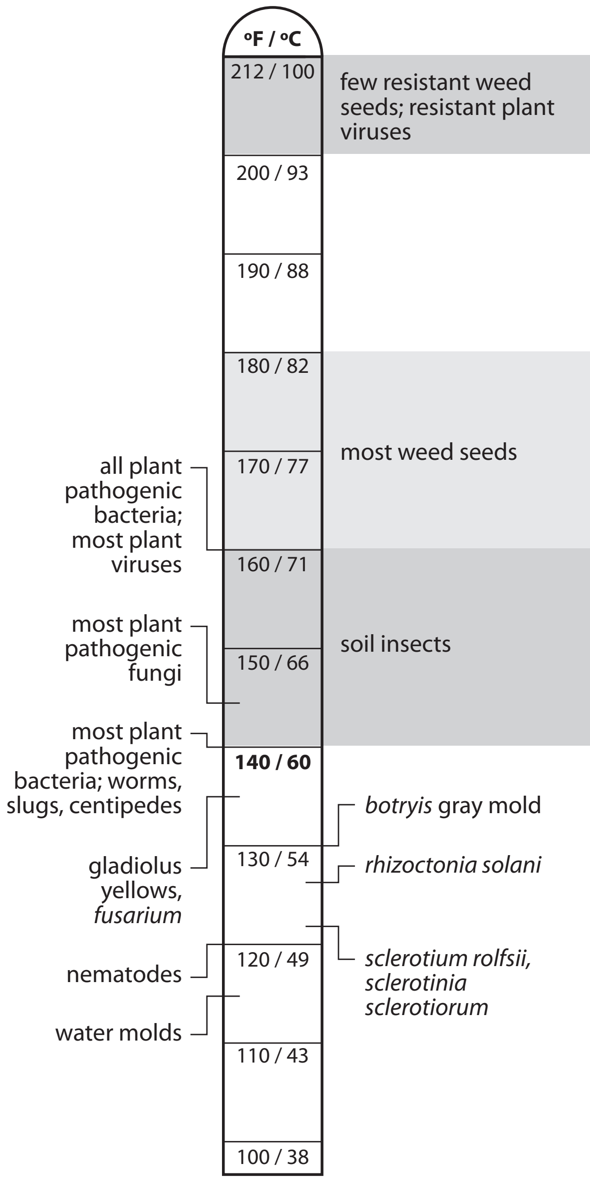


Figure 3.1. Temperatures at which soil organisms are killed.

to ensure that the mix reaches a temperature of 140°F (or up to 180°F to control weed seeds) for at least 30 minutes. Avoid overheating, as it can be extremely damaging to the soil. Be aware that the heat will release unpleasant odors during the sterilization process. This treatment should prevent damping-off and other plant diseases as well as eliminate potential plant pests. Growing containers and implements should be washed to remove any debris then rinsed in a solution of one part chlorine bleach to 10 parts water.

An artificial, soilless mix can also provide a good germination medium and produce uniform plant growth. The basic ingredients of such a mix are sphagnum peat moss and vermiculite, both of which are readily available, easy to handle, and lightweight. One mixture that has these characteristics is a combination of one-third sterilized soil, one-third sand or vermiculite or perlite, and one-third sphagnum peat moss.

"Peatlite" mixes or similar products are commercially available or can be made at home using this recipe: four quarts of shredded sphagnum peat moss, four quarts of fine vermiculite, one tablespoon of superphosphate, and two tablespoons of ground limestone. (Superphosphate and ground limestone are generally readily available from most garden centers or farm supply stores and can be found in the fertilizer section.)Mix thoroughly. These mixes have little fertility, so seedlings must be watered with a diluted fertilizer solution soon after they emerge. Do not use garden soil by itself to start seedlings; it is not sterile, is too heavy, and will not drain well.

Containers

Flats and trays can be purchased, or you can make your own from scrap lumber. A convenient size would be 12 to 18 inches long, 12 inches wide, and two inches deep. To ensure good drainage, leave an opening about one-eight inch wide between boards in the bottom of the tray or drill a series of holes where two board meet.

You can also make your own containers for starting seeds by recycling cottage cheese containers, bottoms of milk cartons, bleach bottles, metal pie pans, etc., as long as good drainage is provided. At least one company has developed a form for recycling newspaper to make pots, and another has developed a method for the consumer to make and use compressed blocks of soil mix instead of pots. Clay or plastic pots also can be used.

Numerous types of pots and strips made of compressed peat are on the market. Plant bands and plastic cell packs, which are strips of connected individual pots, are also available. With these types of containers, each cell or minipot holds a single plant, which reduces the risk of root injury when transplanting. Peat pellets, peat or fiber-based blocks, and expanded foam cubes can also be used for seeding.

Seeding

The proper time for sowing seeds for transplants depends upon when plants may safely be moved outdoors in your area. This period can be from four to 12 weeks prior to transplanting, depending upon speed of germination, rate of growth, and cultural conditions such as temperature and amount of sunlight (Table 3.1). A common mistake is to sow seeds too early and then attempt to hold the seedlings back under poor light or improper temperature ranges, which usually results in tall, weak, spindly plants that do not perform well in the garden.

Steps for seeding (see Figure 3.2):

After selecting a container, fill it with moistened growing medium to within three-quarters of an inch of the top. For very small seeds, at least the top one-quarter inch should be a fine, screened mix or a layer of vermiculite. Firm the medium at the corners and edges with your fingers or a block of wood to provide a uniform, flat surface.

For medium and large seeds, make furrows one to two inches apart and one-eighth to one-quarter inch deep across the surface of the container using a narrow board, pointed end of a plastic

Table 3.1. Seed Requirements.

Approx. Time to Seed before Last Spring Frost*	Plant	Approx. Germ. Time (days)	Germ. Temp. (Degrees F)	Germ. in Light (L) or Dark (D)
12 weeks or more	Begonia	10 - 15	70	L
	Browallia	15 - 20	70	L
	Geranium	10 - 20	70	L
	Larkspur	5 - 10	55	D
	Pansy (Viola)	5 - 10	65	D
	Vinca	10 - 15	70	D
10 weeks	Dianthus	5 - 10	70	--
	Impatiens	15 - 20	70	L
	Petunia	5 - 10	70	L
	Portulaca	5 - 10	70	D
	Snapdragon	5 - 10	65	L
	Stock	10 - 15	70	--
	Verbena	15 - 20	65	D
8 weeks	Ageratum	5 - 10	70	L
	Alyssum	5 - 10	70	--
	Broccoli	5 - 10	70	--
	Cabbage	5 - 10	70	--
	Cauliflower	5 - 10	70	--
	Celosia	5 - 10	70	--
	Coleus	5 - 10	65	L
	Dahlia	5 - 10	70	--
	Eggplant	5 - 10	70	--
	Head lettuce	5 - 10	70	L
	Nicotiana	10 - 15	70	L
	Pepper	5 - 10	80	--
	Phlox	5 - 10	65	D
6 weeks	Aster	5 - 10	70	--
	Balsam	5 - 10	70	--
	Centurea	5 - 10	65	D
	Marigold	5 - 10	70	--
	Tomato	5 - 10	80	--
	Zinnia	5 - 10	70	--
4 weeks or less	Cucumber	5 - 10	85	--
	Cosmos	5 - 10	70	--
	Muskmelon	5 - 10	85	--
	Squash	5 - 10	85	--
	Watermelon	5 - 10	85	--

*Length of time is based on relative rate of seeding growth and how long it will take to obtain a sizeable transplant.

pot label, or even the dull point of a pencil. Sowing in rows produces good exposure to light and air movement, and if dampingoff fungus appears, there is less chance of it spreading. Also, seedlings in rows are easier to label and handle at transplanting time than those that have been sown in a broadcast manner. Sow seeds thinly and uniformly in rows by gently tapping the packet of seed as you move it along the row. If seeds require darkness for germination, lightly cover them with dry vermiculite or sifted medium.

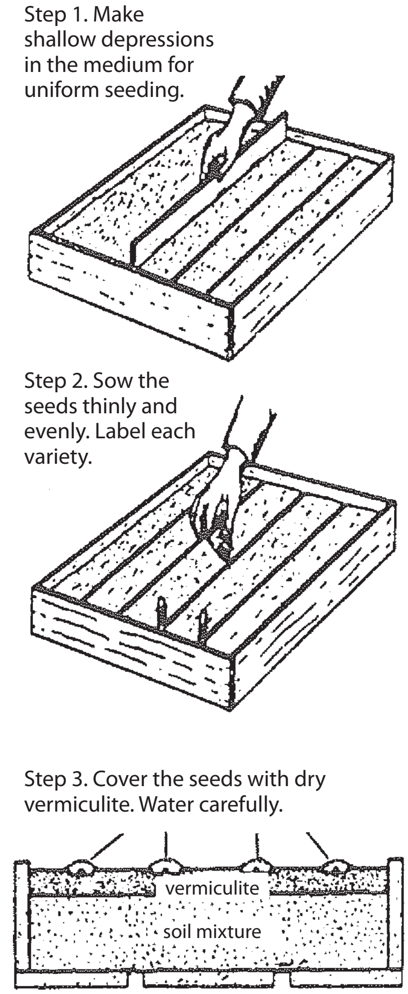


Figure 3.2. Sowing seeds in a starter flat.

Do not plant seeds too deeply. A suitable planting depth is usually about twice the diameter of the seed. Extremely fine seed such as petunia, begonia, and snapdragon are not covered; they are lightly pressed into the medium or watered in with a fine mist. If fine seeds are broadcast, strive for a uniform stand by sowing half the seeds in one direction, then sowing the remaining seed in the opposite crosswise direction.

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

Seed Tape

Most garden stores and seed catalogs offer indoor and outdoor seed in tape. Seed tape, although much more expensive per seed, has precisely spaced seeds enclosed in an organic, water-soluble material. When planted, the tape dissolves and seeds germinate normally. Seed tapes are especially convenient for tiny, hard-to-handle seeds. They allow uniform emergence, eliminate overcrowding, and permit sowing in perfectly straight rows. 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 seeds before they are planted in pots or in the garden. This method reduces time to germination, as temperature and moisture are easy to control. A high percentage of germination is achieved, since environmental factors are optimum. To pregerminate seeds, lay them between folds of a cotton cloth or on a layer of vermiculite in a shallow pan. Keep seed in a warm place, and, because continued attention to watering is critical, keep the cloth or vermiculite moist. When roots begin to show, place seeds in containers or plant them directly in the garden. While transplanting pregerminated seedlings, be careful not to break off tender roots.

When planting pregerminated seeds in containers that will be set out in the garden later, use containers that are two to three inches in diameter, with one seed per container. Plant the seeds at only half the recommended depth. Gently press a little soil over the sprouted seed and then add about one-quarter inch of milled sphagnum or sand to the soil surface, which will keep the surface uniformly moist and enable the shoot to push through easily. Keep these containers in a warm place and care for the seedlings as for any other newly transplanted seedlings.

Watering

After the seed has been sown, thoroughly moisten the planting mix. Use a fine mist or place the containers in a pan or tray that contains about one inch of warm water. Avoid splashing or excessive flooding, which might displace small seeds. When the planting mix is saturated, set the container aside to drain. The soil should be moist but not wet.

Ideally, seed flats should remain sufficiently moist during the germination period without having to add water. One way to maintain moisture is to slip the whole flat or pot into a clear plastic bag after the initial watering. The plastic should be at least one inch from the soil. Keep the container out of direct sunlight; otherwise, the temperature may rise to the point at which the seeds will be harmed. Many home gardeners cover their flats with panes of glass instead of a plastic sleeve. Be sure to remove the plastic bag or glass cover as soon as the first seedlings appear. You can then surface-water if you do it carefully and use good judgment.

Manual watering, if not done uniformly, can result in plants being overwatered or drying out. Excellent germination and moisture uniformity can be obtained with a low-pressure misting system. In the spring, a satisfactory schedule might be, during the daytime, four seconds of mist every six minutes or 10 seconds of mist every 15 minutes. Misting should be monitored from time to time and the frequency adjusted to ensure that the medium is not waterlogged.

Bottom heat is an asset with a mist system. As mist and water in the medium evaporate, the medium is cooled. Bottom heat will provide more uniform temperatures to aid germination. Sub-irrigation or watering from below can work well to keep the flats moist, but because the flats or pots are sitting in water constantly, the soil may absorb too much water, and the seeds may rot due to lack of oxygen.

Temperature and Light

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 thermostatically controlled heating cables is an excellent method of providing constant heat.

After germination and seedling establishment, move flats to a light, airy, cooler location at a 55° to 60°F night temperature and a 65° to 70°F day reading, which will prevent soft, leggy growth and minimize disease troubles. Some crops, of course, may germinate or grow best at a different constant temperature and must be handled separately from the bulk of the plants.

Seedlings must receive bright light after germination. Place them in a window facing south, if possible. If a large, bright window is not available, place seedlings under a fluorescent light. Use two 40-watt, cool-white fluorescent tubes or special plant growth lamps. Position plants six inches from the tubes and keep lights on about 16 hours each day. As seedlings grow, lights should be raised.

Transplanting and Handling

If plants have not been seeded in individual containers, they must be transplanted to give them proper growing space. One of the most common mistakes made is leaving the seedlings in the seed flat too long. The ideal time to transplant young seedlings is when they are small and there is little danger from setback. This is usually 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 tall and leggy.

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

To transplant, carefully dig up the small plants with a knife or wooden plant label. Let the group of seedlings fall apart and pick out individual plants. Gently ease them apart in small groups, which will make it easier to separate individual plants. Avoid tearing roots, and handle small seedlings by their leaves, not their delicate stems. Punch a hole in the medium into which the seedling will be planted. Make it deep enough so the seedling can be put at the same depth at which it was growing in the seed flat. Small plants or slow growers should be placed one inch apart, and rapidly growing, large seedlings about two inches apart. 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, and continue watering and fertilizing as in the seed flats.

Most plants transplant well and can be started indoors, but a few plants are difficult to transplant. These are generally directly seeded outdoors or sown directly into individual containers indoors. Examples include zinnias and cucurbits such as melons and squash.

Propagation of Ferns by Spores

Though ferns are more easily propagated by other methods, some gardeners like the challenge of raising ferns from spores. One tested method for small quantities follows:

Put a solid, sterilized brick (bake at 250°F for 30 minutes) in a pan and add water to cover the brick. When the brick is wet throughout, squeeze a thin layer of moist soil and peat (1:1) onto the top of the brick.

Pack a second layer (about an inch) on top of that. Sprinkle spores on top. Cover with plastic (not touching the spores) and put the plastic-encased brick in a warm place in indirect light. It may take up to a month or more for the spores to germinate. Keep the brick moist at all times.

A prothallus (one generation of the fern) will develop first from each spore, forming a light green mat. Mist the mat lightly once a week to maintain high surface moisture; the sperm must be able to swim to the archegonia (female parts). After about three weeks, fertilization should have occurred.

Pull the mat apart with tweezers in one-quarter-inch squares and space the squares one-half inch apart in a flat layering two inches of sand, one-quarter inch of charcoal, and about two inches of soil/peat mix. Cover with plastic and keep moist.

When fern fronds appear and become crowded, transplant them to small pots. Gradually reduce humidity until the fern plants can survive in the open. Exposure to light may be increased at this time.

Containers for Transplanting

A wide variety of containers for transplanting seedlings is available. Containers should be economical, durable, and make good use of space. The type selected will depend on the type of plant to be transplanted and individual growing conditions. Standard pots may be used, but they waste a great deal of space and may not dry out rapidly enough for the seedling to have sufficient oxygen for proper development.

Containers made out of pressed peat can be purchased in varying sizes. Individual pots or strips of connected pots fit closely together are inexpensive, and can be planted directly in the garden. When setting out plants grown in peat pots, be sure to cover the pot completely. If the top edge of the peat pot extends above the soil level, it may act as a wick and draw water away from the soil in the pot. To prevent this, tear off the top lip of the pot and then plant flush with the soil level.

Compressed peat pellets, when soaked in water, expand to form compact, individual pots. They waste no space, don't fall apart as badly as peat pots, and can be set directly out in the garden. If you wish to avoid transplanting seedlings altogether, compressed peat pellets are excellent for direct sowing.

Community packs are containers in which there is room to plant several plants. They are generally inexpensive. The main disadvantage of a community pack is that roots of individual plants must be broken or cut apart when separating the plants to put out in the garden.

Both community packs and cell packs are frequently used by commercial bedding plant growers, as they withstand frequent handling. In addition, many homeowners find a variety of materials from around the house useful for containers. These homemade containers should be deep enough to provide adequate soil and have plenty of drainage holes in the bottom.

Hardening Plants

Hardening is the process of altering the quality of plant growth to withstand the change in environmental conditions that occurs when plants are transferred from a greenhouse or home to the garden. A severe check in growth may occur if plants produced in the home are planted outdoors without a transition period. Hardening is most critical with early crops, when adverse climatic conditions can be expected.

Hardening can be accomplished by gradually lowering temperatures and relative humidity and reducing water. This procedure results in an accumulation of carbohydrates and a thickening of cell walls. A change from a soft, succulent type of growth to a firmer, harder type is desired.

This process should be started at least two weeks before planting in the garden. If possible, plants should be moved to a 45° to 50°F temperature indoors or outdoors in a shady location. A cold frame is excellent for this purpose. When put outdoors, plants should be shaded, then gradually moved into sunlight. Each day, gradually increase the length of exposure. Reduce the frequency of watering to slow growth, but don't allow plants to wilt. Don't put tender seedlings outdoors on windy days or when temperatures are below 45°F. Even cold-hardy plants will be hurt if exposed to freezing temperatures before they are hardened. After proper hardening, however, plants can be planted outdoors and light frosts will not damage them.

The hardening process is intended to slow plant growth. If carried to the extreme of actually stopping plant growth, significant damage can be done to certain crops. For example, cauliflower will make thumb-size heads and fail to develop further if hardened too severely. Cucumbers and melons will stop growth if hardened.

Asexual Propagation

Asexual propagation is the best way to maintain some species, particularly an individual plant that best represents that species. Clones are groups of plants that are identical to their one parent and can only be propagated asexually. The Bartlett pear (first selected in 1770) and Delicious apple (first selected in 1870) are two examples of clones that have been asexually propagated for many years.

Major methods of asexual propagation are cuttings, layering, division, and budding/grafting. Cuttings involve rooting a severed piece of the parent plant; layering involves rooting a part of the parent and then severing it; and budding/grafting is joining two plant parts from different varieties.

Cuttings

Many types of plants, both woody and herbaceous, are frequently propagated by cuttings. A cutting is a vegetative plant part that is severed from the parent plant in order to regenerate itself, thereby forming a whole new plant.

Take cuttings with a sharp blade to reduce injury to the parent plant. First, dip the cutting tool in rubbing alcohol or a mixture of one part bleach to nine parts water to prevent transmitting diseases from infected plant parts to healthy ones. When making cuttings, start with the youngest tissues and move toward older tissue. Re-dip (disinfect) the cutting tool each time you move to a new branch or a new plant. Remove flowers and flower buds from cuttings to allow the cutting to use its energy and stored carbohydrates for root and shoot formation rather than fruit and seed production. To hasten rooting, increase the number of roots, or to obtain uniform rooting (except on soft, fleshy stems), use a rooting hormone, preferably one containing a fungicide. Prevent possible contamination of the entire supply of rooting hormone by putting some in a separate container for dipping cuttings.

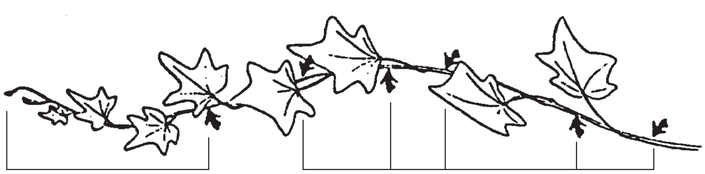


Figure 3.3. Two types of stem cuttings: tip and medial.

Insert cuttings into a rooting medium such as coarse sand, vermiculite, soil, water, or a mixture of peat and perlite. It is important to choose the correct rooting medium to get optimum rooting in the shortest time. In general, the rooting medium should be sterile, low in fertility, drain well enough to provide oxygen, and retain enough moisture to prevent water stress.

Moisten the medium before inserting cuttings, and keep it evenly moist while cuttings are rooting and forming new shoots.

Place stem and leaf cuttings in bright, indirect light. Root cuttings can be kept in the dark until new shoots appear.

Stem Cuttings

Numerous plant species are propagated by stem cuttings. Some can be taken at any time of the year, but stem cuttings of many woody plants must be taken in the fall or in the dormant season.

Tip Cuttings

Detach a two- to six-inch piece of stem, including the terminal bud (Figure 3.3). Make the cut just below a node. Remove lower leaves that would touch the medium or be below it. Dip the stem in rooting hormone if desired. Gently tap the end of the cutting to remove excess hormone. Insert the cutting deeply enough into the media to support itself. At least one node must be below the surface.

Medial Cuttings

Make the first cut just above a node and the second cut just above a node two to six inches down the stem (Figure 3.3). Prepare and insert the cutting as you would a tip cutting. Be sure to position the cutting right side up. Axial buds are always above leaves.

Cane Cuttings

Cut cane-like stems into sections containing one or two eyes, or nodes (Figure 3.4). Dust ends with fungicide or activated charcoal. Allow to dry several hours. Lay horizontally with about half of the cutting below the media surface, eye facing upward. Cane cuttings are usually potted when roots and new shoots appear, but new shoots from dracaena and croton are often cut off and re-rooted in sand.

Figure 3.4. Other types of stem cuttings.

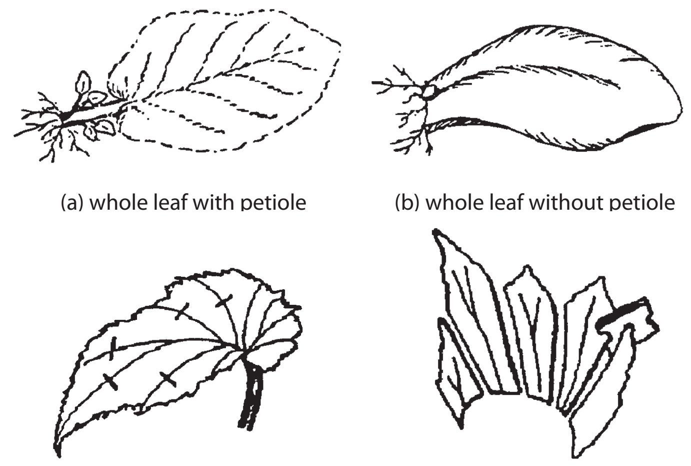


Figure 3.5. Types of leaf cuttings.

Single-eye

The eye refers to the node. This is used for plants with alternate leaves when space or stock materials are limited. Cut the stem about one-half inch above and one-half inch below a node. Place cutting horizontally or vertically in the medium.

Double-eye

This is used for plants with opposite leaves when space or stock material is limited. Cut the stem about one-half inch above and one-half inch below the same node. Insert the cutting vertically in the medium with the node just touching the surface.

Heel Cuttings

This method efficiently uses stock material with woody stems. Make a shield-shaped cut about halfway through the wood around a leaf and axial bud. Insert the shield horizontally into the medium.

Leaf Cuttings

Leaf cuttings are used almost exclusively for a few indoor plants. Leaves of most plants will either produce a few roots but no plant or just decay (Figure 3.5).

Whole Leaf with Petiole

Detach the leaf and up to 1½ inches of petiole. Insert the lower end of the petiole into the medium. One or more new plants will form at the base of the petiole. The leaf may be severed from new plants when they have their own roots and the petiole reused.

Whole Leaf without Petiole

This type of cutting is used for plants with sessile leaves. Insert the cutting vertically into the medium. A new plant will form from the axillary bud. The leaf may be removed when the new plant has its own roots.

Split Vein

Detach a leaf from the stock plant. Slit its veins on the lower leaf surface. Lay the cutting, lower side down, on the medium. New plants will form at each cut. If the leaf tends to curl up, hold it in place by covering margins with rooting medium.

Leaf Sections

This method is frequently used with snake plant and fibrous-rooted begonias. Cut begonia leaves into wedges with at least one vein. Lay leaves flat on the medium. A new plant will arise at the vein. Cut snake plant leaves into two-inch sections. Consistently make the lower cut slanted and the upper cut straight so you can tell which is the upper cut. Insert the cutting vertically. Roots will form fairly soon, and eventually a new plant will appear at the base of the cutting. These and other succulent cuttings will rot if kept too moist.

Root Cuttings

Root cuttings are usually taken from two- to three-year-old plants during their dormant season, when they have a large carbohydrate supply. Root cuttings of some species produce new shoots, which then form their own root systems, while root cuttings of other plants develop root systems before producing new shoots.

The method of taking root cuttings depends on the root size, as follows:

Plants with Large Roots

Make a straight top cut. Make a slanted cut two to six inches below the first cut. Store about three weeks in moist sawdust, peat moss, or sand at 40°F. Remove from storage. Insert the cutting vertically with the top approximately level with the surface of the rooting medium. This method is often used outdoors (Figure 3.6).

Plants with Small Roots

Take one- to two-inch sections of roots. Insert the cuttings horizontally about 12 inches below the medium surface (Figure 3.6). This method is usually used indoors or in a hotbed.

Layering

Stems still attached to their parent plants may form roots where they touch a rooting medium. Severed from the parent plant, the rooted stem becomes a new plant. This method of vegetative propagation, called layering, promotes a high success rate because it prevents the water stress and carbohydrate shortage that plague cuttings (Figure 3.7).

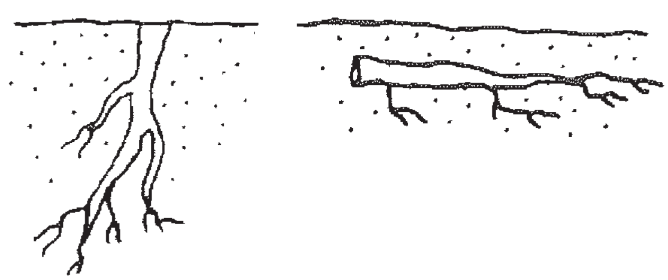
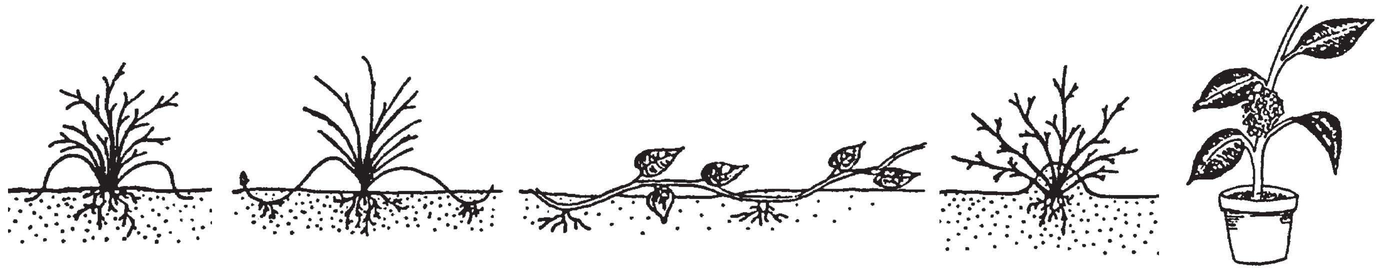


Figure 3.6. Root cuttings.



(a) tip layering (b) simple layering (c) compound layering (d) mound layering (e) air layering

Figure 3.7. Types of layering.

Some plants layer themselves naturally, but sometimes plant propagators assist the process. Layering is enhanced by wounding one side of the stem or by bending it very sharply. Rooting medium should always provide aeration and a constant supply of moisture.

Tip

Dig a hole three to four inches deep. Insert the shoot tip and cover it with soil. The tip grows down first, then bends sharply and grows upward. Roots form at the bend, and the re-curved tip becomes a new plant. Remove the tip layer and plant it in the early spring or late fall. *Examples:* purple and black raspberries, trailing blackberries.

Simple

Bend the stem to the ground. Cover part of it with soil, leaving the top six to 12 inches exposed. Bend the tip into a vertical position and stake in place. The sharp bend will often induce rooting, but wounding the lower side of the branch or loosening the bark by twisting the stem may help. *Examples:* rhododendron, honeysuckle.

Compound

This method works for plants with flexible stems. Bend the stem to the rooting medium as for simple layering, but alternately cover and expose stem section, wounding the lower side of the stem sections to be covered. *Examples:* heart-leaf philodendron, pothos.

Mound (Stool)

Cut the plant back to one inch above the ground in the dormant season. Mound soil over the emerging shoots in the spring to enhance their rooting. *Examples:* gooseberries, apple rootstocks.

Air

Air layering is used to propagate some indoor plants with thick stems or to rejuvenate them when they become leggy. Slit the stem just below a node. Pry the slit open with a toothpick. Surround the wound with wet, unmilled sphagnum moss. Wrap plastic or foil around the sphagnum moss and tie in place. When roots pervade the moss, cut the plant off below the root ball. *Examples:* dumbcane, rubber tree.

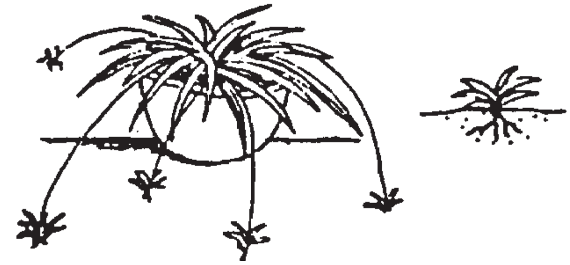


Figure 3.8. Propagation using stolons.

Figure 3.9. A plant with offsets.

The following propagation methods can all be considered types of layering, as new plants form before they are detached from their parent plants:

Stolons and Runners

A stolon is a horizontal, often fleshy stem that can root, then produce new shoots where it touches the medium (Figure 3.8). A runner is a slender stem that originates in a leaf axil and grows along the ground or downward from a hanging basket, producing a new plant at its tip. Plants that produce stolons or runners are propagated by severing new plants from their parent stems. Plantlets at the tips of runners may be rooted while still attached to the parent or detached and placed in a rooting medium. *Examples:* strawberry, spider plant.

Offsets

Plants with a rosetted stem often reproduce by forming new shoots at their base or in leaf axils (Figure 3.9). Sever new shoots from the parent plant after they have developed their own root system. Unrooted offsets of some species may be removed and placed in a rooting medium. Some of these offsets must be cut off, while others may be simply lifted off the parent stem. *Examples:* date palm, haworthia, bromeliads, many cacti.

Separation

Separation is a term applied to a form of propagation by which plants that produce bulbs or corms multiply.

Bulbs

New bulbs form beside the originally planted bulb. Separate these bulb clumps every three to five years for largest blooms and to increase bulb population. Dig up the clump after the leaves have withered. Gently pull the bulbs apart and replant them immediately so their roots can begin to develop. Small, new bulbs may not flower for two or three years, but large ones should bloom the first year. *Examples:* tulip, narcissus.

Corms

A large new corm forms on top of the old corm, and tiny cormels form around the large corm (Figure 3.10). After the leaves wither, dig up the corms and allow them to dry in indirect light for two or three weeks. Remove the cormels, then gently separate the new corm from the old corm. Dust all new corms with a fungicide and store in a cool place until planting time, when both the new corms and the cormels can be planted. The new corms are planted just like the previous corm and usually produce plants with bloom the first year. Cormels may take more than one year to produce blooms and should be planted at a more shallow depth (about two inches) during the first year and then planted as normal in succeeding years. *Examples:* crocus, gladiolus.

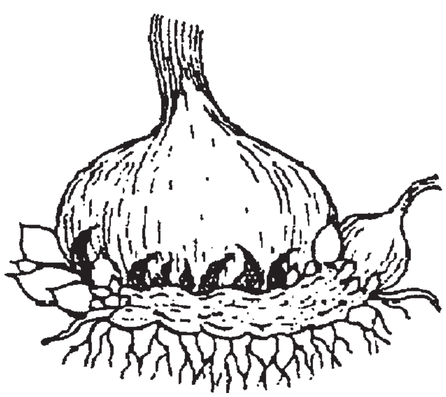


Figure 3.10. Separating corms.

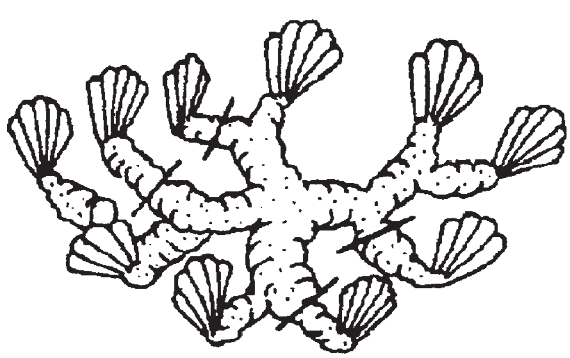


Figure 3.11. Division.

Division

Plants with more than one rooted crown may be divided and the crowns planted separately. If the stems are not joined, gently pull the plants apart. If the crowns are united by horizontal stems, cut the stems and roots with a sharp knife to minimize injury (Figure 3.11). Divisions of some outdoor plants should be dusted with a fungicide before they are replanted. *Examples:* snake plant, iris, prayer plant, day lilies.

Grafting

Grafting and budding are methods of asexual plant propagation that join plant parts so they will grow as one plant. These techniques are used to propagate cultivars that will not root well as cuttings or whose own root systems are inadequate. One or more new cultivars can be added to existing fruit and nut trees by grafting or budding.

The portion of the cultivar that is to be propagated is called the "scion." It consists of a piece of shoot with dormant buds that will produce the stem and branches. The rootstock, or stock, provides the new plant's root system and sometimes the lower part of the stem. The cambium is a layer of cells located between the wood and bark of a stem from which new bark and wood cells originate. (See Chapter 22, Growing Tree Fruits, for discussion of apple rootstock).

Four conditions must be met for grafting to be successful: scion and rootstock must be compatible; each must be at the proper physiological stage; the cambial layers of the scion and stock must meet; and the graft union must be kept moist until the wound has healed.

Cleft Grafting

Cleft grafting (Figure 3.12) is often used to change the cultivar or top growth of a shoot or a young tree (usually a seedling). It is especially successful if done in the early spring.

Collect scion wood three-eighths to five-eighths of an inch in diameter. Cut the limb or small tree trunk to be reworked perpendicular to its length. Make a two-inch vertical cut through the center of the previous cut. Be careful not to tear the bark.

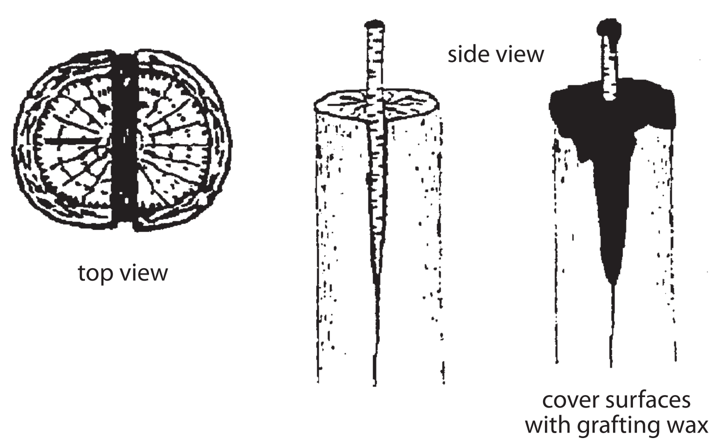


Figure 3.12. Cleft grafting.

Keep this cut wedged apart. Cut the lower end of each scion piece into a tapered point similar in size to the wedge used to hold the cut in the limb apart. Prepare two scion pieces three to four inches long. Insert scions at the outer edges of the cut in the stock. Tilt the top of the scion slightly outward and the bottom slightly inward to be sure cambial layers of the scion and stock touch. Remove the wedge propping the slit open, and cover all cut surfaces with grafting wax.

Bark Grafting

Unlike most grafting methods, bark grafting (Figure 3.13) can be used on large limbs, although these limbs often become infected before the wound can heal completely. Collect scion wood three-eighths to one-half inch in diameter when the plant is dormant. Store the wood wrapped in moist paper in a plastic bag in the refrigerator. Saw off the limb or trunk of the rootstock at a right angle to itself. In the spring, when the bark is easy to separate from the wood, make a half-inch diagonal cut on one side of the scion and a 1½-inch diagonal cut on the other side. Leave two buds above the longer cut. Make two parallel upright cuts through the bark of the stock so that the width of the cuts is a little wider then the width of the scion. Remove the top third of the bark from this cut. Insert the scion with the longer cut against the wood. Nail the graft in place with flat-headed wire nails. Cover all wounds with grafting wax.

Whip or Tongue Grafting

Whip or tongue grafting (Figure 3.14) is often used for material one-quarter to one-half inch in diameter. The scion and rootstock are usually of the same diameter, but the scion may be narrower than the stock. This strong graft heals quickly and provides excellent cambial contact. Make one 2½-inch sloping cut at the top of the rootstock and a matching cut on the bottom of the scion. On the cut surface, slice downward into the stock and up into the scion so the pieces will interlock. Fit the pieces together, then tie and wax the union.

Care of the Graft

Very little success in grafting will be obtained without proper care for the following year or two. If a binding material such as strong cord or nursery tape is used on the graft, this tape must be cut shortly after growth starts to prevent girdling or constricting. Rubber budding strips have some advantages over other materials. They expand with growth and usually do not need to be cut because they deteriorate and break after a short time. It is also an excellent idea to inspect grafts after two or three weeks to see if the wax has cracked. If necessary, rewax exposed areas. The union will probably be strong enough after this waxing, and no more waxing will be necessary.

Limbs of the old variety that are not selected for grafting should be cut back at the time of grafting. The total leaf surface of the old variety should be gradually reduced until the new variety has taken over, which will take one or two years. Completely removing all limbs of the old variety at the time of grafting increases the shock to the tree and causes excessive suckering and may also cause scions to grow too fast, making them susceptible to wind damage.

Budding

Budding, or bud grafting, is the union of one bud and a small piece of bark from the scion with a rootstock. It is especially useful when scion material is limited. It is also faster and forms a stronger union than grafting.

Patch Budding

Plants with thick bark should be patch budded, which is done while plants are actively growing, so that their bark slips easily. Remove a rectangular piece of bark from the rootstock. Cover this wound with a bud and matching piece of bark from the scion (Figure 3.15). If the rootstock's bark is thicker than that of the scion, pare it down to meet the thinner bark so that when the union is wrapped the patch will be held firmly in place.

Chip Budding

This budding method can be used when bark is not slipping. Slice downward into the rootstock at a 45° angle through one-quarter of the wood. Make a second cut upward from the first cut, about one inch. Remove a bud and attending chip of bark and wood from the scion that is shaped so it fits the rootstock wound. Fit the bud chip to the stock and wrap the union (Figure 3.16).

Figure 3.13. Bark graft.

Figure 3.14. Whip or tongue graft.

Figure 3.15. Patch budding.

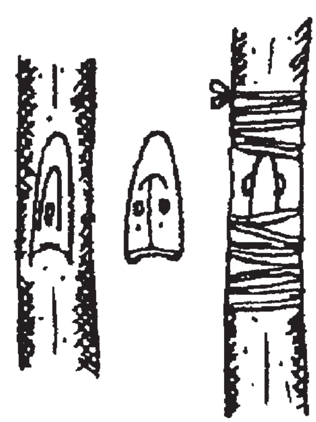


Figure 3.16. Chip budding.

T-budding

This is the most commonly used budding technique. When bark is slipping, make a vertical cut (same axis as the rootstock) through the bark of the rootstock, avoiding any buds on the stock. Make a horizontal cut at the top of the vertical cut (in a T shape) and loosen the bark by twisting the knife at the intersection. Remove a shield-shaped piece of the scion, including a bud, bark, and a thin section of wood. Push the shield under the loosened stock bark. Wrap the union, leaving the bud exposed (Figure 3.17).

Care of Buds

Place the bud in the stock in August. Force the bud to develop the following spring by cutting the stock off three to four inches above the bud. A new shoot will develop from the inserted bud, and other shoots may develop along the stem of the stock. Remove all buds from the stock except the one that arises from the inserted bud (scion). As the new shoot grows, it may be tied to the existing stub of the stock to prevent wind damage. The new shoot may be tied to the resulting stub to prevent damage from wind. After the shoot has made a strong union with the stock, cut the stub off close to the budded area.

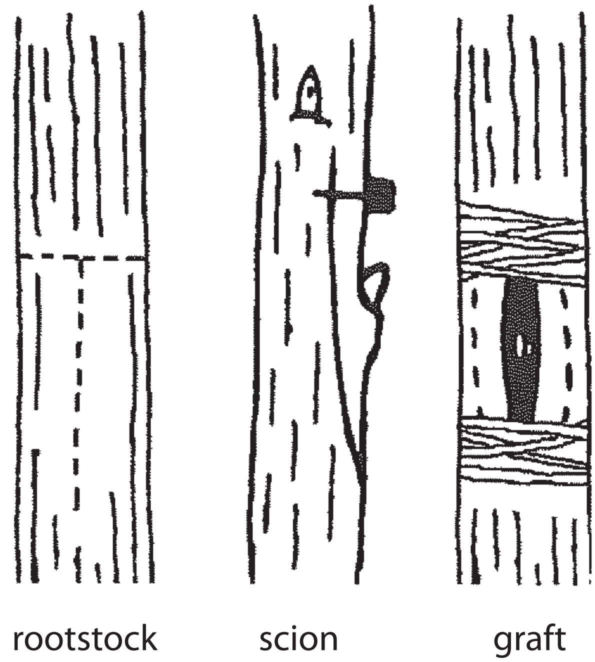


Figure 3.17. T-budding.

Chapter 04

Soils and Fertility

By Craig Cogger, Extension soil scientist, Washington State University. Adapted for Kentucky by Edwin Ritchey, Extension soils specialist, and Brad Lee, Extension water quality specialist, University of Kentucky.

In this chapter:

Soil is a mixture of weathered rock fragments (minerals) and organic matter at the earth's surface. It is biologically active—a home to countless microorganisms, invertebrates, and plant roots. It varies in depth from a few inches to eight feet or more. An ideal soil is roughly 50 percent pore space (50 percent voids between soil particles). This space forms a complex network of pores of varying sizes, much like those in a sponge. Soil provides nutrients, water, and physical support for plants as well as air for plant roots. Soil organisms are nature's primary recyclers, turning dead cells and tissue into nutrients, energy, carbon dioxide, and water to fuel new life.

Soil and Water

A productive soil is permeable to water and is able to supply water to plants. A soil's permeability and water-holding capacity depend on its network of two types of pores:

- Large pores (macropores) control a soil's permeability and aeration. Macropores include earthworm and root channels. Because they are large, water moves through them rapidly by gravity so that rainfall and irrigation infiltrate into the soil, and excess water drains through it.
- Micropores are fine soil pores, typically a fraction of a millimeter in diameter. They are responsible for a soil's water-holding capacity. Like the fine pores in a sponge or towel, micropores hold water against the force of gravity. Much of the water held in micropores is available to plants, but some is held so tightly that plant roots cannot use it.

Soil that has a balance of macropores and micropores provides adequate permeability and water-holding capacity for good plant growth. Soils that contain mostly macropores drain readily but are droughty and need more frequent irrigation. Soils that contain mostly micropores have good water-holding capacity but take longer to dry out, and excessive wetness can reduce plant growth.

Soil texture, structure, organic matter, and human activity affect porosity. You can evaluate your garden soil in terms of these properties to understand their impact. The only tools you need are your eyes, fingers, and a shovel.

Texture

Texture describes the relative abundance of sand, silt, and clay-sized materials. Anything greater than two millimeters in size is considered gravel or rock and is not soil. The coarsest soil particles are sand. They are visible to the eye and give soil a gritty feel. Silt particles are smaller than sand—about the size of individual particles of white flour. They give soil a smooth, floury feel. On close inspection, sand and silt particles look like miniature rocks (Figure 4.1).

Clay particles are the smallest—about the size of bacteria and viruses—and can be seen only with a microscope. They typically have a flat shape, similar to a sheet of mica, and when microscopically viewed from the side, they look like the pages of a book. Soils high in clay feel very hard when dry but are easily shaped and molded when moist.

Although all of these particles seem small, the relative difference in their sizes is quite large. If a typical clay particle were the size of a penny, a sand particle would be as large as a house.

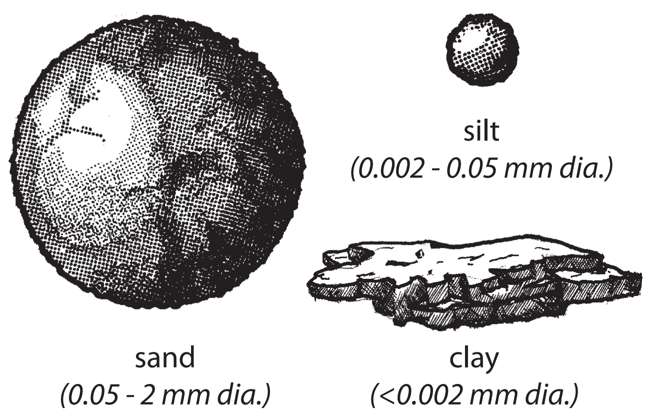


Figure 4.1. Shapes of soil particles.

Soil texture directly affects porosity. Pores between sand particles tend to be large, while those between silt and clay particles tend to be small. That means sandy soils contain mostly macropores and usually have rapid permeability but limited water-holding capacity. In soils containing mostly silt and clay, micropores predominate, creating high water-holding capacity but reducing permeability.

Particle size also affects the surface area in soil. Surface area is important because surfaces are the most active part of the soil. Soil surfaces hold plant nutrients, bind contaminants, and provide a home for microorganisms. Clay particles have a large surface area relative to their volume, so a small amount of clay makes a large contribution to a soil's surface area.

Nearly all soils have a mixture of particle sizes and pore sizes. As shown in Figure 4.2, a soil's textural class can be determined based on the percentages of silt, slay and sand that are present. A soil with roughly equal influence from sand, silt, and clay particles is called a loam. Loams usually make good agricultural and garden soils. They have a balance of macropores and micropores, so they usually have both good water-holding capacity and moderate permeability.

A sandy loam is similar to a loam, but it contains more sand. It feels gritty, yet has enough clay to hold together in your hand. Sandy loams usually have low to moderate water-holding capacity and good permeability.

Silt loams are richer in silt and feel smooth rather than gritty. They are pliable when moist but not very sticky. Silt loams usually have high water-holding capacity and low to moderate permeability. Much of Kentucky's surface soils have a silt loam texture.

Clays and clay loams are very hard when dry, sticky when wet, and can be molded into wires and ribbons when moist. They generally have low permeability and high water-holding capacity; however, much of this water is unavailable to plants.

For more information on soil textural determination, refer to the Cooperative Extension publication *Determining Soil Texture by Feel* (AGR-217). Almost any texture of soil can be suitable for gardening as long as you are aware of the soil's limitations and adjust your management to compensate. Clay soils hold a lot of water but are hard to dig and dry slowly in the spring. Sandy soils need more frequent watering and lighter, more frequent fertilization, but you can plant them earlier in the spring. All soils can benefit from additions of organic matter, as described later in this chapter under "Adding Organic Matter."

Many soils contain coarse fragments greater than two millimeters in diameter—gravel and rocks. Coarse fragments do not

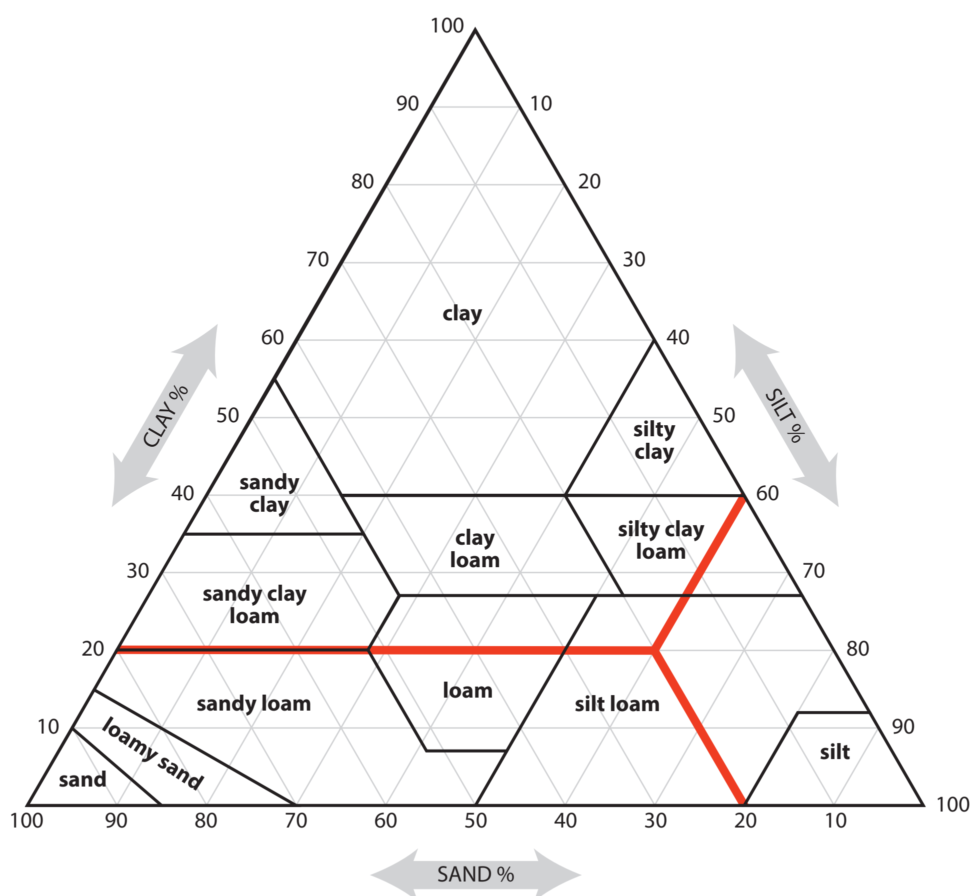


Figure 4.2. Basic soil textural classes can be determined based on percentages of clay, silt, and sand present. For example, a soil comprised of 20 percent sand, 60 percent silt and 20 percent clay, as highlighted in red, would be a silt loam.

contribute to a soil's productivity and can be a nuisance when you are digging. Don't feel compelled to remove all of them from your garden, however. Coarse fragments aren't harmful, and your time is better spent on other gardening tasks. The only time rocks are a problem is when you have nothing but rocks on your land. Then, water- and nutrient-holding capacities are so low that it is difficult to grow healthy plants.

Structure

Individual particles of sand, silt, and clay tend to cluster and bind together, forming aggregates called peds, which provide structure to a soil. Dig up a piece of grass sod and examine the soil around the roots. The granules of soil clinging to the roots are examples of peds. They contain sand, silt, clay, and organic matter.

Aggregation is a natural process caused largely by biological activity such as earthworm burrowing, root growth, and microbial action. Soil organic matter is an important binding agent that stabilizes and strengthens peds.

The spaces between peds are a soil's macropores, which improve permeability, drainage, and recharging of air into the soil profile. The pores within peds are predominantly micropores, contributing to the soil's water-holding capacity. A well-structured soil is like a sponge, allowing water to enter and soak into the micropores and letting excess water drain down through the macropores. Good structure is especially important in medium- to fine-textured soils (soils with appreciable amounts of clay), because it increases the soil's macroporosity, improving permeability and drainage.

Figure 4.3. Compacted soil resists root penetration and water movement.

Human Activity

Soil structure is fragile and can be damaged or destroyed by compaction, excessive tillage, or tilling when the soil is too wet. Loss of organic matter, typically a result of tillage, also weakens structure.

Compaction squeezes macropores into micropores and creates horizontal aggregates that resist root penetration and water movement (Figure 4.3). Compaction often occurs during site preparation or house construction, creating a difficult environment for establishing plants. Protect your soil from compaction by avoiding unnecessary foot or machine traffic.

Tilling when soil is too wet also damages soil structure. If you can mold a piece of soil into a wire or worm in your hand, it is too wet to till, and traffic should be avoided until it dries. If the soil crumbles when you try to mold it, it is dry enough to till.

Structural damage caused by human activity usually is most severe within the top foot of soil and can be overcome by proper soil management.

Organic Materials, Organic Matter, and Humus

Organic materials (called organic residues), such as plant and animal residues of recognizable origin, are the building blocks of organic matter, or humus. Soil organic matter and humus (terms often used synonymously) contain decomposed plant and animal remains of unrecognizable origin, their partial decomposition products, and the wastes from soil biomass.

Increasing soil organic matter is the best way to improve the plant environment in nearly all soils, because it helps build and stabilize soil structure in fine-textured and compacted soils, improving permeability and aeration and reducing the risk of runoff and erosion. Organic matter is less susceptible to compaction than the mineral components of soil and can reduce compaction potential. In addition, when organic material decomposes, it forms humus, which acts as a natural glue to bind and strengthen soil aggregates. Organic matter also helps soils, particularly sandy soils, hold water and nutrients and is a reservoir of energy for soil microbes. See "Adding Organic Matter" later in this chapter for more information.

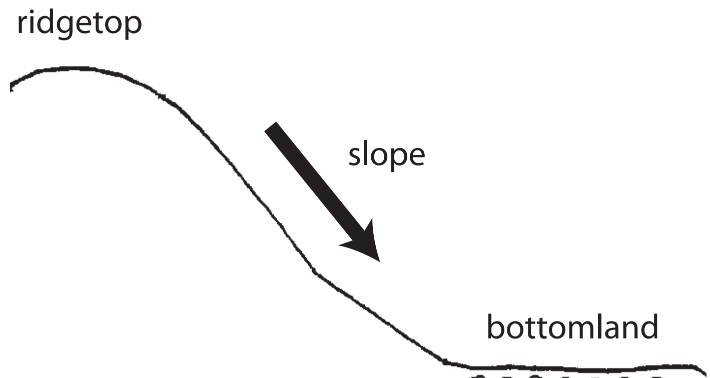


Figure 4.4. Ridgetops and slopes tend to shed water, while soils at the bottom of slopes and in low areas collect water.

Water Management in Your Garden

Slope, Aspect, and Soil Depth

Slope, aspect (direction of exposure), and soil depth affect availability of water and its use in a soil. Choose plants that are best suited to your property's conditions.

Ridgetops and side slopes tend to shed water, while soils at the bottom of slopes and in low areas collect it (Figure 4.4). Soils that collect water often have high winter water tables, which can affect the health of some plants. Soils on ridgetops are more likely to be droughty.

Site aspect also is important. Exposures facing south or southwest collect the most heat and use the most water.

Soil depth also affects water availability by determining the rooting zone. Soil depth is limited by compacted, cemented, or gravelly layers, or by bedrock. A shallow soil has less available water simply because the volume of soil available to roots is smaller. Dig below the topsoil in your garden. The deeper you can dig before hitting a restrictive layer, the greater the soil volume for holding plant-available water.

See the Cooperative Extension publication *Improving the Productivity of Landscapes with Little or No Topsoil* (AGR-203) for more information.

Irrigation

Most gardens in Kentucky require summer irrigation. The need for irrigation varies, depending on soil water-holding capacity, weather, site aspect, the plants grown, and the plants' growth stage.

In most cases, the goal of irrigation is to recharge the available water in the top foot or so of soil. For sandy soil, one inch of irrigation water is all you need. Any more will leach (move downward) through the root zone, carrying nutrients with it. A silt loam or clay soil can hold more than two inches of water, but you may need to irrigate more slowly to prevent runoff.

Wet Soils

If your soil stays wet in the spring, you will have to delay tilling and planting. Working wet soil can damage its structure, and seeds are less likely to germinate in cold, wet soil.

Some plants don't grow well in wet soil. Raspberries, for example, often become infected by root diseases in wet soil and lose vigor and productivity.

A soil's color gives clues to its tendency to stay wet. If a subsoil is brown or reddish, the soil probably is well drained and is rarely too wet. Gray subsoils, especially those with brightly colored mottles, often are wet. If your soil is gray and mottled directly beneath the topsoil, it will be saturated in some part of the year.

Sometimes, simple practices can reduce problems with wet soil, including the following:

- Divert runoff from roof drains away from your garden.
- Avoid plants that perform poorly in wet conditions.
- Use raised beds for perennials that require well-drained soil and for early-season vegetables.
- Investigate whether a drain on a slope will remove excess water on your property. Installing drainage can be expensive, however. When considering drainage, make sure there is a place to drain the water. Check with local regulatory agencies about any restrictions on the project.

Organisms

Soil abounds with life. Besides the plant roots, earthworms, insects, and other creatures you can see, soil is home to an abundant and diverse population of microorganisms.

Soils with more organic matter tend to have more microorganisms—and the more microorganisms, the better. The important thing is to make the environment favorable for microorganism activity, which includes well-aerated soils that are warm and moist, with near-neutral pH and good levels of organic matter. Other factors must also be considered; for example, if trying to grow blueberries, which like more acidic conditions, this constraint for plant growth would be more important than a near-neutral pH for microbial growth. You must first satisfy the needs of the plant.

Table 4.1. Approximate abundance of microorganisms in agricultural topsoil.

Organism	Number/Gram (Dry-Weight Basis)
Bacteria	100 million to 1 billion
Actinomycetes	10 million to 100 million
Fungi	100,000 to 1 million
Algae	10,000 to 100,000
Protozoa	10,000 to 100,000
Nematodes	10 to 100

A single gram of topsoil (about one-quarter teaspoon) can contain as many as a billion microorganisms (Table 4.1). Microorganisms are most abundant in the rhizosphere—the thin layer of soil surrounding plant roots.

The main function of soil organisms is to break down the remains of plants and other organisms. This process releases energy, nutrients, and carbon dioxide and creates soil organic matter.

Organisms ranging from tiny bacteria to insects and earthworms take part in a complex soil food web (Figure 4.5). Mammals such as moles and voles also are part of the food web, feeding on insects and earthworms and mixing organic matter throughout the soil profile. This mixing also improves soil structure.

Some soil organisms play other beneficial roles. Mycorrhizae are fungi that infect plant roots and increase their ability to take up nutrients from the soil. Rhizobia bacteria are responsible

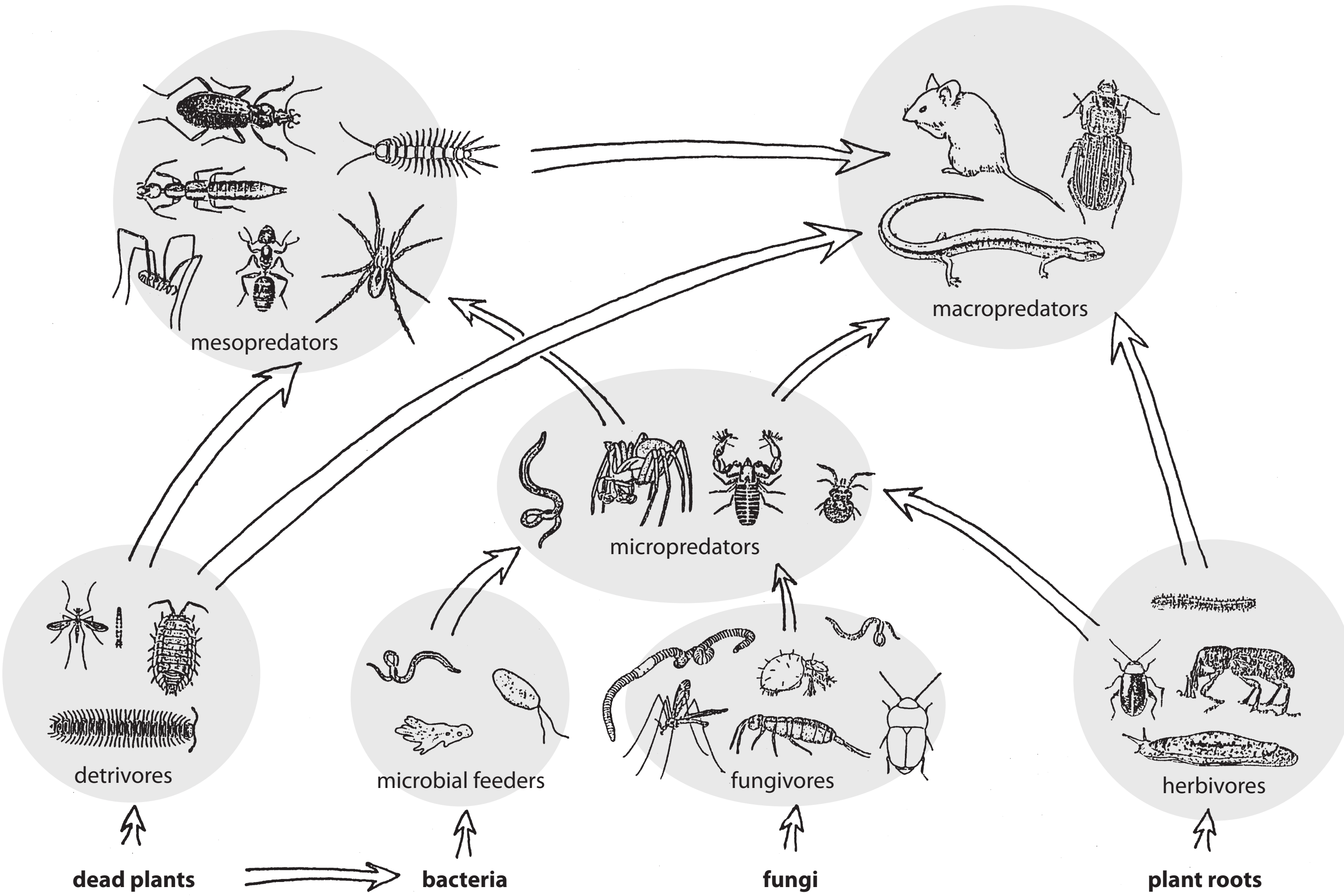


Figure 4.5. The soil food web.

for converting atmospheric nitrogen to plant-available forms, a process known as nitrogen fixation. Earthworms mix large volumes of soil and create macropore channels that improve permeability and aeration (Figure 4.6). "Soil health" is often judged by the numbers of earthworms in the soil—the more earthworms, the better.

Not all soil organisms are beneficial. Some are pathogens, which cause diseases such as root rot of raspberries and scab on potatoes. Moles can damage crops and lawns, and slugs are a serious pest in many Kentucky gardens.

The activity of soil organisms depends on soil moisture and temperature as well as on the soil's organic matter content. Microorganisms are most active between 70°F and 100°F, while earthworms are most active and abundant at soil temperatures of about 50°F. Most organisms prefer moist soil. The relationships between gardening practices, microbial populations, and soil quality are complex and often poorly understood. Almost all gardening activities—including tillage; the use of fertilizers, manures, and pesticides; and the choice of crop rotations—affect the population and diversity of soil organisms. For example, amending soils with organic matter, returning crop residues to the soil, and rotating plantings tend to increase the number and diversity of beneficial organisms.

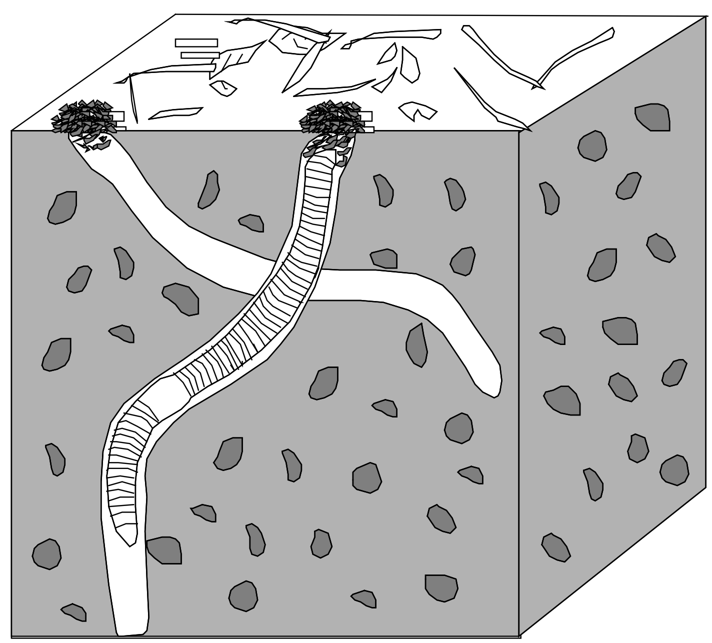


Figure 4.6. Earthworm channels create macropores, which improve a soil's permeability and aeration.

Table 4.2. Essential plant nutrients.

Primary Nutrients (Macronutrients)		Secondary Nutrients		Micronutrients (Trace Nutrients)	
Name	**Chemical Symbol**	**Name**	**Chemical Symbol**	**Name**	**Chemical Symbol**
Nitrogen	N	Sulfur	S	Zinc	Zn
Phosphorus	P	Calcium	Ca	Iron	Fe
Potassium	K	Magnesium	Mg	Copper	Cu
				Manganese	Mn
				Boron	B
				Molybdenum	Mo
				Chlorine	Cl

Nutrients

Soil supplies 13 essential plant nutrients. Each nutrient plays one or more specific roles in plants. Nitrogen (N), for example, is a component of chlorophyll, amino acids, proteins, DNA, and many plant hormones. It plays a vital role in nearly all aspects of plant growth and development, and plants need a lot of nitrogen to grow well. In contrast, plants need only a tiny amount of molybdenum, which is involved in the functioning of only a few plant enzymes. Molybdenum nonetheless is essential, and plant growth is disrupted if it is deficient. Plants also require carbon, hydrogen, and oxygen, which they derive from water and air.

A soil nutrient is classified as a primary nutrient (macronutrient), secondary nutrient, or micronutrient, based on the amount of the nutrient needed by plants (Table 4.2). If a soil's nutrient supply is deficient, fertilizers can provide the additional nutrients needed for healthy plant growth.

Deficiencies

The most common nutrient deficiencies are for the primary nutrients—nitrogen, phosphorus (P), and potassium (K)—which are in largest demand by plants. Nearly all soils lack enough available nitrogen for ideal plant growth. Unlike many states in the United States, Kentucky's urban soils typically have an abundance of phosphorus and potassium.

Secondary nutrients also are deficient in some Kentucky soils, but not very often. The secondary nutrients are calcium (Ca), magnesium (Mg), and sulfur (S). Calcium and magnesium are almost always sufficient when proper pH management practices are followed. Micronutrient deficiencies do occur in Kentucky, but to a limited extent. Maintaining proper soil pH typically alleviates most micronutrient deficiency issues.

Except for boron and zinc, micronutrients are rarely deficient. Boron deficiencies occur most often in root crops, brassica crops (e.g., broccoli), and caneberries (e.g., raspberries). Zinc deficiency usually is associated with high phosphorus levels and high pH soils and most often affects tree fruits and corn.

Each nutrient deficiency causes characteristic symptoms. In addition, deficient plants grow more slowly, yield less, and are less healthy than plants with adequate nutrient levels.

Because most soil in the central and outer Bluegrass region of Kentucky has been formed from limestone that is naturally high in phosphorus, plant-available phosphorus is very high (exceeding 200 pounds per acre), and soils in the Bluegrass region may never need phosphorus fertilization. Adding fertilizer phosphorus in this region simply increases the chances for eutrophication (algal blooms that may cause fish kills) and can diminish the uptake of other essential plant nutrients like zinc. Since fertilizer analysis is given in percent of N, P_20_5, and K_20, make certain that the center number in a fertilizer product is zero (for example 23–0–30) when soils have adequate or high amounts of phosphorus.

Outside of the Bluegrass area, research has identified elevated levels of phosphorus in all urban areas of the state, regardless of physiographic region. Likely this is due to continuous overapplication of phosphorus fertilizers in lawns and gardens across the Commonwealth. Therefore it is imperative that all phosphorus fertilizer application rates be based upon a soil test result and a recommendation from your local county Cooperative Extension Service agent.

Long-term use of complete fertilizers or animal manures can also increase phosphorus concentrations to levels so that no additional phosphorus is required, which is another reason to soil test before applying nutrients—so you will know what nutrients are needed and the correct amount to add.

Excess Nutrients

Excess nutrients can be a problem for plants and the environment. Excesses usually occur because too much of a nutrient is applied or it is applied at the wrong time.

Too much boron is toxic to plants. Too much nitrogen can lead to excessive foliage production, increasing the risk of disease; wind damage; and delayed flowering, fruiting, and dormancy. Available nitrogen left in the soil at the end of the growing season can leach into groundwater and threaten drinking water quality.

The key to applying fertilizers is to meet plant needs when the plant needs it without creating excesses that can harm plants or the environment.

Nutrient Availability to Plants

Plants can take up only nutrients that are in solution (dissolved in soil water). Most soil nutrients are not in solution but instead are tied up in soil mineral and organic matter in

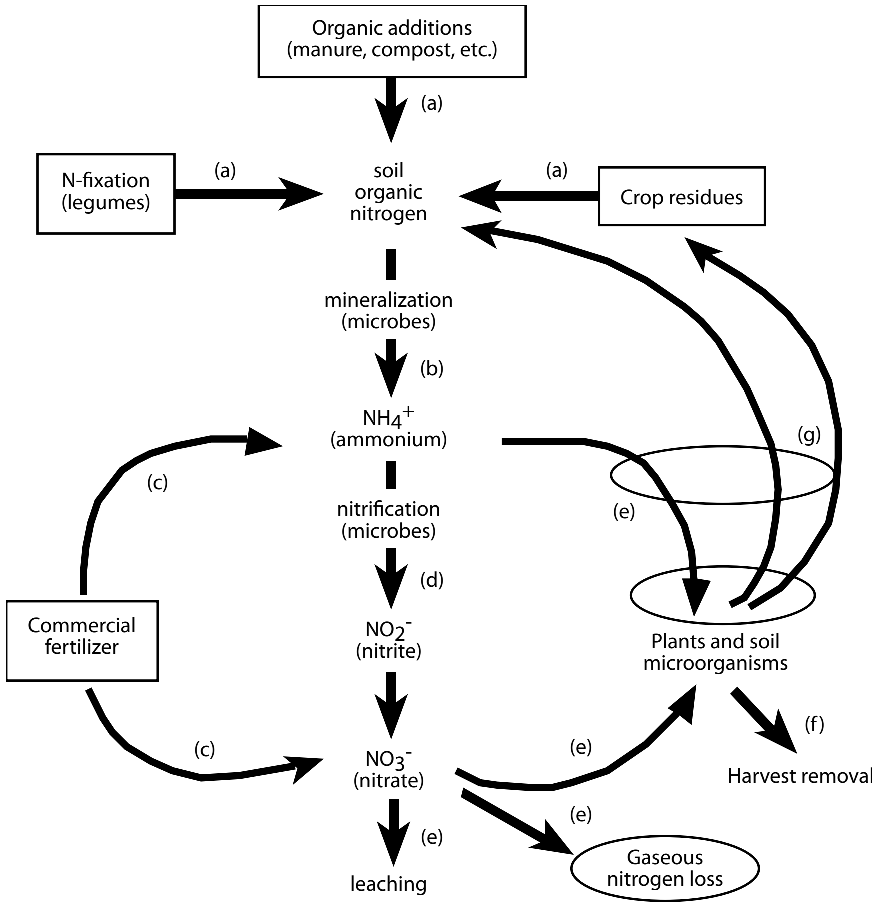


Figure 4.7. Nitrogen cycle:
a. Legumes, soil organic matter, crop residues, and organic additions (manures, composts, etc.) are sources of organic N.
b. Organic N is mineralized into ammonium (NH_4^+) by soil microbes.
c. Commercial fertilizer supplies N as ammonium or nitrate (NO_3^-).
d. Microbes nitrify ammonium to nitrite and then nitrate.
e. Plants, microorganisms, leaching below the root zone, and release of gaseous N to the atmosphere remove N from the root zone soil solution.
f. Crop harvest removes N stored in plants.
g. Nitrogen present in both crop residues and soil microorganisms becomes a part of the soil organic N content.

(Note: An alternate schematic of the nitrogen cycle is illustrated in Chapter 12, Your Yard and Water Quality.)

insoluble forms. These nutrients become available to plants only after they are converted to soluble forms and dissolve in the soil solution.

This process occurs through weathering of mineral matter and biological decomposition of organic matter. Weathering of mineral matter is a very slow process that releases small amounts of nutrients each year. The rate of nutrient release from soil organic matter is somewhat faster and depends on the amount of biological activity in the soil.

Nutrient release from soil organic matter is fastest in warm, moist soil and nearly nonexistent in cold or dry soil. Thus, the seasonal pattern of nutrient release is similar to the pattern of nutrient uptake by plants. About one to four percent of the nutrients in soil organic matter are released in soluble form each year.

Soluble, available nutrients are in ionic form, meaning they have either positive or negative charges. Positively charged ions are cations, of which potassium, calcium, and magnesium are examples. Negatively charged ions are anions. Chlorine and nitrates are examples of anions.

Clay particles and soil organic matter have negative charges on their surfaces and can attract cations. They hold nutrient cations in ready reserve for rapid release into soil solution to replace nutrients taken up by plant roots. This reserve supply of nutrients contributes to a soil's fertility. A soil's capacity to hold cations is called its cation exchange capacity, or CEC.

The Nitrogen Cycle

Managing nitrogen is a key part of growing a productive and environmentally friendly garden. Nitrogen is the nutrient needed in the largest amount by plants, but excess nitrogen can harm plants and degrade water quality. Understanding how the nitrogen cycle affects nitrogen availability can help you become a better nutrient manager (Figure 4.7).

Table 4.3. Common forms of nitrogen in soil.

Form of Nitrogen	Characteristics
Organic N	Primary form of N in soil. Found in proteins, lignin, amino acids, humus, etc. Not available to plants. Mineralized to ammonium by soil microorganisms.
Ammonium N (NH_4^+)	Inorganic, soluble form. Available to plants. Converted to nitrate by soil microorganisms.
Nitrate (NO_3^-)	Inorganic, soluble form. Available to plants. Can be lost by leaching. Converted to gases in wet soils.
Atmospheric N (N_2)	Makes up about 80% of the soil atmosphere. Source of N for N-fixing plants. Not available to other plants.

Note: Any nitrogen source that contains ammonium or has an ammonium intermediary is acid forming.

Nitrogen is found in four different forms in the soil (Table 4.3). Only two of them, ammonium and nitrate, can be used directly by plants.

Most nitrogen in soil is tied up in organic matter and plant, animal, and microbial biomass. This organic nitrogen is not available to plants. As soil warms in the spring, soil microbes begin breaking down organic matter, releasing some of the nitrogen as ammonium (NH_4^+). Any nitrogen source that contains ammonium or has an ammonium intermediary is acid forming. Urea, $(NH_2)_2CO$, will form NH_4^+ when applied to the soil. When the soil is warm, a group of microbes called nitrifiers convert the ammonium to nitrate (NO_3^-). When the nitrifiers convert the NH_4^+ to NO_3^-, they release H^+ (acidity), which will lower soil pH. On the other hand, nitrate forms (NO_3^-) are not acid forming. Ammonium, retained by the soil due to its positive charge, is a soluble ion that is available to plants and soil microbes. Nitrate is also soluble and available to plants. The ammonium and nitrate ions released from soil organic matter are the same as the ammonium and nitrate contained in processed fertilizers.

Because nitrate has a negative charge, it is not held to the surface of clay or organic matter, so it can be lost readily by leaching. Nitrate remaining in the soil at the end of the growing season will leach during the fall and winter and may reach groundwater, where it becomes a contaminant. In soils that are saturated during the wet season, soil microbes convert nitrate to nitrogen gases, which diffuse back into the atmosphere.

Ammonium and nitrate taken up by plants are converted back to organic forms in plant tissue. When plant residues are returned to the soil, they decompose, slowly releasing nitrogen back into the soil as plant-available forms.

The nitrogen cycle is a leaky one, with losses to leaching and the atmosphere. Harvesting crops also removes nitrogen. To maintain an adequate nitrogen supply, nitrogen must be added back into the system through fixation or fertilization.

Nitrogen fixation is a natural process involving certain plants and Rhizobia bacteria. The Rhizobia form nodules in the plant roots, and through these nodules they are able to take atmospheric nitrogen (N_2 gas) from the soil air and convert it to available nitrogen within the plant. Legumes (plants that produce seeds in pods) such as peas, beans, alfalfa, and clover are common nitrogen fixers. The Kentucky coffeetree, the honey locust, redbuds, and Alder trees also fix nitrogen. Growing legumes as a cover crop will supply nitrogen to future crops.

Understanding Fertilizers

Fertilizers supplement a soil's native nutrient supply. They are essential to good plant growth when the soil nutrient supply is inadequate. Rapidly growing plants such as annual vegetable crops generally need more nutrients than slowly growing plants such as established perennials.

You can use processed fertilizers, organic fertilizers, or a combination of the two to supply soil nutrients. Plants do not prefer one source of nutrients over another, but the nutrients' behavior in the soil often differs (Table 4.4).

Processed fertilizers are manufactured or refined from natural ingredients to make them more concentrated and more available to plants. Typically, they are processed into soluble, ionic forms that are immediately available to plants.

Organic fertilizers are natural materials that have undergone little or no processing. They include both biological (plant and animal) materials and mineral materials.

Once in the soil, organic fertilizers release nutrients through natural processes, including chemical weathering of mineral materials and biological breakdown of organic matter. The released nutrients are available to plants in water-soluble forms. These soluble forms of nutrients are the same as those supplied by processed fertilizers.

When compared with processed fertilizers, organic fertilizers usually have a lower concentration of nutrients and release

Table 4.4. Comparing organic and processed fertilizers.

	Organic Fertilizers	Processed Fertilizers
Source	Natural materials; little or no processing	Manufactured or extracted from natural materials; often undergo extensive processing
Examples	Manure, cottonseed meal, rock phosphate, fish by-products	Ammonium sulfate, processed urea, diammonium phosphate (DAP), potassium chloride
Nutrient Availability	Usually slow-release; nutrients are released by biological and chemical processes in soil	Nutrients usually are almost immediately available to plants
Nutrient Content	Usually low	Usually high

nutrients more slowly. That means larger amounts of organic fertilizers are needed, but their effects last longer.

Using organic fertilizers recycles materials that otherwise would be discarded as wastes. Production of processed fertilizers, on the other hand, can create wastes and use substantial amounts of energy.

Choosing organic fertilizers involves trade-offs in cost or convenience. Farmyard manure usually is inexpensive or free, but can be inconvenient to apply. Packaged organic blends, on the other hand, are convenient but often more expensive.

Nutrient Release

Nutrients in most processed fertilizers are available almost immediately. Processed fertilizers can furnish nutrients to plants in the spring before the soil is warm. However, nitrogen in these fertilizers is vulnerable to leaching loss from heavy rainfall or irrigation. Once nitrogen moves below the root zone, plants no longer can use it, and it may leach into groundwater.

Organic fertilizers are slow-release fertilizers because their nutrients become available to plants over the course of the growing season. The rate of nutrient release from organic materials depends on the activity of soil microorganisms, just as it does for nutrient release from soil organic matter. Temperature and moisture conditions that favor plant growth also favor the release of nutrients from organic matter.

Some organic fertilizers contain immediately available nutrients as well as slow-release nutrients. These fertilizers can supply nutrients to plants both early in the season and later. Fresh manure, biosolids, and fish emulsion are examples of organic fertilizers containing available nutrients.

We assume that in manures, 100 percent of potassium (potash) is available the first year, along with 80 percent of phosphorus and about 50 percent of the nitrogen. Remember that nitrogen values vary depending on the type of manure, the environmental conditions during the growing season, and when during the season the manure was applied.

As manure ages, the most readily available nutrients are lost into the air or leached into the soil, leaving slow-release material in the aged manure.

Some material in organic fertilizers breaks down so slowly that it is not available the first season after application. Repeated application of organic fertilizers builds up a pool of material that releases nutrients very slowly. In the long run, this nutrient supply decreases the need for supplemental fertilizer.

Fertilizer Labels

The labels on fertilizer packages tell the amount of each of the three primary nutrients in the fertilizer, expressed as a percent of total fertilizer weight. Nitrogen (N) always is listed first, phosphorus (P) second, and potassium (K) third.

Historically, the amount of phosphorus in fertilizer has been expressed not as P, but as units of the oxide form P_2O_5 (phosphate). Similarly, fertilizer potassium is expressed as K_2O (potash). This practice still is used for fertilizer labels and recommendations, even though there is no practical reason for the system except that people are accustomed to it. (If you need to convert from P to P_2O_5, the conversion is:

$$1 \text{ lb P} = 2.29 \text{ lb } P_2O_5$$

For potassium, the conversion is:

$$1 \text{ lb K} = 1.2 \text{ lb } K_2O$$

Thus, a bag of fertilizer labeled 5–10–10 contains 5 percent nitrogen, 10 percent phosphate (4.4 percent phosphorus), and 10 percent potash (8.3 percent potassium). This information is called a fertilizer analysis.

The analysis for processed fertilizers guarantees the amount of available nutrients in the fertilizer. The analysis for organic fertilizers represents the total amount of nutrients rather than available nutrients. Because nutrients in most organic fertilizers are released slowly, the amount of immediately available nutrients is less than the total.

Common Processed Fertilizers

Nitrogen

The raw material for processed nitrogen fertilizer is nitrogen gas from the atmosphere. The manufacturing process is the chemical equivalent of biological nitrogen fixation and requires a substantial amount of fossil fuel energy. Examples of processed nitrogen fertilizers available for home garden use include those listed in Table 4.5.

Table 4.5. Examples of processed nitrogen fertilizer materials.

Material	Analysis	Comments
Urea	46-0-0	Rapidly converted to ammonium in soil.
Ammonium sulfate	21-0-0	Also contains 24% available sulfur. Used with acid-loving plants.
Diammonium phosphate	18-46-0	Used in mixed fertilizers as a source of nitrogen and phosphorus.
Sulfur-coated urea (SCU)	35-0-0	Sulfur coating slows release of available N, making this a slow-release fertilizer.

Phosphorus and Potassium

Processed phosphorus fertilizers come from phosphate rock. The rock is treated with acid to release phosphorus into plant-available forms.

The most common raw material for potassium fertilizers is sylvinite, a mixture of sodium chloride and potassium chloride salts. The potassium in sylvinite is already in soluble form, but the sylvinite is treated to remove the sodium salts to make it suitable for use as a fertilizer. Some other potassium fertilizers are made from potassium sulfate salts, which supply sulfur as well as potassium. Table 4.6 lists examples of processed phosphorus and potassium fertilizers.

Table 4.6. Examples of processed phosphorus and potassium fertilizer materials.

Material	Analysis	Comments
Monoammonium phosphate	11–52–0	Used in mixed fertilizers as a source of nitrogen and phosphorus.
Diammonium phosphate	18–46–0	Used in mixed fertilizers as a source of nitrogen and phosphorus.
Potassium chloride	0–0–60	High salt index.
Potassium magnesium sulfate	0–0–22	Also contains 11% magnesium and 18% sulfur.
Potassium sulfate	0–0–50	Also contains 18% sulfur.

Table 4.7. Typical nitrogen, phosphate, and potash content (%) of some manures.

Animal Manures[1]	Water (%)	Nutrients (%)		
		N*	P_2O_5	K_2O
Dairy Cattle	80	0.55	0.45	0.60
Beef	80	0.55	0.35	0.50
Poultry Litter	20	2.75	2.75	2.25
Goat	70	1.10	0.25	0.75
Horse	80	0.60	0.30	0.60

[1] Animal manures contain chloride, which can reduce the quality of some crops.
* Plant-available N can range from 20% to 80% of the total N in the year of application. See UK Cooperative Extension publication *Using Animal Manures as Nutrient Sources* (AGR-146) for more details.
This table was taken from UK Cooperative Extension publication *Lime and Fertilizer Recommendations* (AGR-1).

Mixed Fertilizers

Mixed, or complete, fertilizers contain all three primary nutrients. The ratios can vary. Fertilizers for annual gardens typically have $N:P_2O_5:K_2O$ ratios in the range of 1:1:1 or 1:2:2. Examples include 8–8–8 and 10–20–20 blends. Fertilizer blends for starting plants usually have a higher proportion of phosphorus. Lawn fertilizers are higher in nitrogen; an example is a 12–4–8 blend.

Common Organic Fertilizers

Farmyard manure can be an inexpensive source of nutrients. If you or your neighbors have livestock, it makes environmental and economic sense to recycle the manure as fertilizer. Packaged manure products cost more than manure off the farm, but they usually are more uniform and convenient to handle.

Animal manures vary widely in nutrient content and nutrient availability, depending on the type of animal that produced the manure and the manure's age and handling. For example:

- Fresh manure has higher nutrient levels than aged manure.
- Manure diluted with large amounts of bedding has fewer nutrients than undiluted manure.
- Exposure to rain leaches nutrients.
- Composting under cover retains more nutrients but reduces nutrient availability.

Table 4.7 compares average nutrient contents of typical manure products.

It doesn't take much fresh manure to fertilize a garden. One five-gallon bucket of fresh cow manure is enough for about 50 square feet of garden. The same amount of fresh poultry manure covers 100-150 square feet. Larger amounts can harm crops and leach nitrogen into groundwater. Sampling manure and testing for nutrient content is the best approach to matching plant needs with nutrient content of the manure.

Fresh manure can carry disease-causing pathogens. Be sure to refer to the information on manure safety below before using fresh manure.

It takes larger amounts of aged, diluted, or leached manure to provide the same amount of nutrients as fresh manure. If you're using it, increase the amount applied based on how much it is aged, diluted, and/or leached. Composted manure solids from dairy farms also have low nutrient availability, so you can apply them at higher rates than fresh manure. Use these manures as much for the organic matter they supply as for nutrients. You can add as much as one to two inches of manure and still have very low nutrient availability.

To fine-tune your application rate, experiment with the amount you apply and observe your crops' performance. It's better to be conservative and add more nutrients later if crops seem deficient than to risk overfertilizing.

To use manure, simply spread it over the soil and turn it in if you wish. Turning the manure in will help conserve some of the nitrogen in the manure and reduce the potential to lose manure due to runoff. However, tillage does increase erosion potential.

The best time to apply manure is in the spring before planting. You also can apply manure in the fall, but environmental risks of leaching and runoff increase in winter. If you do apply manure in the fall, apply it early and plant a cover crop to help capture nutrients and prevent runoff. See "Green Manure (Cover Crops)" later in this chapter for more information.

Using Manure Safely

Fresh manure sometimes contains disease-causing pathogens that can contaminate garden produce. *Salmonella* bacteria are among the most serious pathogens found in animal manure. Pathogenic strains of *E. coli* bacteria also can be present in cattle manure. Manure from swine, dogs, cats, and other carnivores should not be used in home gardens as it can contain helminths, which are parasitic worms.

These pathogens are not taken up into plant tissue, but they can adhere to soil on plant roots or to the leaves or fruit of low-growing crops. The risk is greatest for root crops (for example, carrots and radishes) or leaf crops (such as lettuce), where the edible part touches the soil. The risk is negligible for crops such as sweet corn, which do not contact the soil, or for any crop that is thoroughly cooked. Avoid using fresh manure where you grow high-risk crops.

Cooking destroys pathogens, but raw food carries a risk. Washing and peeling raw produce removes most pathogens, but some may remain.

Composting manure at high temperatures kills pathogens, but it is very hard to maintain rigorous composting conditions in a backyard pile. Commercial manure composts are composted under controlled conditions to destroy pathogens.

Bacterial pathogens die naturally over a period of weeks or months, so well-aged manure should not contain them. Helminths in dog, cat, or pig manure can persist for years, so do not add these manures to your garden or compost pile.

Biosolids

Biosolids are a by-product of wastewater treatment. Most of the biosolids produced in Kentucky are used to fertilize agricultural and forest crops. Biosolids also are available to gardeners from some wastewater treatment plants.

Use only biosolids that are free of disease-causing pathogens (Class A biosolids). Examples include biosolids compost and some heat-treated biosolids. Class B biosolids have not been treated to the same extent and may contain pathogens, including some that are long-lived in the soil. Check with the wastewater treatment plant offering biosolids to find out whether its biosolids meet Class A requirements and are available for home use.

A common form of biosolids is a spongy, black substance called "cake." Biosolids cake is about 20 percent to 25 percent dry matter and 75 percent to 80 percent water. It typically contains about 3 percent to 6 percent nitrogen and 2 percent to 3 percent phosphorus on a dry-weight basis, as well as small amounts of potassium and trace elements. Some of the nitrogen in biosolids is immediately available to plants. The rest is released slowly. Nutrient application of biosolids should be based on the nutrient content of the material being used. A nutrient analysis should be available from where the biosolid was processed.

Biosolids also are an ingredient in some commercial composts. Like other composts, biosolid compost releases nutrients very slowly (other than the immediately released nitrogen). It is a good source of organic matter and provides small amounts of nutrients to plants.

Biosolids contain small amounts of trace elements. Some trace elements are micronutrients, which can be beneficial to crops. However, large amounts can be toxic to crops, animals, or humans. When you apply biosolids at proper rates to provide nutrients, the risk of applying harmful amounts of trace elements is negligible.

Because biosolids come from the wastewater treatment process, they contain synthetic materials that were present in the wastewater or added during treatment. Biosolids are not certified as organic fertilizers.

Biosolids do have two important characteristics common to organic fertilizers:

- Their nutrients are released slowly from the organic form by natural processes in the soil.
- They are a product of the waste stream that can benefit crop growth.

Commercial Organic Fertilizers

Many organic by-products and some unprocessed minerals are sold as organic fertilizers. Table 4.8 shows approximate nutrient contents of some of these materials. The numbers represent total nutrient content. Because most are slow-release fertilizers, not all of the nutrients are available the year they are applied.

Table 4.8 shows that most organic fertilizer materials contain one main nutrient. The other nutrients are present in smaller amounts, which means that although organic fertilizers contain a variety of nutrients, they may not be present in the proportions needed by plants. Several companies produce balanced organic fertilizers by blending these materials into a single product that provides all of the primary nutrients in balanced proportions.

Commercial organic fertilizers tend to be more expensive per pound of nutrients than either processed fertilizers or manures. Sometimes the difference in price is substantial. Nevertheless, many gardeners use these products because of convenience. They are most economical for small gardens where little fertilizer is needed.

The cost per pound of nutrients in organic fertilizers varies widely, depending on the type of material, the concentration of nutrients, and the package size. Compare costs and nutrient availability when shopping for organic fertilizers.

Table 4.8. Total nitrogen, phosphate, and potash content of selected organic fertilizers.

Material	Nitrogen (%)	P_2O_5 (%)	K_2O (%)
Cottonseed meal	6–7	2	1
Blood meal[1]	12–15	1	1
Alfalfa	2	0.5	2
Bat guano[1]	10	3	1
Fish meal[1]	10	4	0
Fish emulsion[1]	3–5	1	1
Bone meal	1–4	12–24	0
Rock phosphate[2]	0	25–30	0
Greensand	0	0	3–7
Kelp meal	1	0.1	2–5

1 Contains a substantial amount of quickly available nitrogen that plants can use early in the season.
2 Very low P availability (only 2–3%). Useful only in acid soils.

How Much Fertilizer to Use

The goal of applying fertilizer is to supply enough nutrients to meet plant needs without accumulating excess nutrients in the soil that could leach into groundwater or run off into surface water. Soil tests and use of Cooperative Extension publications can help you estimate fertilizer needs.

Soil Tests

A soil test gives information on the levels of nutrients in your soil and recommends how much fertilizer to add each year based on the test results and the crops you grow. You don't need to test your soil every year; every three to five years is enough.

A garden soil test typically includes the nutrients phosphorus, potassium, calcium, magnesium, and zinc. The test also includes soil pH and recommends lime if it's needed to raise pH. In areas with historically high manure applications, a test for soluble salts can be worthwhile.

Soil test labs don't routinely test for nitrogen because there is no simple way to predict nitrogen availability. The lab will give a general nitrogen recommendation, however, based on the plants you are growing and on information you provide about the soil (such as whether there is a history of manure applications, which would increase soil-available nitrogen).

To take a soil sample, first collect subsamples from at least 10 different spots in your garden. Avoid any unusual areas, such as the site of an old trash dump, burn pile, or rabbit hutch. Sample the top six inches of soil (zero to six inches) if the soil has been tilled and zero to four inches for non-tilled soil and lawns. Air-dry the samples and mix them together well. Send about a pint of the mixed sample to your local county Cooperative Extension Service office.

If you're planting different crops but the area has had similar previous fertilizer additions, it's probably not necessary to submit more than one soil sample. Instead, use the fertilizer recommendations for the various crops.

Before choosing a lab, call to make sure it tests and makes recommendations for garden soils. Ask a lab representative the following questions:

- Do you routinely test garden soils for plant nutrients and pH?
- Do you use Kentucky test methods and fertilizer guides?
- Do you give recommendations for garden fertilizer applications?
- Are there forms to fill out? What information do you need?
- How much does a test cost?
- How quickly will you send results?

Cooperative Extension Publications

Soil testing is highly recommended, but if you are unable to submit a sample for testing, you can use Cooperative Extension publications to estimate your needed fertilizer additions. These publications usually give recommendations for processed fertilizers, but some give guidelines for organic fertilizers as well. Kentucky has published fertilizer recommendations for a variety of crops. See "For More Information" at the end of this chapter. Also see other chapters in this series for information on specific crops.

A typical extension recommendation is for two pounds of nitrogen per 1,000 square feet of garden, usually applied in a mixed fertilizer with a 1:0:1 ratio. (Fast-growing crops such as sweet corn need more nitrogen.) Gardens with a history of fertilizer application will most likely not need any phosphorus and will only require a small amount of potassium. You won't know for sure unless you test. Due to the environmental risks associated with excess phosphorus, the University of Kentucky does not recommend any phosphorus fertilizer application unless a soil test is conducted.

Estimating Organic Fertilizer Rates

Estimating how much organic fertilizer to use can be a challenge because you must estimate the availability of nutrients in the fertilizer. Here are some tips:

- Organic fertilizers with large proportions of available nutrients (such as bat guano and fish emulsion) can be substituted for processed fertilizers on a one-to-one basis. Use the same quantity called for in the processed fertilizer recommendation.
- Apply other packaged fertilizers according to their nutrient availability. Composts, rock phosphate, and plant residues generally have lower nutrient availability than more concentrated animal products (for example, blood meal, bone meal, and chicken manure). The recommended application rates on packaged organic fertilizers are a good guideline. Check these recommendations against other products to make sure they seem reasonable.
- Nutrient concentration and availability in farmyard manures vary widely, depending on the type of manure and its age and handling. Application rates range from five gallons per 100-150 square feet for high-nitrogen poultry manure to one to two inches deep for cow or horse manure composted with bedding. Estimate application rates based on the type of manure.
- Observe your crops carefully. Lush plant growth and delayed flowering and fruiting are signs of high amounts of available nitrogen and may indicate overfertilization.
- Experiment with different fertilizer rates in different parts of a row, and see whether you notice differences in crop performance. Plan your experiment carefully so you are confident that differences are the result of different fertilizer rates rather than differences in soil, water, sunlight, or management practices.
- Soil testing is valuable in understanding your soil's nutrient status. Many established gardens have high levels of soil fertility, so that crops grow well with little fertilizer.

How to Calibrate a Fertilizer Spreader by the Volume Method

1. Based on the fertilizer analysis, determine the amount of actual fertilizer that needs to be spread per 1,000 square feet. (To get a rate of 1.5 pounds of nitrogen per 1,000 square feet, 30 pounds of 5-5-5 or 15 pounds of 10-10-10 would be required.)
2. Start with a known amount of fertilizer (for example, a 50-pound bag) and a known volume (for example, two five-gallon buckets of same size).
3. Pour the fertilizer into the buckets and measure the total height, leveled. If the measurement is in inches, there will be a known amount of fertilizer (50 pounds) per so many inches. For example, if 50 pounds measures 31 inches total in the two buckets, 50 pounds/31 inches equals 1.6 pounds per inch of bucket height. This standard calculation will allow determination of a weight if scales are not available.
4. Determine the width of the fertilizer spread pattern, then the total area.

(Known width x distance = total area)

5. Set the spreader's gate to manufacturer's recommendation. Most fertilizers will have a different flow pattern and density, so one factory setting will not work for all fertilizers.
6. Measure a known distance—for example, 50 feet. Apply the fertilizer to the 50-foot line. Do not collect the fertilizer. Pour remaining fertilizer in the spreader back into the bucket, and measure the height. (Remember that for this example, one inch in the bucket weighs 1.6 pounds.)

Example:

With a 10-foot spread width and 50-foot length, total area equals 500 square feet.

For this area, we want 1.5 pounds of nitrogen per 1,000 square feet, or 15 pounds of 10-10-10.

- After spreading 50 feet of fertilizer at a 10-foot width, pour the remaining fertilizer back into the bucket and measure. For this example, let's assume the measurement is seven inches.
- Based on the previous determination of a fertilizer weight of 1.6 pounds per inch, seven inches multiplied by 1.6 pounds per inch equals 11.2 pounds of fertilizer.
- Because calibration is on 500 square feet and the recommendation is for 1,000 square feet, multiply by two, which equals 22.4 pounds of fertilizer per 1,000 square feet.
- Amount of 10-10-10 needed to achieve the 1.5 pounds of nitrogen per acre is 15 pounds and our calculations show that 22.4 pounds was applied; therefore, we are applying too much. We need to reduce the amount coming out of the spreader and calibrate again.
- Continue using this procedure until you have the desired rate.

When to Fertilize

In most cases, the best time to apply fertilizer is close to the time when plants need the nutrients. This timing reduces the potential for nutrients to be lost before they are taken up by plants. Not only is nutrient loss inefficient, it may contaminate groundwater or surface water.

Plants need the largest amount of nutrients when they are growing most rapidly. Rapid growth occurs in midsummer for corn and squash, earlier for spring plantings of lettuce and other greens. Plants also need available nutrients shortly after seeding or transplanting.

For a long-season crop such as corn, many gardeners apply a small amount of fertilizer as a starter at the time of seeding and then add a larger amount in early summer just before the period of rapid growth. When using organic fertilizers, a single application usually is adequate, because nutrient release usually is fastest just before plant demand is greatest.

For perennial plants, timing depends on the plant's growth cycle. Blueberries, for example, benefit most from fertilizer applied early in the season at bud break, while June-bearing strawberries are fertilized after harvest. Refer to other chapters in this manual and to other Extension publications for information on timing fertilizer applications for specific crops.

Adding Organic Matter

Organic matter builds and stabilizes soil structure, thus reducing erosion and improving soil porosity, infiltration, and drainage. It holds water and nutrients for plants and soil organisms. It also is a long-term, slow-release storehouse of nitrogen, phosphorus, and sulfur, which continuously become available as soil microorganisms break down the organic matter.

The value of organic materials varies, depending on their nitrogen content (more specifically, their carbon to nitrogen, or C:N, ratio). Organic materials with a low C:N ratio, such as undiluted manure or blood meal, are rich in nitrogen. They are a good source of nutrients but must be used sparingly to avoid overfertilization.

Materials with an intermediate C:N ratio (including many composts, leaf mulches, and cover crop residues) have lower nutrient availability. They are the best materials to replenish soil organic matter. Because they are relatively low in available nutrients, you can add them to the soil in large amounts.

Materials with a high C:N ratio (such as straw, bark, and sawdust) contain so little nitrogen that they reduce levels of available nitrogen when mixed into the soil. Soil microorganisms use available nitrogen when they break down these materials, leaving little nitrogen for plants. This process is called "immobilization" and results in nitrogen deficiency. If you use materials with a high C:N ratio in your garden, add extra nitrogen fertilizer to compensate for immobilization. The best use for these materials is for mulches around perennial crops or in walkways. They do not cause nitrogen immobilization until you mix them into the soil.

Compost

Compost is an excellent source of organic matter for garden soils. Composting also closes the recycling loop by turning waste materials into a soil amendment. You can make compost at home or buy commercially prepared compost.

Homemade Compost

The key to composting is to supply a balance of air, water, energy materials (materials with a low C:N ratio, such as grass clippings, green garden trimmings, or fresh manure), and bulking agents (materials with a high C:N ratio, such as corn stalks, straw, and woody materials). You don't need additives to stimulate your compost pile. You just need to provide conditions favorable for natural composting organisms.

You can compost in the following ways:

- Hot (fast) composting produces high-quality, finished compost in six to eight weeks. To maintain a hot compost pile, mix together balanced volumes of energy materials and bulking agents, keep the pile moist, and turn it frequently to keep it aerated.
- Cold (slow) composting requires less work than hot composting. Build the pile and leave it until it decomposes. This process may take months or longer. Cold composting does not kill weed seeds or pathogens. Rats and other pests can be attracted to edible wastes in cold compost piles.
- You can compost fruit and vegetable scraps in a worm bin. This method works well for urban gardeners who have little space.
- You can bury fruit and vegetable scraps and allow them to decompose in the soil.

Commercial Compost

Yard debris is the major raw material in most commercial compost sold in Kentucky. Commercial compost also may contain animal manure, biosolids, food waste, or wood waste. Commercial compost is made on a large scale, with frequent aeration and/or turning to create conditions that kill weed seeds, plant pathogens, and human pathogens.

Compost Use

Adding one to two inches of compost each year helps build a productive garden soil. You can till or dig compost directly into your garden or use it as a mulch before turning it into the soil. One cubic yard of compost covers about 325 square feet to one inch deep. In the first year after application, partially decomposed woody compost may immobilize some soil nitrogen, resulting in nitrogen deficiency for plants. If plants show signs of nitrogen deficiency (poor growth or yellow leaves), add extra nitrogen fertilizer (either organic or inorganic). In subsequent years, most compost contributes small amounts of available nitrogen to the soil.

It is important to know the source of composted materials derived from grass clippings or animal manure used as fertilizer amendments on your garden or landscape plants. Herbicide residues could be present that can cause injury to sensitive garden plants such as tomatoes and other broadleaf plants. Active ingredients in certain herbicide products applied to lawns can be retained in grass clippings, or animals consuming herbicide-treated pastures and hay can pass the material through the digestive system, so that the herbicide in the manure persists at concentrations that will cause injury to sensitive crops. Furthermore, the composting process may not fully degrade these herbicide compounds. To be safe, make sure that composted grass clippings and manure used on your garden or landscape areas have not been directly or indirectly exposed to herbicides.

Green Manure (Cover Crops)

Green manures are cover crops grown specifically to be tilled or dug into the soil. Planting green manure is a way to grow your own organic matter. The value of cover crops goes beyond their contribution of organic matter, however. They also can do the following:

- Capture and recycle nutrients that otherwise would be lost by leaching during winter
- Protect the soil surface from rainfall impact
- Reduce runoff and erosion
- Suppress weeds
- Supply nitrogen (legumes only)

Roots from cover crops, especially crops that produce taproots, can penetrate a moderately compacted zone and help distribute nutrients deeper into the soil profile.

No one cover crop provides all of these benefits. Deciding which cover crop or combination to grow depends on which benefits are most important to you and which cover crops best fit into your garden plan (Table 4.9). With the exception of buckwheat, all of the cover crops listed in Table 4.9 are suitable for fall planting and spring tillage.

Table 4.9. Examples of cover crops for Kentucky.

Cover Crop	Characteristics
Annual ryegrass	Hardy, tolerates wet soils, can be difficult to control if seeds
Austrian winter peas	Legume, does not compete well with winter weeds, must establish early fall
Buckwheat	Rapid germination and growth, frost sensitive, drought tolerant
Cereal rye	Hardy, rapid growth, matures rapidly in spring
Crimson clover	Legume, grows more slowly than vetch
Hairy vetch	Legume, slow initial growth, grows quickly in the spring, can be difficult to kill
Winter triticale	Produces more vegetation than cereal rye or winter wheat
Winter wheat	Most common cover crop, covers soil well, matures slowly
Turnip/mustard greens	Grow well in fall, strong taproots to break compacted layers, edible

Note: All legumes fix nitrogen.

Gardeners usually plant cover crops in the fall and till them into the soil before planting in the spring. The earlier cover crops are planted, the more benefits they provide.

Termination time for cover crops can affect nutrient availability for subsequent crops and other management issues. Late termination of a cereal can tie up nitrogen due to the cover crop's high C:N ratio, and early termination of a cover crop can release nitrogen before it is needed, reducing its benefit to the garden.

Legumes such as vetch and crimson clover need an early start to achieve enough growth to cover the soil before cold weather arrives.

If your garden contains crops into November or December, it will not be possible to plant early cover crops over the entire area. In this case, plant cover crops in areas you harvest early and use mulch in those you harvest later. For example, plant a cover crop in a sweet corn bed immediately following harvest in September, and mulch a bed of fall greens after you remove the crop in November. You also can start cover crops between rows of late crops if space allows.

Till or dig cover crops into the soil before they flower. After flowering, plants become woody and decline in quality. Also, digging plants into the soil becomes quite difficult if they grow too large. If you cannot till a cover crop before it blooms, cut it off and compost it for later use. You will still get the short-term benefit of organic matter from the crowns and roots when you till your garden.

The organic matter benefits of cover crops last only about one year, so make cover crops an annual part of your garden rotation. If they do not fit into your garden plan, you can use winter mulches as a substitute.

Soil pH

Soil pH measures the acidity or alkalinity of a soil. At a pH of 7 (neutral), acidity and alkalinity are balanced. Acidity increases by a factor of 10 with each one-unit drop in pH below 7. For example, a pH of 5.5 is 10 times as acidic as a pH of 6.5. Alkalinity increases by a factor of 10 with each one-unit change in pH above 7.

Native soil pH depends on the minerals present in the soil and on rainfall. Soils in arid areas tend to be alkaline, and those in rainy areas tend to be acid. Gardening and farming also affect soil pH; for example, many nitrogen fertilizers tend to reduce pH, while liming increases pH.

Soil pH influences plant growth in three ways, affecting the following:

- availability of plant nutrients (Figure 4.8)
- availability of toxic metals
- activity of soil microorganisms, which in turn affects nutrient cycling and disease risk

The availability of phosphorus decreases in acid soils, while the availability of iron increases. In alkaline soils, the availability of iron and zinc can be quite low.

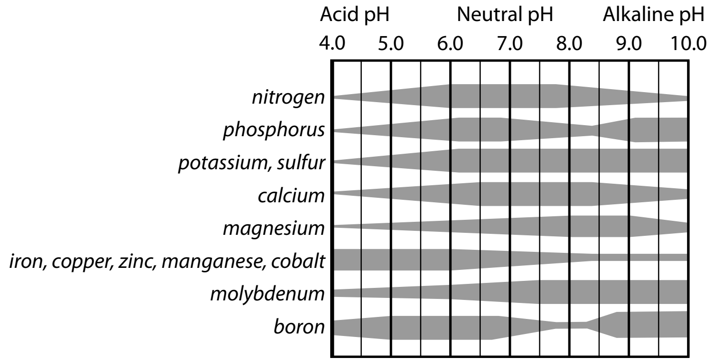


Figure 4.8. Effect of soil pH on the availability of plant nutrients.

Aluminum availability increases in acid soils. Aluminum is one of the most common elements in soil, but it is not a plant nutrient and is toxic to plants in high concentrations. Very little aluminum is in solution in soils above pH 6, and what is present causes no problems for plants. As pH declines and aluminum availability increases, aluminum toxicity can become a problem.

Microbes also are affected by soil pH. The most numerous and diverse microbial populations exist in the middle of the pH range. Fewer organisms are adapted to strongly acid or strongly alkaline soils. Nutrient cycling is slower in acid and alkaline soils because of reduced microbial populations.

Many garden crops perform best in soil with pH of 5.5 to 7.5, but some (such as blueberries and rhododendrons) are adapted to more strongly acidic soils. Before amending soil to adjust pH, it is important to know the preferred pH ranges of your plants.

Increasing Soil pH

The most common way to increase soil pH is to add lime, which is ground limestone, a rock containing calcium carbonate. It is an organic (natural) amendment, suitable for use by organic gardeners.

Lime raises the pH of acid soils and supplies calcium, an essential nutrient. Dolomitic lime contains magnesium as well as calcium.

The best way to determine whether your soil needs lime is to have it tested. Do not lime areas where you grow acid-loving plants, because they are adapted to acid soils.

Lime is a slow-release material. Apply it in the fall to benefit spring crops.

Wood ashes are a readily available source of potassium, calcium, and magnesium. Like lime, they also raise soil pH. High rates of wood ashes may cause short-term salt injury, so apply less than 15 to 25 pounds per 1,000 square feet. We do not recommend using wood ashes in alkaline soils.

Gypsum (calcium sulfate) is not a substitute for lime. It supplies calcium and sulfur, but has little effect on soil pH. Gypsum has been promoted as a soil amendment to improve soil structure. In the vast majority of cases, it does not work. Gypsum improves structure only when poor structure results from excess sodium in the soil, a rare condition in Kentucky.

Use organic amendments to improve soil structure, as described earlier under "Adding Organic Matter."

Some composts can increase soil pH, as can poultry litter, due to diet and amendments added to bedding material.

Decreasing Soil pH

You may need to decrease soil pH if you wish to grow acid-loving plants. Elemental sulfur and aluminum sulfate lower soil pH. Soil testing is the best way to determine whether sulfur is needed, and if so, how much. Refer to Table 4.10 to determine the amount of sulfur needed when lowering soil pH.

Ammonium sulfate fertilizer also lowers pH, but it takes longer than sulfur to have an effect. All nitrogen fertilizers that contain ammonium (NH_4^+) also reduce pH slowly.

Table 4.10. Materials required to lower soil pH to specific levels. Use the following table for each 100 sq ft.[1] Multiply by 436 for lb/A.

To Change pH from:	Add		
	Wettable Sulfur (lb)	or	Aluminum[3] Sulfate (lb)
8.0 to 7.0	2		3.0
8.0 to 6.5	3		4.5
8.0 to 6.0	4		6.0[2]
8.0 to 5.5	5		7.5[2]
8.0 to 5.0	6		9.0[2]
7.5 to 7.0	1		1.5
7.5 to 6.5	2		3.0
7.5 to 6.0	3		4.5
7.5 to 5.5	4		6.0[2]
7.5 to 5.0	5		7.5[2]
7.5 to 4.5	6		9.0[2]
7.0 to 6.5	1		1.5
7.0 to 6.0	2		3.0
7.0 to 5.5	3		4.5
7.0 to 5.0	4		6.0[2]
7.0 to 4.5	5		7.5[2]
6.5 to 6.0	1		1.5
6.5 to 5.5	2		3.0
6.5 to 5.0	3		4.5
6.5 to 4.5	4		6.0[2]
6.0 to 5.5	1		1.5
6.0 to 5.0	2		3.0
6.0 to 4.5	3		4.5
5.5 to 5.0	1		1.5
5.5 to 4.5	2		3.0
5.0 to 4.5	1		1.5

1 Aluminum sulfate is faster in reaction than sulfur. The two materials may be applied together (half of each). Incorporate into the top 6 inches of the soil.
2 Rates higher than 4.5 lb per 100 sq ft can cause excess soluble salt problems. Split the amount in half and apply in the spring and fall.
3 Aluminum sulfate is less effective in reducing soil pH but is quicker acting than wettable sulfur. More frequent applications may be necessary.
Prepared by Kathy Keeney, McCracken County extension agent for horticulture.

Soils and Fertilizer Terminology

Aggregation—The process by which individual particles of sand, silt, and clay cluster and bind together to form peds.

Anion—A negatively charged ion. Plant nutrient examples include nitrate (NO^-_3), phosphate ($H_2PO_4^-$), and sulfate (SO_4^{2-}).

Aspect—Direction of exposure to sunlight.

Biosolids—A by-product of wastewater treatment sometimes used as a fertilizer.

Capillary force—The action by which water molecules bind to the surfaces of soil particles and to each other, thus holding water in fine pores against the force of gravity.

Cation—A positively charged ion. Plant nutrient examples include calcium (Ca^{2+}) and potassium (K^+).

Cation exchange capacity (CEC)—A soil's capacity to hold cations as a storehouse of reserve nutrients.

Clay—The smallest type of soil particle (less than 0.002 millimeters in diameter).

C:N ratio—The ratio of carbon to nitrogen in organic materials. Materials with a high C:N ratio are good bulking agents in compost piles, while those with a low C:N ratio are good energy sources.

Cold composting—A slow composting process of simply building a pile and leaving it until it decomposes. This process may take months or longer. Cold composting does not kill weed seeds or pathogens.

Compaction—Pressure that squeezes soil into layers that resist root penetration and water movement. Often the result of foot or machine traffic or tilling when the soil is too wet.

Compost—The product created by the breakdown of organic materials under conditions manipulated by humans.

Cover crop—A crop planted in the offseason to reduce soil loss and capture nutrients not used during the growing season. Called a green manure when planted with the intention of incorporating into the soil.

Decomposition—The breakdown of organic materials by microorganisms.

Fertilizer—A natural or synthetic product added to the soil to supply plant nutrients.

Fertilizer analysis—The amount of nitrogen, phosphorus (as P_2O_5), and potassium (as K_2O) in a fertilizer, expressed as a percent of total fertilizer weight. Nitrogen (N) always is listed first, phosphorus (P) second, and potassium (K) third.

Green manure—See *Cover crop*.

Hot composting—A fast composting process that produces finished compost in six to eight weeks. High temperatures are maintained by mixing balanced volumes of energy materials and bulking agents, keeping the pile moist, and turning it frequently to keep it aerated.

Humus—The stable end product of decomposed animal and plant remains of unrecognizable origin, their partial decomposition products, and waste for soil biomass. Same as soil organic matter.

Immobilization—The process by which soil microorganisms use available nitrogen as they break down materials with a high C:N ratio, thus reducing the amount of nitrogen available to plants.

Infiltration—The movement of water into soil.

Ion—An atom or molecule with either positive or negative charges.

Leaching—Movement of water and soluble nutrients down through the soil profile.

Loam—A soil with roughly equal influence from sand, silt, and clay particles.

Macropore—A large soil pore. Macropores control a soil's permeability and aeration and include earthworm and root channels.

Micronutrient—A nutrient used by plants in small amounts (iron, zinc, molybdenum, manganese, boron, copper, and chlorine). Also called a trace element.

Micropore—A fine soil pore, typically a fraction of a millimeter in diameter. Micropores are responsible for a soil's ability to hold water.

Mycorrhizae—Beneficial fungi that infect plant roots and increase the plants' ability to take up nutrients from the soil, particularly phosphorus.

Nitrifier—A microbe that converts ammonium to nitrate.

Nitrogen cycle—The sequence of biochemical changes undergone by nitrogen as it moves from living organisms to decomposing organic matter, to inorganic forms, and back to living organisms.

Nitrogen fixation—The conversion of atmospheric nitrogen into plant-available forms by Rhizobia bacteria.

Organic fertilizer—A natural fertilizer material that has undergone little or no processing. Can include plant, animal, and/or mineral materials.

Organic materials—Recognizable materials originating from living organisms, the precursors to soil organic matter.

Organic matter—Plant remains of unrecognizable origin, their partial decomposition products, and waste for soil biomass. See *Humus.*

Pathogen—A disease-causing organism. Pathogenic soil organisms include bacteria, viruses, fungi, and nematodes.

Ped—A cluster of individual soil particles.

Permeability—The rate at which water moves through a soil.

pH—A measure of acidity or alkalinity. Values from 0 to 7 indicate acidity, a value of 7 is neutral, and values from 7 to 14 indicate alkalinity. Most soils have a pH between 4.5 and 9.

Phosphate—The form of phosphorus listed in most fertilizer analyses (P_20_5).

Potash—The form of potassium listed in most fertilizer analyses (K_20).

Primary nutrient—A nutrient required by plants in a relatively large amount (nitrogen, phosphorus, and potassium). See *Macronutrient*.

Processed fertilizer—A fertilizer that is manufactured or is refined from natural ingredients to be more concentrated and more available to plants.

Quick-release fertilizer—A fertilizer that contains nutrients in plant-available forms such as ammonium and nitrate.

Rhizobia bacteria—Bacteria that live in association with roots of legumes and convert atmospheric nitrogen to plant-available forms, a process known as nitrogen fixation.

Rhizosphere—The thin layer of soil immediately surrounding plant roots.

Sand—The coarsest type of soil particle (0.05 to 2 millimeters in diameter).

Secondary nutrient—A nutrient needed by plants in a moderate amount (sulfur, calcium, and magnesium).

Silt—A type of soil particle that is intermediate in size between sand and clay (0.002 to 0.05 millimeters in diameter).

Slow-release fertilizer—A fertilizer that is not immediately available for plant use after application. This can be a processed fertilizer that has a coating or additive or a type that must be converted into a plant-available form before being utilized.

Soil—A natural, biologically active mixture of weathered rock fragments and organic matter at the earth's surface.

Soil salinity—A measure of the total soluble salts in a soil.

Soil solution—The solution of water and dissolved minerals found in soil pores.

Soil structure—The arrangement of aggregates (peds) in a soil.

Soil texture—How coarse or fine a soil is. Texture is determined by the proportions of sand, silt, and clay in the soil.

Soluble salt—A compound often remaining in soil from irrigation water, fertilizer, compost, or manure applications.

Water-holding capacity—The ability of a soil's micropores to hold water for plant use.

For More Information

For more information, contact your county Extension agent.

University of Kentucky Cooperative Extension Service Publications

Home Composting: A Guide to Managing Home Yard Waste (HO-75)
Home Vegetable Gardening (ID-128)
Lime and Fertilizer Recommendations (AGR-1)
Organic Manures and Fertilizers for Vegetable Crops (https://www.uky.edu/hort/sites/www.uky.edu.hort/files/documents/organicmanures.pdf)
Water Quality and Nutrient Management at Home (HENV-402)
Winter Cover Crops for Kentucky Gardens and Fields (ID-113)

Other Resources

Bohn, H.L., B.L. McNeal, and G.A. O'Connor. *Soil Chemistry, 3rd edition* (John Wiley & Sons, New York, 2001).
Brady, N.C., and R.R. Weil. *The Nature and Properties of Soils, 14th edition* (Prentice-Hall, New York, 2007).
Craul, P.J. *Urban Soil in Landscape Design* (John Wiley & Sons, New York, 1992).
Donahue, R.L., R.W. Miller, and J.C. Shickluna. *Soils: An Introduction to Soils and Plant Growth* (Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1990).
Tisdale, S.L., and W.L. Nelson. *Soil Fertility and Fertilizers* (Macmillan Publishing Co., Inc., New York, 1985).

Chapter 05
Plant Diseases

By Kimberly Leonberger, plant pathology Extension associate; Kelly Jackson and Robbie Smith, Extension horticulture agents; and Nicole Gauthier, Extension plant pathologist.

In this chapter:

Anyone who has ever planted a garden knows not only the rewards of beautiful flowers, fruit, and/or vegetables, but also the disappointment when plants become diseased or damaged. Many factors cause plants to exhibit poor vigor, changes in appearance, or even death. Both abiotic (non-living) and biotic (living) factors can negatively impact plant heath. Disorders that result from non-living factors (such as nutrient deficiencies, too much or too little watering, temperature stress, and chemical damage) are discussed in subsequent chapters. This chapter focuses on those living organisms that cause disease: fungi, water molds, bacteria, viruses, nematodes, phytoplasmas, and parasitic plants.

History and Significance

Plant loss to homeowners may result in frustration and minor monetary cost. However, on a global scale, plant diseases cause an estimated $38 billion[1] in annual losses. History also provides some perspective on the impacts of plant disease.

One of the most notable historical impacts of plant disease was caused by late blight of potato. This disease was a major contributing factor in the Irish potato famine of 1845. During this time, approximately one million people perished from starvation; a million and a half more are believed to have left Ireland and immigrated to the United States. The late blight pathogen is still present in production systems today, but it is managed by resistant varieties, sanitation, and fungicides.

Near complete loss of the American chestnut was caused by a fungal disease that nearly wiped out forests in the eastern United States. The trees once grew to majestic heights within their native forest habitat, as well as in urban plantings. They provided high-quality hardwood for building construction and nuts as a food source for people and wildlife. However, in the late 1800s, chestnut blight was accidentally introduced to the United States through imported Chinese chestnut trees. While Chinese chestnuts are tolerant to the blight, American chestnut trees are not, and in less than 40 years, approximately 30 million acres of chestnut trees died. Chestnut blight remains a problem, and researchers are still seeking options for management.

Disease management changed drastically when the French wine industry gave way to the first fungicide, Bordeaux mixture. France's grape production had long been devastated by powdery mildew and downy mildew. Then in 1882, the discovery of a copper sulfate and lime mixture helped manage these vineyard diseases. Bordeaux mixture is still used in a modified form to manage powdery mildew, downy mildew, and other fungal diseases on numerous types of plants.

These examples represent situations in which plant diseases have reached historical proportions. However, the amount of damage that plant diseases cause varies depending upon factors such as environment, host health and susceptibility, and pathogen biology. There are many options for managing disease development and spread. The effectiveness of management techniques begins with proper identification of the disease and/or causal organism.

Pathogens

A plant disease is any physiological or structural abnormality that is caused by a living organism. Organisms that cause disease are referred to as *pathogens*, and affected plants are referred to as *hosts*. Many organisms rely on other species for sources of nutrients or as a means of survival, but they are not always harmful to the host. For example, saprophytic organisms obtain nutrients from dead organic material and are a vital part of many ecosystems. Plant pathogens, on the other hand, utilize hosts for nutrients and/or reproduction at the hosts' expense. Disease-causing organisms include fungi, oomycetes (fungus-like organisms called water molds), bacteria, viruses, nematodes, phytoplasmas, and parasitic seed plants.

Once a pathogen infects a host, symptoms often develop. Symptoms are the outward changes in the physical appearance of plants. Symptoms take time to develop, and thus, disease development may be delayed for several days, weeks, months, or even years after initial infection occurs. Examples of symptoms include wilt, leaf spots, cankers, rots, and decline.

Physical evidence of pathogens (called signs) may also be observed on diseased tissue. Examples of signs include fungal fruiting bodies, bacterial ooze, nematode cysts, and fungal mycelia. Both symptoms and signs are utilized in making disease diagnoses.

Conditions for Disease Development

Disease development is dependent upon three conditions: a susceptible host plant, a favorable environment, and a viable pathogen. All three of these factors must be present for disease to occur. Figure 5.1 presents this concept as a "disease triangle." Each side of the triangle represents one of these factors: host plant, environment, or pathogen. When all three sides of the triangle are complete, disease occurs. If one of the conditions is not present (one side of the triangle is missing), then disease does not occur. By altering the susceptibility of host plants, the surrounding environment, and/or the viability of pathogens, the disease triangle can be broken and disease development prevented.

Host plant genetic makeup determines its susceptibility to disease. This susceptibility depends upon various physical and biochemical factors within the plant. A plant's stature, growth habit, cuticle thickness (a protective outer layer on plant tissues), and shape of stomata (small openings that allow water, oxygen, and carbon dioxide in and out of plant tissues) are a few physical factors that influence disease development. Plants may also produce biochemical compounds that limit or prevent colonization or infection. Growth stage and ability to deter pathogens can also impact plant susceptibility to disease. For example, young leaves are often more susceptible to infection than mature leaves.

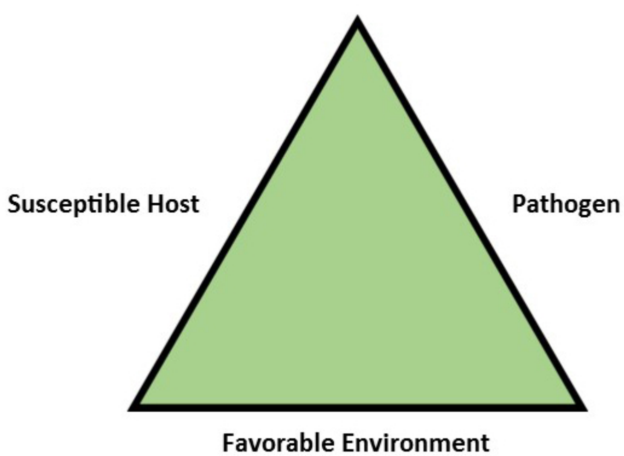


Figure 5.1. Disease Triangle—Plant disease results when there is a susceptible host, viable pathogen, and favorable environment.

Environment plays an important role in disease development. Pathogens generally require specific environmental conditions for infection and spread. Most plant pathogens require high humidity and moderate temperatures. Other pathogens, such as bacteria and water molds, require surface water for spread. In some disease cycles, environmental conditions influence the development of symptoms. For example, extreme temperatures or drought can cause plant stress; this loss of vigor can increase host susceptibility to both infection and disease development. Other environmental factors affecting disease can include those resulting from planting and maintenance practices. For example, high-density plantings can have higher relative humidity, while overhead watering increases leaf surface moisture needed by pathogens to infect plant leaves.

Pathogens must be present and viable in order to infect plants and cause disease. Removal of infected plant parts and other remnants of pathogens makes them unavailable for infection. Fungicides also reduce amounts of inoculum (infective propagules) available for infection. Many pathogens, however, have developed specialized structures that ensure survival during adverse conditions. For example, several water molds and fungi are capable of surviving in soil for many years until conditions are favorable for infection. Pathogens may also survive winter temperatures and other harsh conditions in infected plant tissue. If a susceptible host and favorable environment are not available, some pathogens can assume a dormant state for many years.

Fungi

Fungi are the most abundant group of plant pathogens. There are thousands of fungi capable of causing plant diseases. These multicellular organisms are typically microscopic. The body of a fungus is composed of filament-like threads called *hyphae*. Masses of hyphae are called *mycelia*. When large enough, these masses can be seen without the aid of a microscope. Powdery mildew is one example of a disease in which fungal mycelia are visible.

Fungi reproduce via spores, which can be produced sexually or asexually. Spores vary in color, shape, size, and function, and this variation can often be used by diagnosticians as a means to identify pathogens. Some fungi produce spores within sexual fruiting structures (ascocarps, pustules, mushrooms) or asexual fruiting structures (pycnidia, acervuli). While many of these fruiting structures are small and may require the aid of a microscope, some (such as mushrooms or rust pustules) can be seen with the naked eye. Other types of fungi produce exposed or unprotected spores that are not enclosed in structures. These spore types are more sensitive to environmental conditions than enclosed spores.

Once a fungal spore makes contact with a plant surface, it germinates, much like a seed, as long as conditions are favorable for the pathogen. Hyphae emerge from spores and are capable of infecting plants via natural plant openings (such as stomata), through wounds, or by direct penetration of the plant epidermis. Upon infection, fungi utilize nutrients from their hosts. Many fungi produce additional spores as they grow, which aids in the spread of the pathogen.

Spores or mycelial fragments (these infective units are referred to as *propagules*) can be spread via wind, water, soil, insects, animals, and humans. Fungi spread not only from plant to plant, but also within a single plant. Fungi may spread through a single plant as a systemic infection by utilizing the vascular system or by splashing spores that result in multiple infection sites on multiple plant tissues.

Common symptoms caused by fungi include leaf spots, wilts, blights, cankers, fruit rots, and dieback. For additional information on symptoms that can result from fungal infections, refer to Table 5.1. Fungi cause a wide range of diseases including Septoria leaf spot, powdery mildew, cedar-apple rust, and Armillaria root rot. Life cycles of these diseases are presented in Figures 5.2, 5.3, 5.4, and 5.5 respectively.

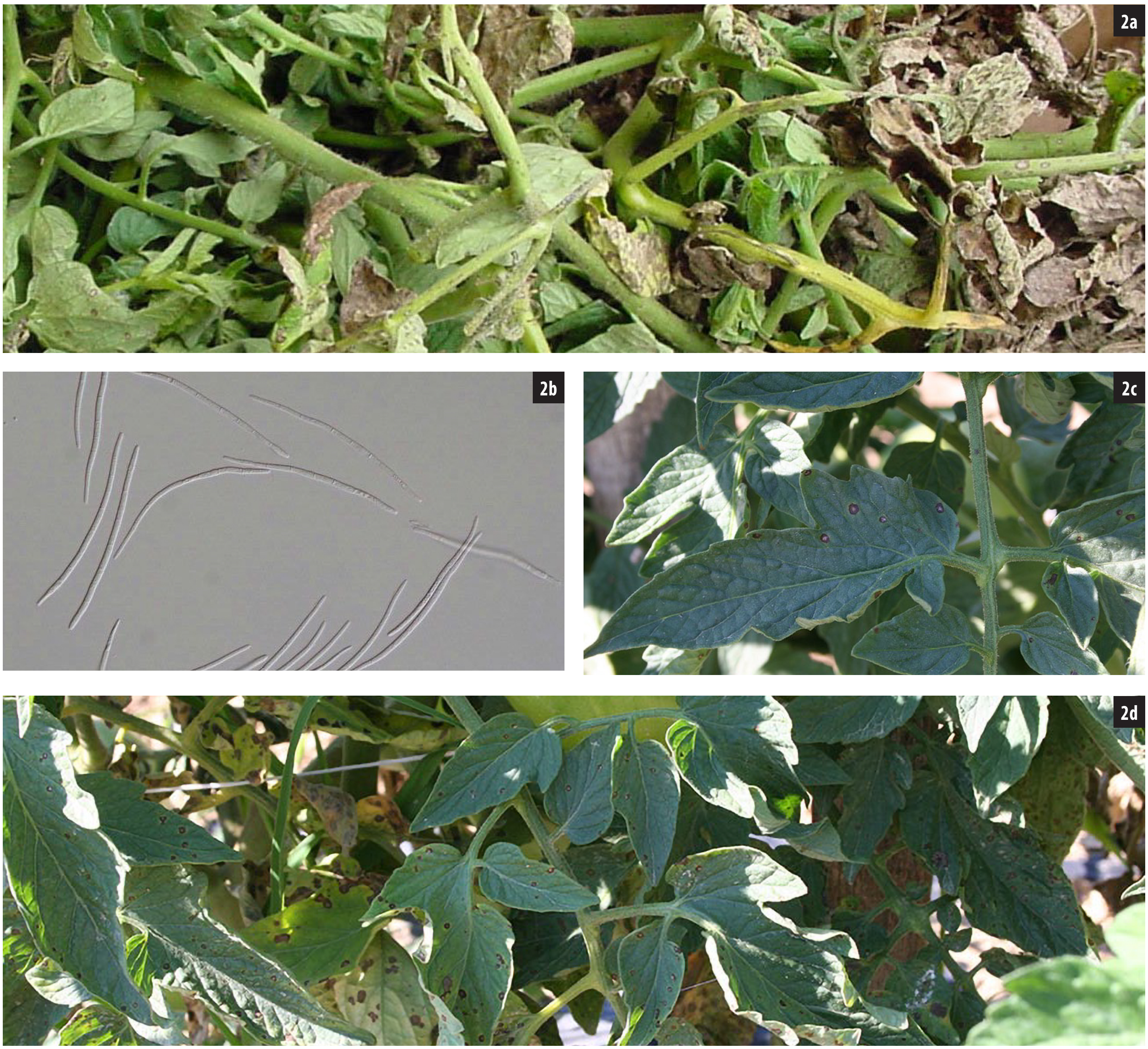


Figure 5.2. Septoria leaf spot of tomato is a disease familiar to many gardeners. Spores survive winter on infected plant debris **(2a)** and weed hosts. In spring, when temperatures are favorable, rain splashes spores **(2b)** onto new plant growth where infection occurs. Small circular lesions develop on leaves **(2c)**, petioles, and stems. This pathogen is not known to infect fruit. Symptoms first develop on lower plant parts where humidity is high and the first splashed spores land. As the season progresses the fungus produces additional spores, which are splashed by water further up plants. Severely infected plants may exhibit necrosis and defoliation **(2d)**.

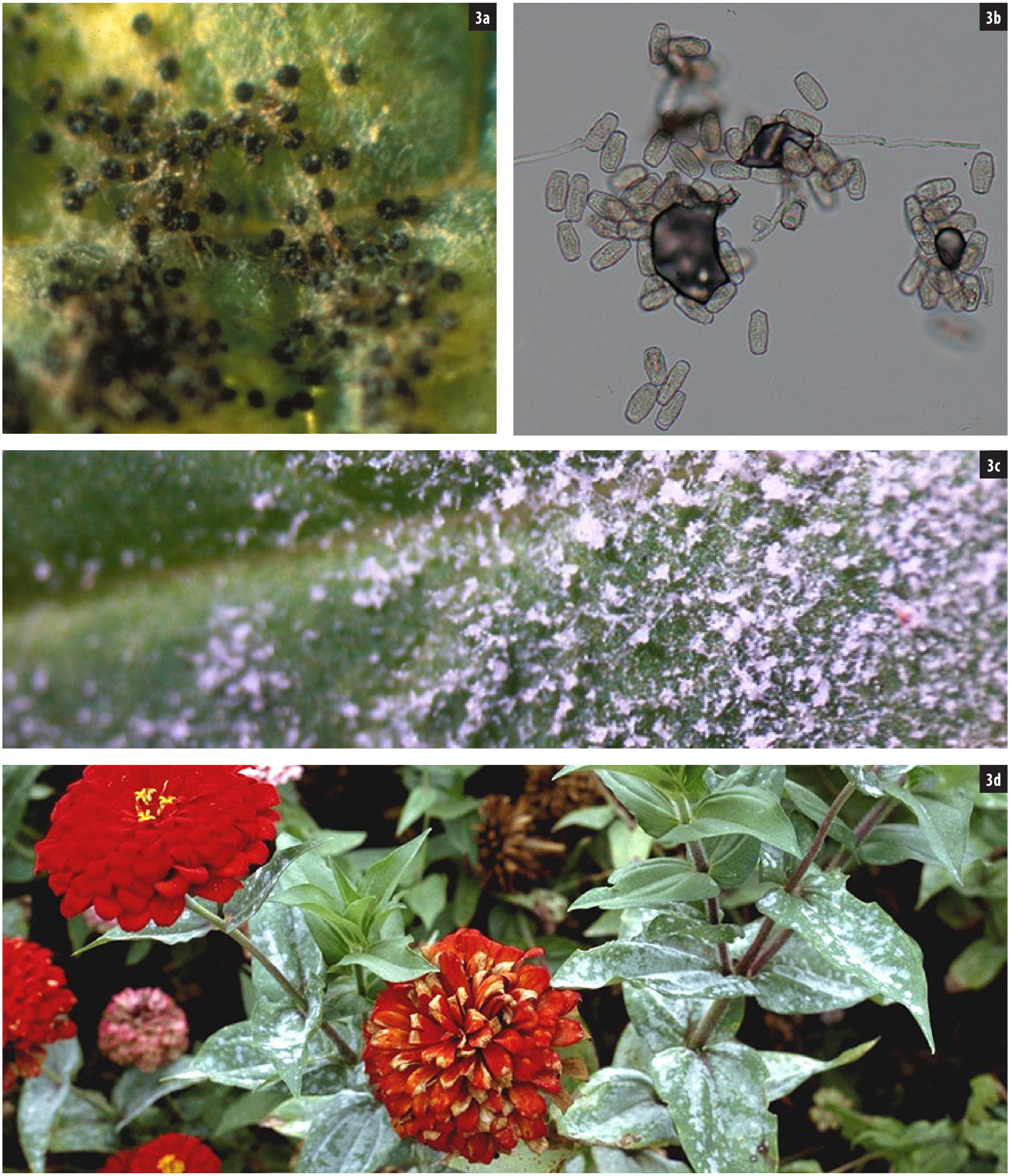


Figure 5.3. Powdery mildew is a common disease that is known to infect numerous landscape and garden plants. Spores of this fungal pathogen survive winter on infected plant debris or woody tissue **(3a)**. In spring, when temperatures are favorable, rain splashes spores **(3b)** from leaf litter onto new plant growth where infection occurs. Throughout the season the fungus produces additional spores **(3c)** causing subsequent infections. The result is a white powdery plant **(3d)** that may exhibit early defoliation.

Figure 5.4. Cedar-apple rust is caused by a unique group of fungi known as rusts. Many rust pathogens require multiple hosts to complete their life cycles. In the case of cedar-apple rust, the pathogen overwinters as galls on juniper **(4a)**. Once spring rains begin, galls produce slimy "horns" comprised of spores **(4b)**. These spores infect leaves and fruit of apple (and related hosts) **(4c)**. In late summer, apple lesions produce another spore type that infects juniper **(4d)**.

Figure 5.5. Recently transplanted and older stressed trees are susceptible to Armillaria root rot (also called shoestring rot). These fungal pathogens survive in dead wood and roots, as well as soil. Infection occurs in the roots or base of the tree via rhizomorphs (cord-like strands of fungal hyphae) **(5a)**. If bark is removed from infected trees, a white mycelial growth may be observed **(5b)**. During rainy weather, pale brown mushrooms may develop at bases of infected trees or along dead or dying surface roots **(5c)**. Severely diseased plants exhibit decline or even death **(5d)**.

Oomycetes (Water Molds)

As the name implies, water is essential for survival, reproduction, infection, and spread of oomycetes (commonly called water molds). Water molds were once considered true fungi, but they are now classified as fungus-like organisms. Water molds and fungi are similar in appearance, as the body is composed of hyphae that mass together to form mycelia. Downy mildew is an example of a disease with visible oomycete mycelia.

Reproduction by water molds may be via sexual or asexual spores. Asexually produced spores (zoospores) have the ability to move in water using tail-like structures (flagella) that propel them, a trait not associated with true fungi. Zoospores develop within capsules (sporangia) under specific environmental conditions. Sporulation can occur numerous times per growing season, as long as water is available. In contrast, sexual spores of water molds are typically produced prior to dormancy in response to environmental stress. They serve as a means for survival under adverse conditions. Spores of water molds are microscopic, but their examination is essential for proper species identification.

Water molds infect in the same ways as true fungi by entering through natural plant openings or by direct penetration into plant tissues. Once infection occurs, water mold pathogens continue to grow and produce additional spores for new infections.

Infective propagules are spread via water, soil, and infected plants and weeds, as well as by wind and wind-driven rain. Survival structures produced by water mold pathogens have the ability to persist in water and soil for several years.

Common symptoms caused by water molds include leaf spots, blights, cankers, root rots, wilt, dampingoff, and dieback. For additional information on symptoms that can result from water mold infections, see Table 5.1. Two common diseases caused by water molds are downy mildew and late blight. Life cycles of these diseases are presented in Figures 5.6 and 5.7, respectively.

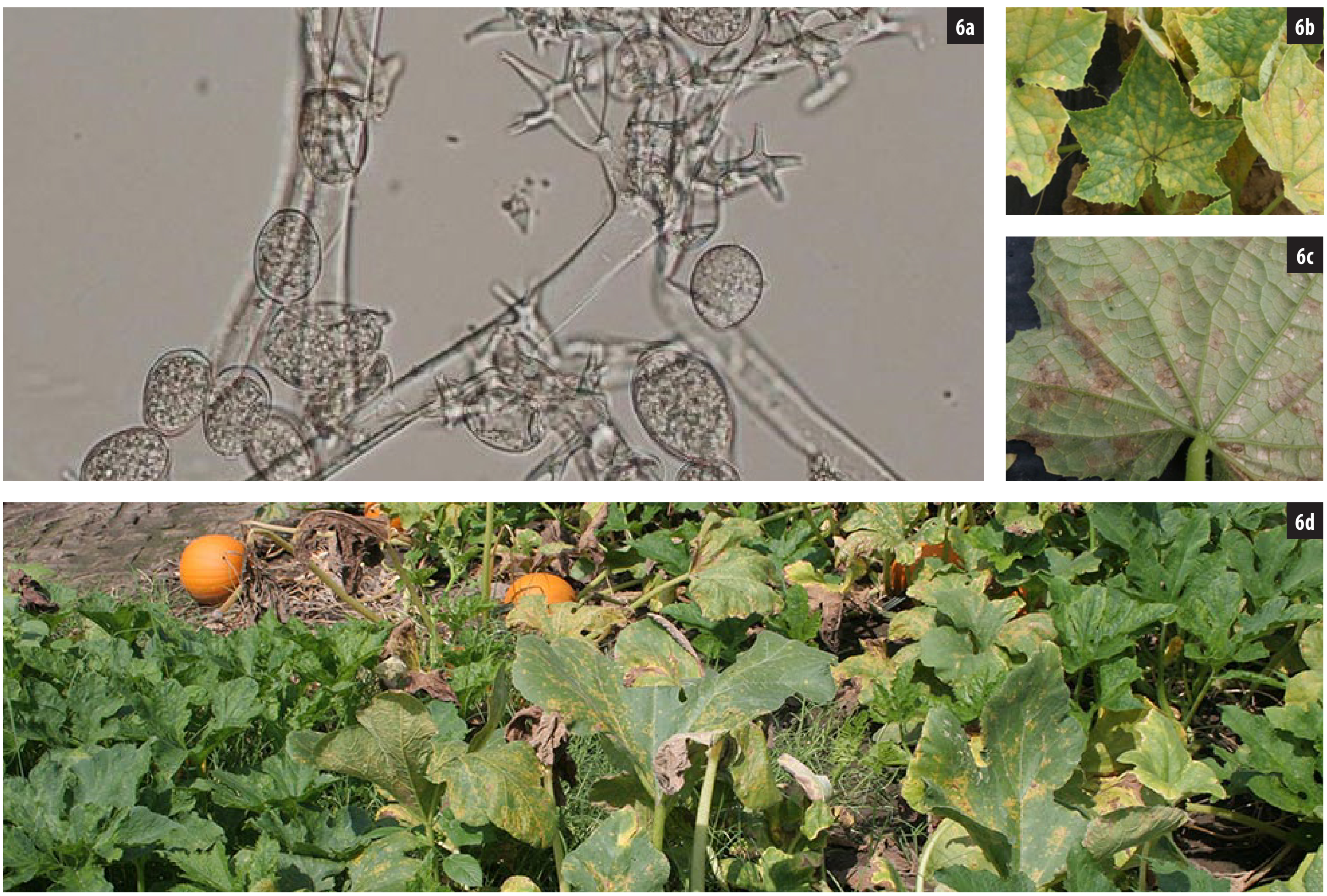


Figure 5.6. Downy mildew is a common disease that is known to infect numerous landscape and garden plants, including cucumber. Most water mold pathogens are host-specific. Spores **(6a)** of the cucurbit downy mildew pathogen are windblown north each year from overwintering sites in the southern United States Soon after infection, yellow, angular leaf spots develop **(6b)**. Spores are produced on the undersides of leaves **(6c)**; spores are spread to new tissue via water/rain. Defoliation may occur on severely infected plants **(6d)**. The cucurbit downy mildew pathogen cannot survive winter in Kentucky because it requires living plant tissue, and it is not known to produce overwintering spores outside of laboratory conditions. Other downy mildew pathogens can overwinter on leaf debris in Kentucky.

Figure 5.7. Late blight is a disease of solanaceous crops, primarily potato and tomato. The pathogen most commonly overwinters in the southern United States in infected plant or weed tissue. In spring, overwintering spores are windblown north from these southern sites. Once infection occurs, water-soaked, grey-brown lesions may develop on leaves **(7a)**, petioles, stems, and/or fruit **(7b)**. Defoliation follows **(7c)**. Potato tubers **(7d)** may become infected via systemic infections or by spores washed into soil.

Bacteria

Bacteria are microscopic organisms typically composed of single cells. About 200 types of bacteria are known to cause plant diseases. Due to their small size, a high-magnification microscope is required to observe bacteria. Occasionally, when a large number of cells are present, plants may be observed "oozing" bacteria and other organic byproducts.

Bacteria are capable of rapid reproduction through a process known as binary fission. In this process, one cell divides to become two, then two divide to become four cells, and so on. Within a few hours, one bacterial cell can become thousands, and under ideal conditions, populations can double in as little as 20 minutes.

Unlike fungi and water molds, bacteria are not able to penetrate plant tissue directly. They must infect via wounds or natural plant openings such as stomata. Free water is required for infection. Once inside plants, bacteria begin to reproduce immediately. Some types of bacteria produce toxins or enzymes that degrade plant tissue, and the tissue is then utilized as a food source. Some bacteria can colonize vascular systems of plants, which results in restriction of water movement.

Bacteria spread by water/splashing rain, wind, or insects and then move across plant tissues in surface water to reach wounds or natural openings. Some can survive for five or more years in soil, as well as in plant debris and cankers.

Common symptoms caused by bacteria include leaf spots, blights, cankers, galls, wilt, dieback, and soft rots. For additional information on symptoms that can result from bacterial infections, refer to Table 5.1. Two common diseases caused by bacteria are bacterial wilt and fire blight. Life cycles of these diseases are presented in Figures 5.8 and 5.9, respectively.

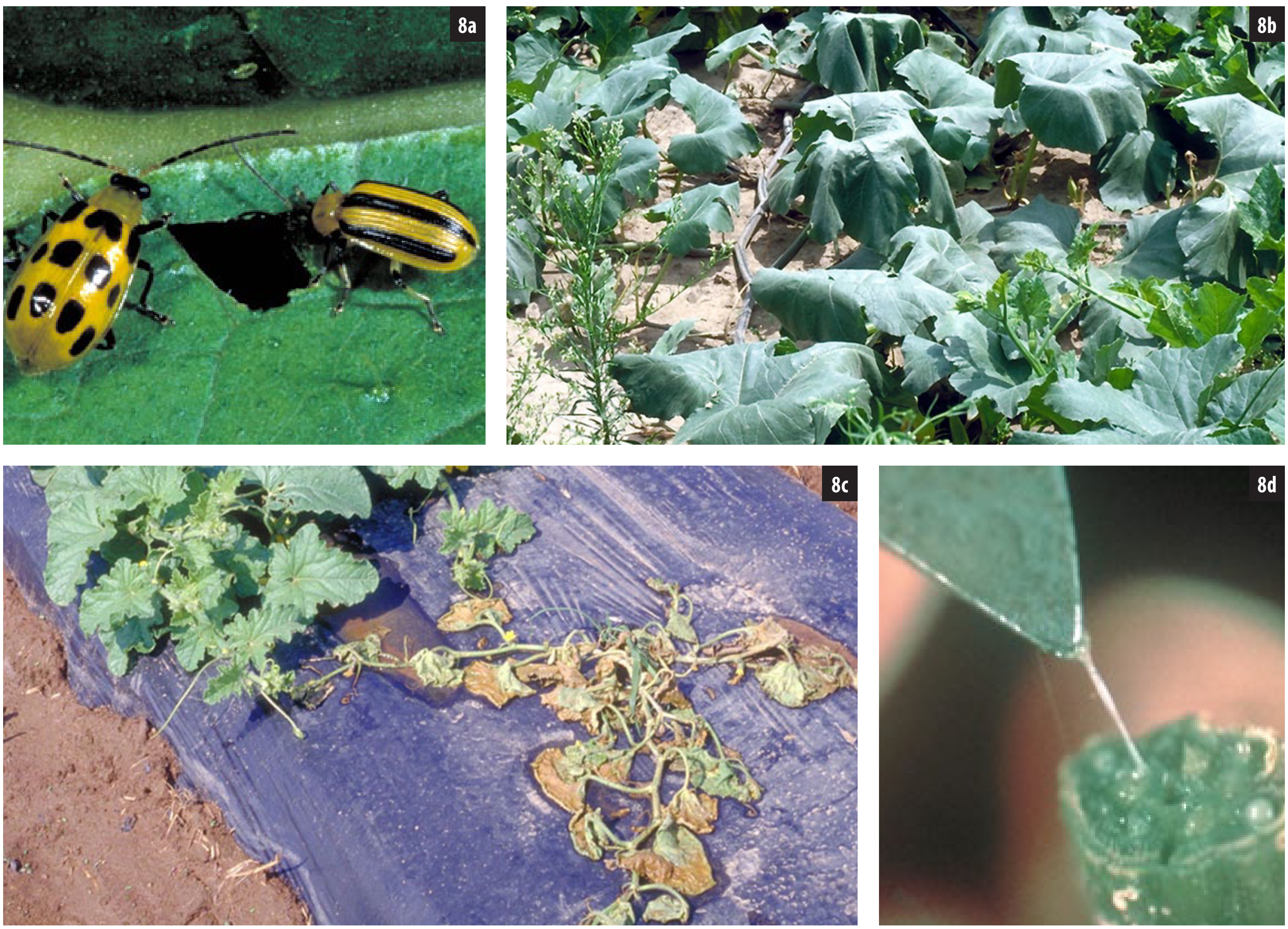


Figure 5.8. Bacterial wilt is a disease of cucumber, melons, and pumpkin. Bacterial cells overwinter in striped and spotted cucumber beetles, which transmit the pathogen during the growing season **(8a)**. When insects feed on plant tissue, bacteria in their feces are deposited near feeding wounds. Infected plants wilt **(8b)** when large numbers of bacterial cells block water movement. Feeding beetles obtain bacterial cells from infected plants and move them to new portions of plants or to new plants. Bacteria continue to reproduce and move throughout plants, eventually resulting in plant death **(8c)**. Bacterial ooze can be observed by cutting vines, holding the two cut ends together for 5 seconds, and then slowly pulling them apart again **(8d)**.

Figure 5.9. Certain apple cultivars and other pome fruit are susceptible to a bacterial disease called fire blight. The pathogen overwinters in cankers and other diseased or dying wood **(9a)**. In spring, bacterial cells are transported from cankers to blossoms by wind and rain or by pollinating insects. This first phase of disease is called the blossom blight phase **(9b)**. Blossom and spur infections move through woody tissue to form cankers **(9c)**. Rain, wind, and insects later carry bacterial cells from infected blossoms to actively growing shoots, causing shoot blight **(9d)**. As weather cools and active plant growth stops, bacteria become dormant until warm rainy weather returns (often the following spring). Over many seasons, bacteria can spread throughout trees, resulting in branch or trunk girdling and eventual plant death.

Viruses

Viruses are extremely small particles that require magnification of 100,000 times or more for observation. This can only be achieved with specialized equipment, such as an electron microscope. Diseases caused by viruses are often named for the first host plant for which symptoms were reported and/or the most common symptom. An example is tobacco mosaic virus; this virus was first reported as a mosaic symptom on tobacco. However, this disease is known to infect more than 100 plant species, including many vegetable and ornamental plants.

Once viruses enter host cells, they "hijack" plants and "instruct" cells to produce more virus particles. As plant cells are converted from their normal function and processes (such as cell division or chlorophyll production), changes in plant growth and development may be observed.

Plant viruses do not move in and out of plant tissue as readily as fungal and bacterial pathogens. They require vectors (such as insects or humans) to carry them from one plant to another. After entry into plant cells, reproduction begins. Viruses spread throughout plant hosts, infecting all plant parts (systemic infection). Viruses are dependent upon live hosts for replication, thus disease progresses slowly. Virus-infected plants often survive for many years before they die, as rapid plant death would be detrimental to a pathogen that depends upon its host for replication.

Insect vectors are a common means for virus spread. Numerous insects are capable of acquiring virus particles while feeding on infected plants. These particles are transferred to new plants or plant parts during subsequent feedings. Some virus particles can enter an insect's gut, where the virus may persist and replicate throughout the insect's life. Other types of particles are only carried for short periods inside probing insect mouthparts. Insects are capable of transmitting viruses multiple times throughout the season. Viruses can also spread by infected seed or pollen, nematodes, humans, animals, or tools. A few viruses with very stable structures can remain viable in dormant plant tissue and on nonliving materials, which can serve as inoculum for future infections.

Common symptoms caused by viruses include mottling, mosaic, leaf distortion, stunting, poor fruit set, and chlorosis. For additional information on symptoms that can result from virus infections, see Table 5.1. Two common viral diseases are rose rosette and tomato spotted wilt. Life cycles of these diseases are presented in Figures 5.10 and 5.11, respectively.

Figure 5.10. Most cultivated roses are susceptible to rose rosette virus. This virus is vectored by a microscopic rose leaf curl mite **(10a)**. These mites move from plant to plant in wind currents, via other insects, or by crawling to adjacent plants. Symptoms, which may develop months or years after infection, can include short internodes (called witches' broom), strapping and reddening of leaf and stem tissue **(10b)**, and excessive thorn development **(10c)**. Infected plants that remain in the landscape **(10d)** serve as inoculum and sources of vectoring mites. When removing infected plants, dig out all roots and destroy all plant parts.

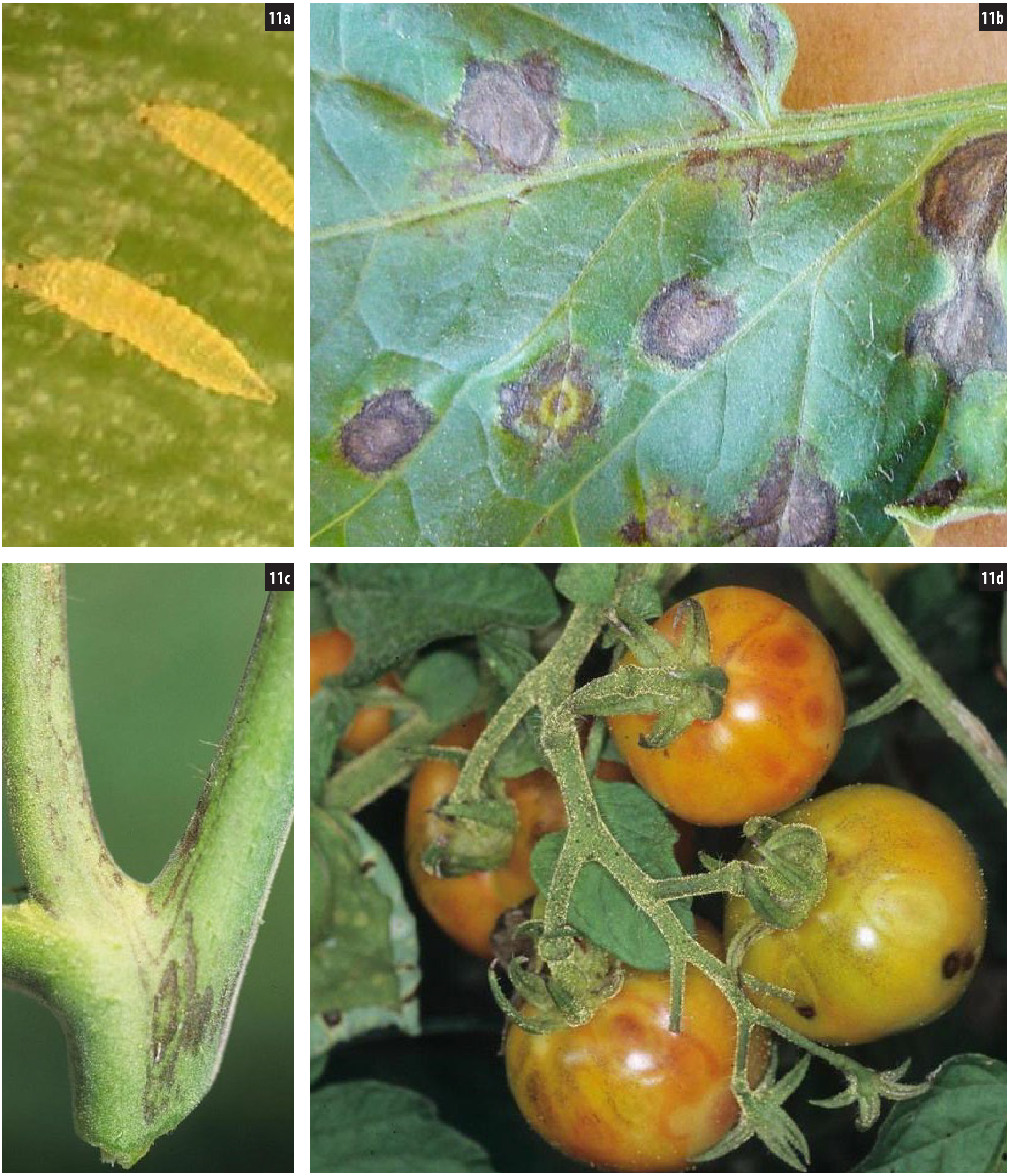


Figure 5.11. Tomato spotted wilt virus (TSWV) is known to infect thousands of different plant species. Virus particles are vectored by thrips, which acquire the virus while feeding during the larval stage **(11a)**. TSWV can replicate within insect hosts and persist throughout an insect's life. Once infected, plants such as tomatoes may exhibit symptoms of wilting and ringspots on leaves **(11b)**, lesions on stems **(11c)**, and mottling or ringspots on fruit **(11d)**. Multiple generations of thrips occur each season, and infected weedy hosts contribute to virus spread.

Plant Parasitic Nematodes

Plant parasitic nematodes are microscopic roundworms that primarily infect roots, but a few occur in foliar portions of plants. While there are many species of nematodes, only a few are known to parasitize plants. All plant parasitic nematodes have needle-like mouthparts (stylets) that are used to pierce plant tissues and extract cell contents. Nematodes reproduce via eggs that result from either the mating of a male and a female or by the female alone.

Symptom development occurs as a result of extracted cellular contents or other plant damage. Nematodes may remain on the exterior of roots during feeding (stubby-root nematode) or penetrate plant tissues completely to feed while inside plants (dagger nematode). Nematodes may select a single feeding site or feed in multiple locations. Long-distance spread is achieved via movement of infested soil, floodwater, or plant material; nematodes are only capable of moving very short distances on their own.

Common symptoms caused by nematode feeding include chlorosis, root galls, damaged or stubby roots, stunting, dieback, and reduced yields. Some heavily infested herbaceous plants develop symptoms similar to nutrient deficiencies as a result of root loss. For additional information on symptoms that can result from nematode infestations, refer to Table 5.1. Two common plant parasitic nematodes include soybean cyst nematode and foliar nematode. Life cycles of these organisms are presented in Figures 5.12 and 5.13, respectively.

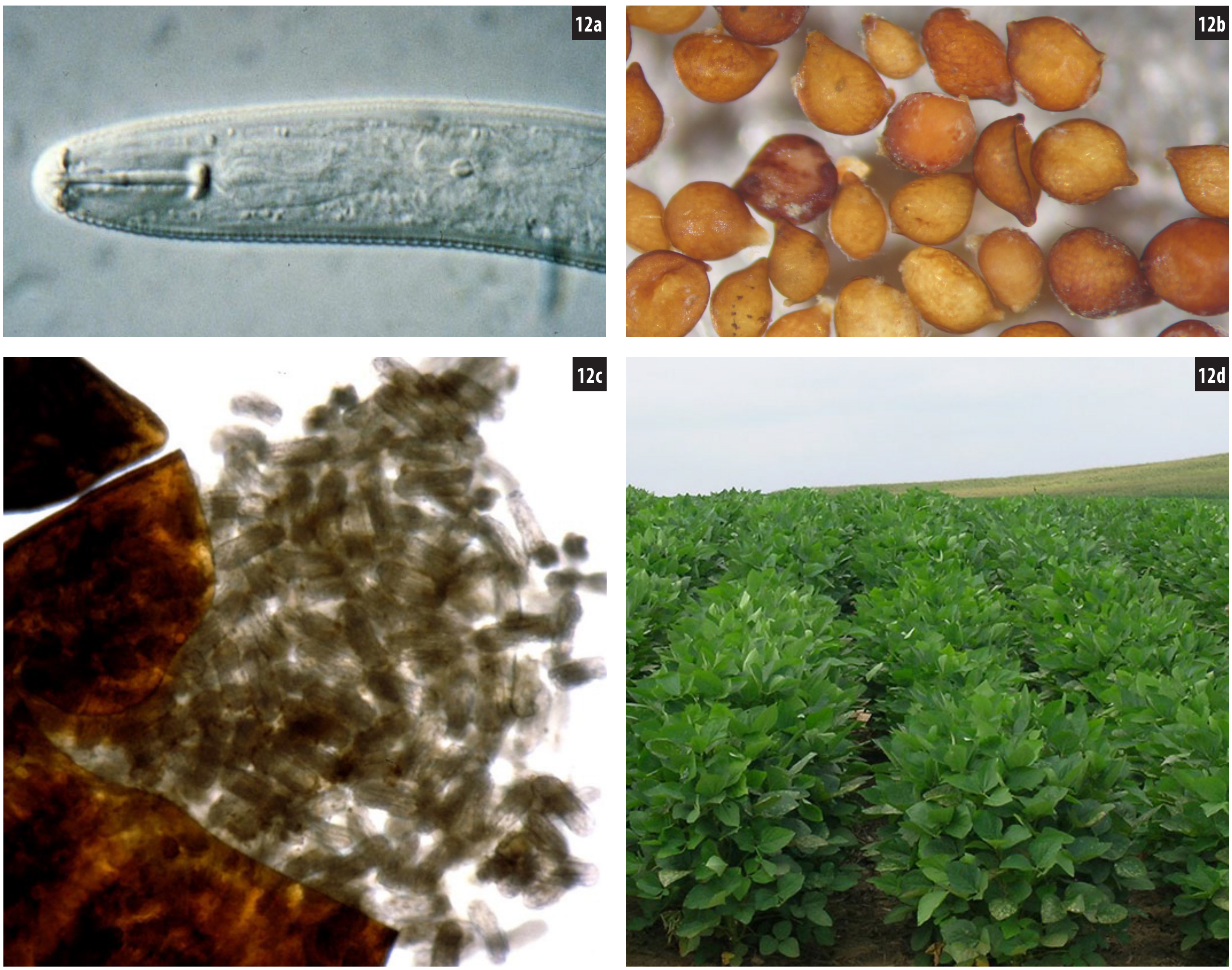


Figure 5.12. Soybean cyst nematode juvenile nematodes **(12a)** infect plants by penetrating root tissue. Males feed for a short time before moving on to another feeding site. Females remain at the same feeding site and expand to encyst egg masses. These lemon-shaped females are white or yellow, but they become brown as they mature and die **(12b)**. The dead female bodies are known as cysts; each cyst contains several hundred eggs. Cysts protect eggs from adverse conditions, such as heat and drought. When conditions are favorable for nematode development, cysts burst open and release eggs **(12c)**. Soybean plants may not exhibit any aboveground symptoms other than poor vigor and/or yield loss **(12d)**.

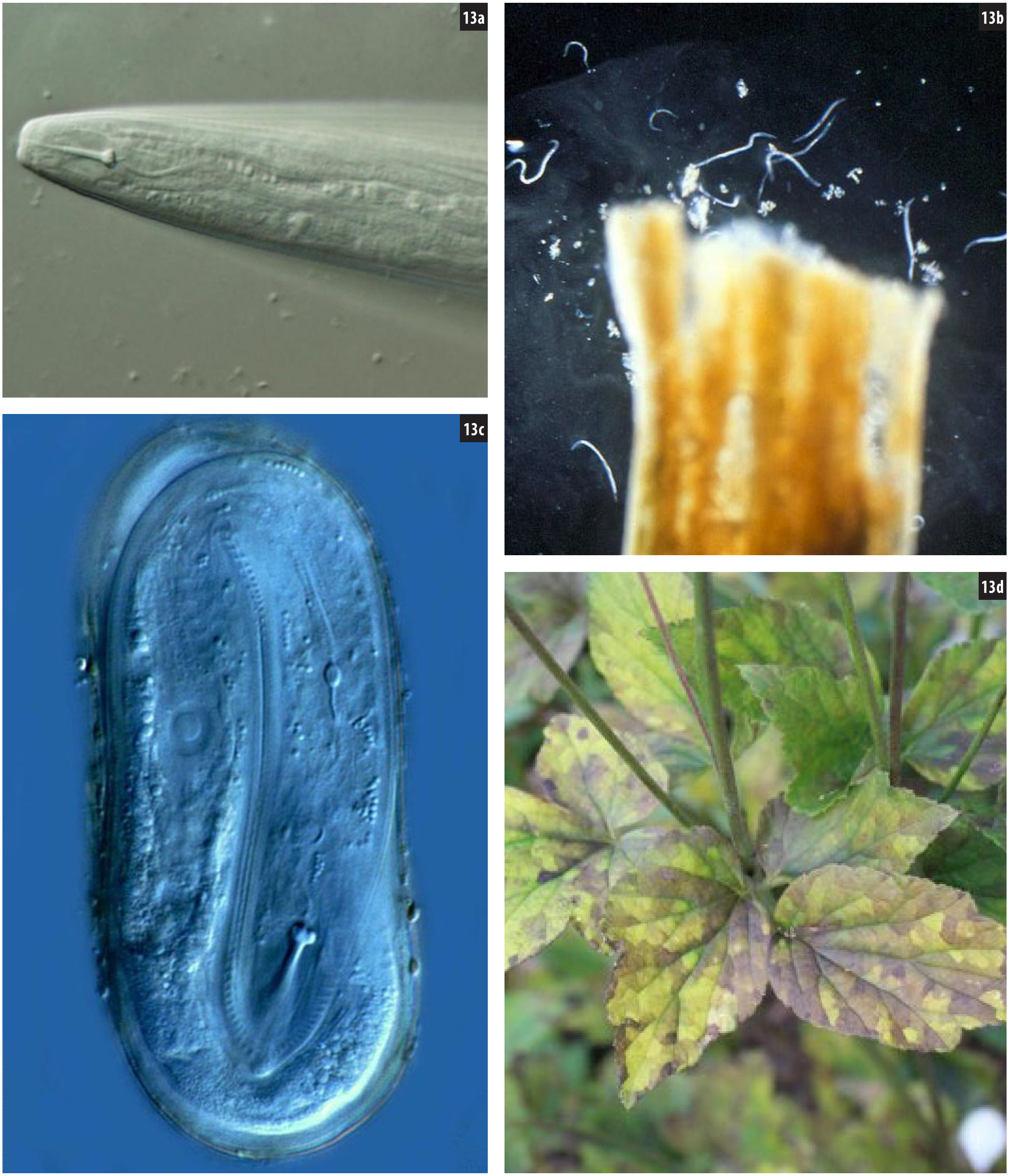


Figure 5.13. Foliar nematodes can infect numerous plant species, including anemone. Adult nematodes **(13a)** survive winter in plant crowns or leaf debris. In spring, foliar nematodes move upward via splashing water. Once adults reach leaves **(13b)**, they enter through stomata and begin feeding. Eggs **(13c)** are produced within leaves, where they hatch, molt, and begin to feed. Infected leaf cells are varying shades of green that turn brown and necrotic **(13d)** as cell contents are consumed.

Phytoplasmas

Phytoplasmas are extremely small, bacteria-like plant pathogens. While they are similar to bacteria, phytoplasmas differ in their inability to survive without a host, their smaller size, and their lack of cell walls. Phytoplasmas rely on insect vectors, such as leafhoppers, for transmission into hosts. During feeding, leafhoppers acquire phytoplasmas from infected host phloem (nutrient-conducting vascular system) and introduce them into healthy tissue. Once in the phloem, phytoplasmas are capable of reproducing and spreading throughout plants, which results in systemic infections. Phytoplasmas persist within their insect vectors, making this the main method of spread for these pathogens.

Common symptoms caused by phytoplasmas are virescence (development of chlorophyll in tissues where it is normally absent) and abnormal growth such as a "witches' broom" symptom. The most common disease caused by a phytoplasma is aster yellows. The symptoms of this disease are depicted in Figure 5.14.

Parasitic Seed Plants

Parasitic seed plants share many common characteristics with true plants, such as their ability to reproduce and spread by seeds. Like other plants, seeds are disseminated via wind, water, and animals. However, parasitic plants lack the ability to produce all of the nutrients or water they require, so they rely on host plants. In some cases, parasitic plants have developed modified structures, such as haustoria, that allow them to penetrate host plants and obtain nutrients and water. Common symptoms caused by parasitic plants are reduced vigor and dieback. The most common parasitic plant is mistletoe, shown in Figure 5.15.

Figure 5.14. Aster yellows, which is caused by a phytoplasma, is a common disease of purple cone flower. Infected plants exhibit symptoms such as stunting, abnormal growth, sterile flowers, and virescence in flowers.

Figure 5.15. Mistletoe often parasitizes oaks and other forest trees. It produces large clumps of foliage on host plant branches. Mistletoe does not produce roots and is reliant upon hosts for water and nutrients. In Kentucky, infected host plants do not suffer major damage or stress. In locations where other mistletoe species are present, extensive damage to the host may occur.

Table 5.1. The most common symptoms associated with each pathogen group.

Symptom	Description	Plant Pathogen Groups						
		Fungi	Water molds	Bacteria	Viruses	Nematodes	Phytoplasmas	Parasitic plants
Blight	Rapid discoloration, wilting and death of plant tissue	X	X	X				
Blotch	Blotch or large spot on leaves, shoots, or fruit	X		X				
Bronzing	Leaves or needles develop a bronze color	X				X		
Canker	Dead region on bark of twigs, stems, or trunks, often discolored and either raised or sunken	X	X	X				
Chlorosis	An abnormal yellowing of plant parts	X	X	X	X	X		
Dampingoff	Decay of seeds in soil or young seedlings shortly after emergence	X	X					
Decline	Gradual, often uniform, decline of plant health or death of plant tissue	X	X	X	X	X		X
Dieback	Progressive death of shoots, branches, or roots, generally starting at tips	X	X	X	X	X		
Distortion	Irregularly shaped plant parts	X	X	X	X		X	
Flagging	Decline of a shoot or branch, while nearby branches remain healthy	X	X	X				
Gall	Abnormal, localized swelling on leaf, stem, or root tissue	X		X		X		
Gummosis	Production of a sticky gum that is exuded by the plant	X	X	X				
Leaf spot	Lesion on a leaf, which may vary in color, shape, and size	X	X	X	X			

Table 5.1. The most common symptoms associated with each pathogen group (continued).

Symptom	Description	Plant Pathogen Groups						
		Fungi	Water molds	Bacteria	Viruses	Nematodes	Phytoplasmas	Parasitic plants
Mosaic	Nonuniform foliage coloration, normally an intermingling of green color variations and yellowish patches				X			
Mottle	Irregular pattern of light and dark areas				X			
Mummy	Hard, dried, diseased fruit	X						
Necrosis	Death of plant tissue	X	X	X				
Ring spot	A lesion with a dark outer ring and lighter center				X			
Rot	Decomposition and destruction of tissue	X	X	X				
Rugose	Wrinkled appearance to plant tissue	X			X			
Russet	Yellowish-brown or reddish-brown scar tissue on a fruit's surface	X						
Scab	Crust-like disease lesion	X		X				
Scorch	Browning and necrosis of leaf margins	X	X	X				
Shot-hole	Lesions where centers have fallen out	X		X				
Stunting	Reduced growth of a plant, where plant or plant parts are smaller than normal	X	X	X	X	X		
Tip blight	Death of tissue at the tip of a shoot	X		X				
Vein clearing	Leaf veins become yellow or clear				X			
Watersoaking	Wet, dark, or greasy lesions, usually sunken and/or translucent	X	X	X				
Wilt	Drooping of leaves or other plant parts	X	X	X		X		
Witches' broom	Abnormal brush-like shoot development				X		X	X

Plant Disease Diagnostics

Plant disease diagnostics begins with the observation of both the symptomatic plant(s) and surrounding environment. Sometimes the cause of plant problems is evident: wildlife damage, insect feeding, or mechanical injury. However, a wide range of abiotic and biotic factors can cause disease or disease-like symptoms. Basic plant diagnostics and differentiation between biotic and abiotic problems are discussed in Chapter 6, Diagnosing Plant Problems. Plant disease diagnostics are covered in this section.

There are several steps to disease diagnostics, including evaluation of vital site information and examination of diseased tissue. Since the majority of plant pathogens cannot be seen without the aid of a microscope, it may not be possible to confirm disease agents by visual assessment alone. In order to diagnose plant problems, it may be necessary to submit samples of symptomatic plants to a university or commercial laboratory for further analysis.

Even though it may not always be possible to diagnose plant diseases by symptoms alone, the following strategies can be used to determine whether an infectious agent is the cause of disease symptoms. In addition, detailed site and plant information can lead to a more complete diagnosis.

Know the Host Plant(s)

A single plant species can have numerous cultivars or varieties, with many different colors, shapes, patterns, textures, and sizes. Occasionally, diversity or variation in plant appearance can be mistaken for disease. The difference between normal growth and appearance and abnormal appearance can indicate whether a problem is present. Furthermore, disease symptoms may differ with plant species or cultivar. Some species and/or cultivars may be more susceptible or tolerant to disease than others. Host information can be critical for diagnosis.

Document Plant Part(s) Affected

In some cases, symptoms develop on plant parts that are different from infected tissue. For example, dieback and wilting seem to indicate problems in the plant canopy. However, a root rot pathogen or bacterial colonization of vascular tissue may cause similar symptoms. It is important to examine all above- and belowground portions of plants to determine potential infection site or symptom origin. Digging or cutting into plant tissue may sometimes be necessary to fully understand the extent of parts affected.

Check for Symptoms and Signs

The presence of symptoms often indicates some sort of plant problem. A wide range of symptoms can be expressed by diseased plants. Appendix A (separate document) presents common diseases and symptoms of woody ornamentals, bedding plants, fruits, vegetables, and turfgrasses. However, multiple pathogen groups can cause similar symptoms (Table 5.1). This is further complicated when abiotic factors induce disease-like symptoms. For example, fungi and bacteria can cause leaf spots that are similar to those caused by herbicides and ozone. Plant disease diagnoses, therefore, cannot be based upon symptoms alone. Identification of signs (mycelial growth, fruiting structures, and bacterial cells) with a hand lens or microscope is required to confirm diagnoses. Often, a trained diagnostician can assist with this task.

Examine the Site

Examine the area around plants for additional clues as to the cause of plant problems. This is particularly important with abiotic problems. Information regarding soil makeup and disturbances, as well as soil compaction and drainage patterns, can assist in differentiating abiotic maladies from diseases. Additionally, examination of surrounding plants can provide vital information regarding disease spread. Patterns of injury or symptoms can give clues as to whether variety- or species-specific infections are possible, or whether a more expansive problem exists.

Ask Questions

Ask questions and collect additional information that is critical in making diagnoses. More information can lead to a more accurate diagnoses. Consider these site specifics:

- Planting date and practices
- Irrigation practices
- Fertilization
- Symptom development
- Weather conditions
- Site disturbances
- Traffic or pedestrians
- Pet and livestock habits
- Herbicide applications (dates applied in relation to when symptoms were observed)

Diagnosis

After collection of site information and analysis of the symptomatic plant(s), it may be possible to diagnose some plant problems at this stage. However, if the cause cannot be determined, it may be necessary to submit symptomatic plant samples to a diagnostic laboratory. Contact a county Extension agent regarding appropriate steps for selecting and submitting samples to the University of Kentucky Plant Disease Diagnostic Laboratories. The University of Kentucky Plant Pathology fact sheet, *Submitting Plant Specimens for Disease Diagnosis* (PPFSGEN-09), provides helpful information for collecting appropriate samples.

Plant Disease Management

Disease management begins with accurate diagnoses. Diseases can only be managed once they are correctly identified. The best management practice is to avoid disease altogether. While disease prevention is not always possible, there are often recommended management practices that can be used to limit disease spread and subsequent infections.

Principles of Plant Disease Management

There are five principles to disease management that focus on prevention and limit of disease spread. These techniques are most effective in combination.

Exclusion

- Definition: Prevent pathogen introductions to areas where they do not currently exist.
- Common Practices: Quarantine, inspection, and certified disease-free plant material.

Avoidance

- Definition: Inhibit establishment of pathogens that exist in other areas.
- Common Practices: Use certified disease-free plants or seed, inspect plants before purchase or installation, reduce plant stresses, rotate crops, and avoid wounding.

Resistance

- Definition: Select plants with increased tolerance to pathogen(s).
- Common Practices: Select seeds or plants with resistance to common pathogens. Consult a county Extension agent or reliable source for information on resistant cultivars.

Protection

- Definition: Implement steps to protect plants from infections.
- Common Practices: Modify environment to prevent pathogen infections, remove alternate hosts, apply physical barriers, use biological or fungicide treatments.

Eradication

- Definition: Limit pathogen spread once a plant is infected.
- Common Practices: Remove infected plant portions, remove (rogue) entire herbaceous plants including roots, practice sanitation, use fungicide applications to minimize inoculum (fungicides do not cure disease or eradicate pathogens).

Important Plant Disease Management Practices

Once plant disease is confirmed, sanitation is the most important management practice in the garden. However, homeowners and growers should implement sanitation practices throughout the growing season to prevent and limit plant disease development. Infected plants and plant parts (leaves, stems, branches, roots, and fruit) should be removed since many pathogens overwinter in plant debris. Throughout the growing season, including senescence and dormancy, all plant debris should be gathered and destroyed by burning, burying, or putting in the trash. Composting diseased plant material is not advised, as most home compost bins do not reach temperatures high enough to kill plant pathogens. Sanitation practices also assist in increasing the effectiveness of other management techniques.

Healthy, stress-free plants are less likely to become diseased. Maintain plant vigor and avoid stress with proper site selection and nutritional balance; this significantly decreases the likelihood of infections. Select plants with resistance or tolerance to common diseases, when available. Never save seeds from diseased fruit or vegetables.

Fungicides can be effective in protecting plants from infection or limiting spread. Although the term "fungicide" is often used as a broad term, products are usually pathogen-specific. True fungicides are used to manage fungal pathogens; other products are specific to water mold pathogens. Bactericides/antibiotics are used to manage bacterial pathogens. All of these products are suppressive, but only a few have curative effects. Fungicide applications will not reverse disease symptoms or save plants from death if disease is severe. Always follow label directions when applying fungicides. For up-to-date information regarding fungicide use and recommendations, consult a county Extension agent.

Summary

Plant diseases can be caused by fungi, water molds, bacteria, viruses, nematodes, phytoplasmas, or parasitic plants. Understanding the biology and symptoms common to these plant pathogens will aid in identification and management of disease problems. Once a disease is properly diagnosed, management options can be deployed to mitigate disease impact.

Appendix

Common diseases and symptoms of woody ornamentals, bedding plants, fruits, vegetables, turfgrass, and grains can be found in the Appendix A document at: https://plantpathology.ca.uky.edu/files/mg_ch6_appendix.pdf

Resources

University of Kentucky Department of Plant Pathology Publications
https://plantpathology.ca.uky.edu/extension/publications
Submitting Plant Specimens for Disease Diagnosis
http://plantpathology.ca.uky.edu/files/ppfs-gen-09.pdf
American Phytopathological Society Introductory Materials https://www.apsnet.org/edcenter/resources/Pages/Introductory.aspx
American Phytopathological Society Glossary
https://www.apsnet.org/edcenter/resources/illglossary/Pages/default.aspx
[1]The Future World Food Situation and the Role of Plant Diseases, Dr. Per Pinstrup-Andersen https://www.apsnet.org/edcenter/apsnetfeatures/Pages/WorldFoodSituation.aspx

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Chapter 06

Diagnosing Plant Problems

By Kimberly Leonberger, plant pathology Extension associate; Nicole Gauthier, Extension plant pathologist; Richard Durham, consumer horticulture Extension specialist and state Master Gardener coordinator; Lee Townsend, Extension entomologist (ret.); Matthew Springer, Extension wildlife specialist; Adam Leonberger, Jessica Bessin and Erica Wood, Extension horticulture agents; and Stacy White, Extension agriculture and natural resources agent.

In this chapter:

For those with a green thumb, growing plants may seem easy. However, when plant problems arise, determining the cause of these issues can be difficult. Developing the skills necessary to determine the cause of a plant problem takes experience and time. The steps involved in the diagnostic process first require analysis of information regarding the history of the symptomatic plant and the surrounding area. Plant symptoms and signs provide additional evidence to aid in determination of a possible cause.

There are numerous potential causes for plant problems. Living factors such as plant pathogens, insects, and wildlife can damage plants. In addition, non-living factors including weather, physiological disorders, mechanical damage, nutrition, and chemical injury may also result in plant damage. Critical thinking is essential to determine which possible causes are the most consistent with the observed damage. While it is not always possible to determine the exact cause of a plant problem, there are numerous resources available to aid in the process. The steps utilized in the diagnostic process are detailed in this chapter.

Figure 6.1. Some evergreen trees, such as pine, shed older needles during the fall, giving the tree a brown appearance.

Data Collection for the Diagnostic Process

Diagnosis of a plant problem begins with the collection of information about the plant and its environment, as well as an evaluation of the symptoms present. After information is gathered, it can be used either to diagnose the issue or to rule out possible causes by process of elimination. The following steps detail this process.

Plant Identification and History

In order to determine whether a problem truly exists, it is important to correctly identify the type of plant. The normal growth of some plants can appear irregular and cause alarm. Time of year should also be considered, as many plants experience alterations in appearance as seasons change. Such is the case with some evergreen trees. For example, pine trees drop older needles in the fall, which can cause distress for those unfamiliar with fall needle drop. However, this process is completely normal for pine trees (Figure 6.1).

Variations in growth and appearance can also be the result of different cultivars or varieties. Keeping accurate records of cultivars can help with the identification of normal growth and appearance of the plant. Many new varieties or cultivars have appearances that vary greatly from those more commonly

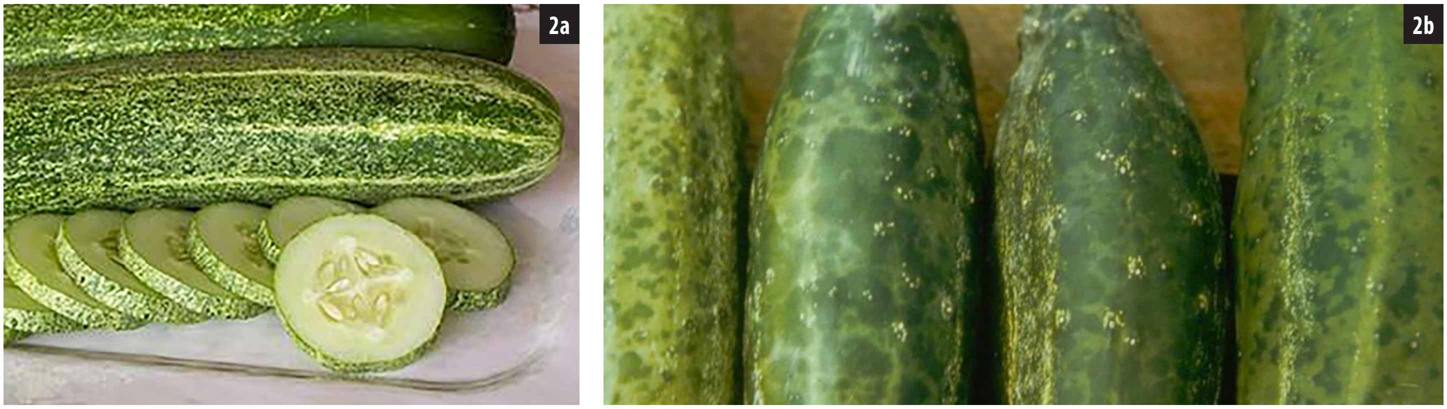


Figure 6.2. The 'Chompers Hybrid' cultivar produces cucumbers with variegation (2a). However, variegation can also be a symptom of a disease such as cucumber mosaic virus (2b).

Figure 6.3. Evaluate the area around a problematic plant to determine whether the damage can result from the topography. When plants are installed into low areas where standing water can collect, plant roots suffocate from lack of available oxygen.

planted. For example, the cucumber variety 'Chompers Hybrid' has a variegated appearance, which may be confused with symptoms from disease or non-living factors (Figure 6.2).

As plants grow and adapt to their environment, appearance may change. It is important to consider the history of plants to determine a possible cause of damage. Keep records of planting dates to determine plant age. Additionally, incorrect planting can stress plants and result in an abnormal appearance. A review of plant care activities, such as frequency and duration of watering and application of nutrients, may help determine possible causes of damage. Consider environmental changes that may have occurred in recent months or years. Severe winters or dry summers can affect plants' appearance and health several months or years after the weather event.

Examine the Site

Examination of the growing site can provide additional information that aids in the diagnostic process. Since growing requirements vary for different plant types and even for different cultivars, it is important to consider the planting site. Plants have specific environmental conditions in which they thrive. When a plant's location provides too much or too little light, water, or drainage, plants exhibit symptoms of damage.

While it may initially appear that only one plant is affected, surrounding plants should be assessed for similar damage. If multiple different types of plants exhibit similar damage, it is likely that the cause of the damage is a non-living factor, such as chemical, environmental, or mechanical injury.

Evaluate the area surrounding the symptomatic plant to identify clues that may establish the cause of a plant problem. Step away from the plant to consider items such as topography (Figure 6.3) and proximity to damage sources, such as wildlife habitats and construction sites. Through an evaluation of the environment surrounding a plant, cause for damage can often be determined.

Figure 6.4. Dieback is a common symptom exhibited by problematic plants (3a). However, the part of the plant where the problem is occurring in this example is the root system (3b).

Inventory of Symptoms and Signs

The type of damage that occurs on plants is important for the diagnostic process. Symptoms are the external response of the plant, which may indicate a problem. Symptoms may include leaf spots, holes in leaves, cankers, fruit spots, holes in fruit, irregular growth, root rots, discoloration, wilting, and dieback, as well as numerous other symptoms. Specific symptoms that can result from diseases, insects, wildlife, and abiotic causes are detailed in the following sections. Symptoms should be documented with as much detail as possible. While diagnostics are not based on symptoms alone, this information can assist in eliminating possible causes, and thereby establishing more likely causes for symptoms or problems.

It is often necessary to examine the whole plant to clearly identify which part or parts are affected. When spots appear on leaves or fruit, it is obvious that these are the parts of the plant that are affected. However, when symptoms such as wilting or dieback are present, the parts of plants affected are less obvious. These symptoms often indicate a problem at the base of the plant or in the root system (Figure 6.4).

Patterns of symptoms can also provide valuable information for the diagnostic process. Take time to assess all plant parts to determine whether damage occurs in uniform or in random patterns. When damage is uniform across all plant parts and/or entire plantings, it often indicates that the cause is abiotic. For example, dieback at the base of shrubs near a road can be the result of salt damage (Figure 6.5). However, when patterns of damage are inconsistent, the cause is more likely to result from disease, insect, or wildlife. Random symptoms may be present on plant parts, whole plants, or groups of similar plants. Damage that results from insect feeding is inconsistent across the leaves of a plant (Figure 6.6). In contrast, diseases usually begin in lower or inner canopies and create gradient patterns.

The timing of symptom appearance and process of change over time can also aid in the diagnosis of plant problems. Damage from wildlife and abiotic factors results in symptoms that appear suddenly and do not spread to other plants over time. Disease and insect damage appears gradually. Over

Figure 6.5. When symptoms such as dieback are evenly distributed along the base of several shrubs near the road, the cause is likely abiotic. In this situation, the cause of the damage is de-icing salt.

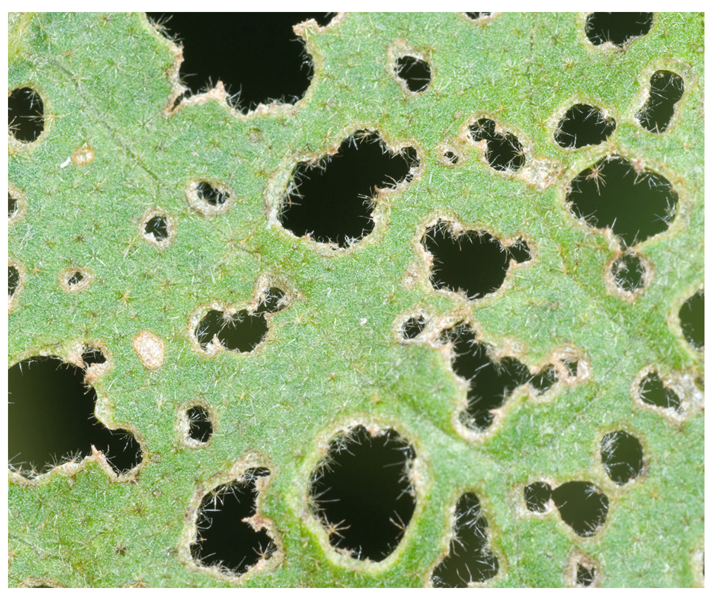


Figure 6.6. Inconsistent patterns are often the result of disease, insect, or wildlife. The damage to this eggplant leaf is the result of flea beetle feeding.

time, the organisms that cause these issues multiply and cause additional damage. Thus, symptoms from diseases and insects worsen over time and move to infect/infest new areas.

Signs are the physical evidence of causal organisms that are responsible for plant damage. Signs indicate the presence of disease-causing pathogens, insects, or wildlife. Signs can include fungal fruiting structures or fungal parts, insects or their frass, and presence of animals or their scat. More details on the types of signs that can be associated with diseases, insects, and wildlife are detailed in the following sections.

While abiotic issues do not produce signs, the lack of observable signs does not necessarily confer that the problem is the result of an abiotic issue. In many cases, visual observation of disease and insect signs requires magnification. Additionally, signs may be limited to specific environmental conditions.

Considerations and Possible Causes of Plant Problems

This critical thinking step is the most challenging portion of the diagnostic process. Determining a possible cause first requires a review of the information that has been collected in the previous steps. This information is then used to either support or eliminate potential causes of injury or damage.

Once information about the plant, site, symptoms, and signs has been gathered, these "clues" may be used to determine a probable cause. Consider all of the known information and possible causes they may indicate. This evidence can also be used to rule out unlikely culprits of the damage. It may be necessary to consult reference materials or additional resources to interpret the collected information. Utilize resources such as university publications, reference books, credible websites, and local county Extension agents.

After review of the material and resources, it may be necessary to gather some additional information. A more thorough inspection of the symptomatic plant may now yield more symptoms not documented before, or a broader view of the site may reveal "clues" not noticed before. This information is then used to continue the process of determining the most likely cause of the plant problem. In order to reach a probable cause for the damage, it may be necessary to repeat this process multiple times.

Disease

Diseases are the observable symptoms that result from infection by plant pathogens. A detailed description of the plant pathogen groups can be found in Chapter 5, Plant Diseases. These organisms can result in a wide range of symptoms. Signs for many plant pathogens are not visible without the aid of a microscope, which increases the difficulty of diagnosing plant disease problems. The following is a description of common symptoms and signs that may be present as a result of infection by specific pathogen groups. A more extensive list of symptoms that can result from each pathogen group can be found in Table 5.1 of Chapter 5. This table presents common symptoms of disease, but other combinations are possible.

Fungi and Water Molds

Fungal and water-mold pathogens are the most common culprits of disease issues. Fungi and water molds have characteristics that make each group unique, but many symptoms are similar. Both are capable of producing a wide range of symptoms on different plant tissues. Leaf and fruit spots are often the first symptoms noticed on symptomatic plants. These spots may be variable in shape, including spots with dark borders and lighter-colored centers or concentric rings (bullseye-like appearance) (Figure 6.7). Spots on plant tissue may expand over time.

Fungi and water molds can also produce stem lesions or cankers (Figure 6.8). Cankers on branches limit the movement of water and nutrients, which may result in symptoms such as wilting, dieback (Figure 6.9), or flagging. When stems or roots become damaged, aboveground symptoms such as wilting, dieback, or plant death may be observed. Rotted plant tissue may appear soft, sunken, discolored, or blackened (Figure 6.10).

Figure 6.7. Leaf spots with concentric rings are often the result of fungal or water-mold diseases. Lesions of early blight of tomato have this appearance.

Figure 6.8. Cankers may appear as cracks or sunken tissue, such as this anthracnose disease on sycamore.

Figure 6.9. Dieback often includes slow decline or canopy thinning and may indicate crown or root disease. Dieback of this catalpa tree was caused by Verticillium wilt.

Figure 6.10. Rotted roots may become brown or black in color, appear thin, and slough off easily. Black root rot is prevalent in both herbaceous and woody plants, including this pansy.

Figure 6.11. A hand lens can be used to magnify plant samples and identify signs.

While most fungal and water-mold signs are only visible with the aid of a microscope, it may be possible to observe some fungal structures with minimal magnification or the naked eye. A hand lens is often used to view symptomatic plant parts with 10, 20, or 40 times magnification (Figure 6.11).

The body of fungi and water molds consists of a mass of threadlike structures (mycelia). These organisms produce sexual and asexual spores, which require magnification to be observed and examined (Figures 6.12 and 6.13). Many fungi produce reproductive structures (fruiting structures such as ascocarps, acervuli, chasmothecia, and pycnidia), which are often visible without magnification. Fruiting structures may appear as small flecks or bumps on infected tissue (Figures 6.14 and 6.15). Overwintering structures that hold numerous spores or fungal tissue for next season's infection, such as chasmothecia and sclerotia, may also appear as small black specks on plant tissue near the end of the growing season (Figure 6.16). Some of these fungal structures can survive for several years in soil (Figure 6.17). One group of fungi produces mushrooms, which are large fruiting structures (Figure 6.18). Some fungi generate spores in abundance, making them visible when they are released from their reproductive structures (Figure 6.19).

Many fungal fruiting structures are only produced under certain conditions; thus the absence of visible signs does not indicate the absence of fungi. Fruiting structures often require conditions such as the presence of moisture (including humidity) and cool to moderate temperatures. It may be possible to induce the development of identifying structures by placing a portion of the symptomatic plant tissue into an incubation chamber (Figure 6.20). This chamber, usually built with a plastic container or bag and a moist paper towel, mimics the ideal environmental conditions that may result in the development of visible mycelium, fruiting structures, and/or spores. Structures typically develop in 24 to 48 hours. Note that not all fungi will develop visible structures with this process.

Figure 6.12. Mycelia can sometimes be observed without the aid of magnification, as is the case with the white mycelial growth of powdery mildew.

Figure 6.13. Magnification can make clusters of spores visible, as with the brown sporulation of leaf mold on tomato.

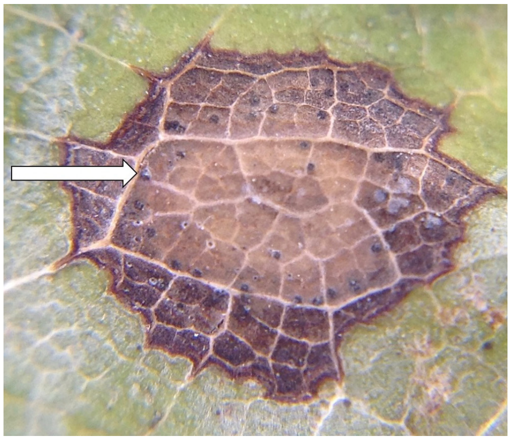


Figure 6.14. Fruiting structures such as the small black bumps (pycnidia) (indicated by the white arrow) are visible with or without magnification.

Figure 6.15. Some fruiting structures may appear as slimy masses, such as the salmon-colored sporodochia of Volutella blight.

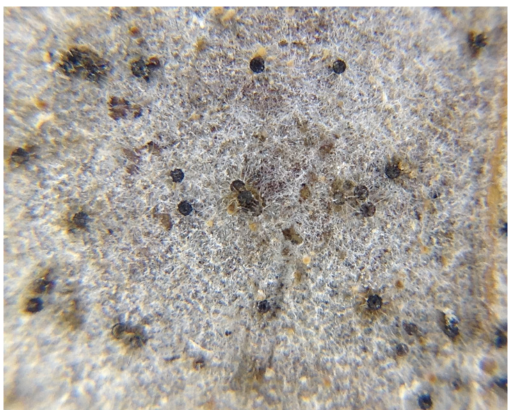


Figure 6.16. Chasmothecia are overwintering structures produced by some powdery mildew fungi at the end of the growing season. They can be observed with or without magnification.

Figure 6.17. Sclerotia (indicated by white arrow) are fungal structures that are visible with the naked eye.

Figure 6.18. Mushrooms are easily-recognizable fruiting structures. They are not always present, even though the fungal body continues to grow below ground.

Figure 6.19. When spores are produced in abundance they may be visible. Puffball fungi produce fruiting structures above ground and release large numbers of spores in a smoke-like manner.

Figure 6.20. When signs are absent, incubation in a bag with a moist paper towel may induce certain fungal structures.

Figure 6.21. Leaf spots that result from bacterial pathogens may have a yellow halo around the lesion, such as with bacterial spot on pepper.

Figure 6.22. Bacterial leaf spots may appear to be oily or water-soaked around the edge of lesions, such as with bacterial blight on beet.

Figure 6.23. Bacterial pathogens can damage plant cells, resulting in rotting of plant tissues. Bacterial soft rot of cabbage results in decay.

Bacteria

Diseases that result from bacterial pathogens can exhibit a range of symptoms, several of which are similar to those caused by fungal or water-mold pathogens. Bacterial pathogens can result in leaf and fruit spots. These spots may have a yellow halo (Figure 6.21) or water-soaked appearance (Figure 6.22). Symptoms such as cankers, dieback, and wilting may also result from bacterial infections. As bacteria commonly break apart cells when they infect plants, wet rots of fruit (Figure 6.23) or stems are common. Some bacterial pathogens may result in galls, which are tumor-like growths on plant tissue (Figure 6.24).

Due to the small size of bacterial cells, it is uncommon to observe bacterial signs. There are a few bacterial pathogens that accumulate, causing large numbers of cells to ooze from tissue (Figure 6.25). This is considered a sign, even though individual bacterial cells cannot be observed. The lack of visual signs makes the diagnosis of bacterial diseases challenging.

Figure 6.24. Galls, or tumor-like growths, can be a symptom of bacterial diseases. Crown gall is prevalent on many different woody plants.

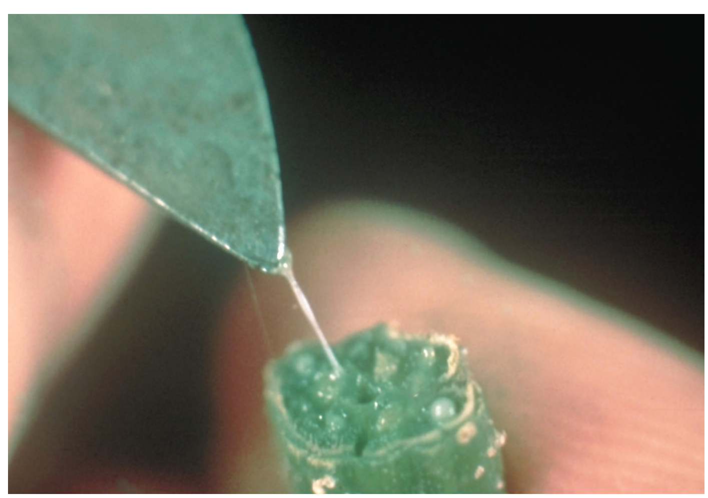


Figure 6.25. Bacterial ooze can be a sign of bacterial infection. Bacterial wilt in cucurbits creates "oozing" signs.

Figure 6.26. Color breaking is the interruption of the primary color pattern by a virus. Tulip color break virus was responsible for "tulipmania" in the 17th century; today color breaking is the result of breeding, not virus infection.

Figure 6.27. Viral pathogens can cause a range of ringspots and line patterns. Tobacco rattle virus on peony may exhibit these symptoms.

Viruses

Viral diseases result in an extremely wide range of symptoms. Plants infected with viruses may exhibit interruption of a color, known as color breaking (Figure 6.26). Ringspots and line patterns are common symptoms of viral pathogens (Figure 6.27). The leaves and fruit of some plants may display a symptom called mosaic or mottling, in which a lighter green, yellow, or cream color is interspersed with a darker green color. Symptoms such as yellowing of plant tissue (chlorosis), tissue death (necrosis), and dieback may develop as a result of viral pathogens.

Some infected plants may exhibit a stunted or distorted appearance, while others may present a prolific amount of growth (witches' broom) (Figure 6.28). Poor fruit set, flower abortion, and abnormal growth are additional symptoms of viral disease. Many of these symptoms are similar to those that may result from other pathogens or abiotic issues.

Viral pathogens are extremely small and are not visible without the aid of an electron microscope. Thus, it is not possible to visually observe signs in the field. Diagnosis of viral diseases relies heavily on symptomology and elimination of other possible causes. Diagnostic laboratories may confirm virus infection with antibody or molecular diagnostic techniques.

Figure 6.28. Witches' broom is the term used for a prolific amount of growth, which can occur as a result of viral pathogens. Rose rosette virus develops a classic witches' broom symptom.

Other Disease Issues (Nematodes, Phytoplasmas, Parasitic Plants)

Nematodes are microscopic, unsegmented worms that infest roots or foliar tissue. When roots become infested, plants commonly appear stunted or lose vigor (Figure 6.29). Nematode feeding on foliar plant parts results in necrosis or leaf blotches (Figure 6.30). Most nematodes are not visible without the aid of a microscope; thus field observation of signs is unlikely.

Infection by phytoplasmas can result in a range of symptoms, including yellowing, stunting, witches' broom, and the production of leaf-like structures in place of flower petals. Plants may also experience virescence, a condition in which chlorophyll (green pigment) develops in tissues where it is normally absent (Figure 6.31). There are no visible signs for phytoplasma pathogens.

Parasitic plants utilize host plants to obtain nutrients and water. As a result, parasitized plants may appear less vigorous or exhibit dieback (Figure 6.32). Parasitic plants can be easily observed, which simplifies diagnosis of disease issues of this type.

Figure 6.29. Roots infested by nematodes may cause the plant canopy to decline or appear stunted. Root-knot nematode infestation has resulted in the stunted appearance of these squash plants.

Figure 6.30. Leaf necrosis or blotches may be a symptom of foliar nematodes. Foliar nematodes can infect a range of leafy plants, including ferns.

Figure 6.31. Some plants infected by phytoplasmas display virescence. Aster yellows is a common disease caused by a phytoplasma.

Figure 6.32. Mistletoe is a common parasitic plant that may result in dieback of the host plant when populations are high.

Insects and Mites

Feeding damage is the most common way to identify a potential insect or mite problem. Caterpillars, aphids, and mites may remain on the foliage for days or weeks after initial infestation. Consequently, infestations can be discovered early by regular examination. However, if pests have completed their development and left, only plant damage may remain. In addition, mobile or intermittent feeders are often missed because they move frequently. Thus, plant damage may be the only observable clue.

Most plant-feeding pests have some type of chewing or sucking mouthparts. Tissue removal by chewing insects is obvious, in contrast with the subtle effects of sap feeders. Beetles, caterpillars, and tree crickets eat portions of leaves, sometimes leaving distinctive damage patterns. The needle-like sucking mouth parts of aphids, leafhoppers, and mites remove plant sap, while the saliva of other insects can break down plant tissues as they feed. Symptoms of insect infestation may be holes, wilting, discoloration, or spotting. Some sap feeders excrete large volumes of nutrient-rich honeydew. An accumulation of honeydew makes leaves, stems, or branches shiny and sticky. Black sooty mold may thrive on the deposits. Finally, thrips tear at flowers and foliage with file-like rasping mouthparts that leave fine scratches.

Consider the following when evaluating possible pest damage to plants:

- Document the range of plant species affected. General feeders, such as Japanese beetles or fall webworms feed on many plant species; damage by specialist pests is confined to closely related species.
- Determine season or activity period. Some pests have relatively well-defined activity periods that can help narrow the list of potential culprits. For example, bagworms begin to feed in early summer. Aphids are cool-season pests, while most mite species are favored by hot, dry weather.
- Consider type of tissue affected or damaged. Some plant feeders prefer buds or expanding leaves, while others target older foliage.

Chewing Insects

Some chewing insects leave characteristic feeding damage. This damage may help identify the type and age of the insect. For example, newly hatched individuals may not be able to chew tough tissue or veins, thus damage is limited to surface “window pane” feeding (Figure 6.33). Older insects can consume tougher tissue and may leave little behind. Table 6.1 presents examples of common feeding damage patterns by chewing insects.

Figure 6.33. Some chewing insects may consume only surface tissue, leaving a “window pane” appearance.

Table 6.1. Characteristic damage by common chewing insects.

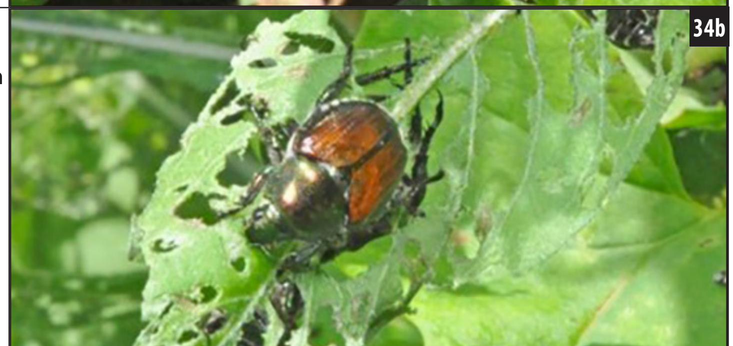
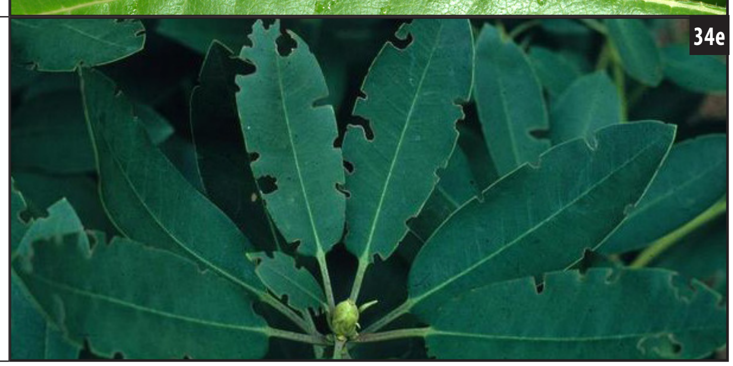
Type of Insect	Illustration of Damage
Many flea beetles chew scattered, rounded "shotholes" in leaves. Other chewing insects such as tree crickets and katydids, chew similar but larger holes. (Figure 34a)	
Some insects feed on soft plant tissue but do not chew through veins. This "skeletonizing" is characteristic of Japanese beetles. Some newly hatched caterpillars (bagworms) and sawfly larvae produce this pattern of injury. Slugs feed on low foliage in shaded, humid areas. They rasp tissue, causing similar damage. Look for their slime trails on foliage and surrounding soil. (Figure 34b)	
Many beetles and larger caterpillars may consume most of the leaf, leaving only the midrib or large veins. (Figure 34c)	
Grasshoppers and some caterpillars hang on to the edges of leaves and feed from the side. Others may feed evenly around the perimeter so the leaf becomes gradually smaller but keeps its general shape. (Figure 34d)	
Weevils chew uneven notches in the sides of leaves as they feed. (Figure 34e)	

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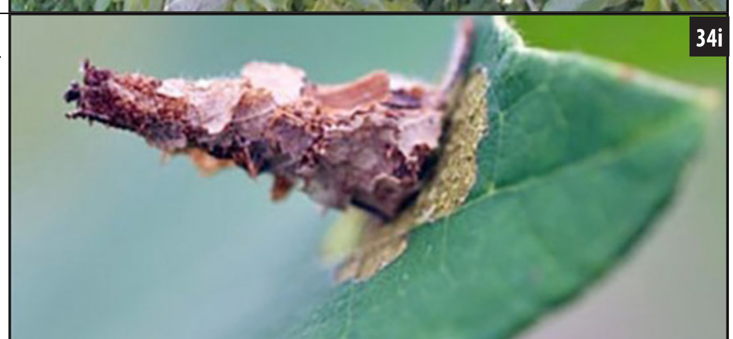
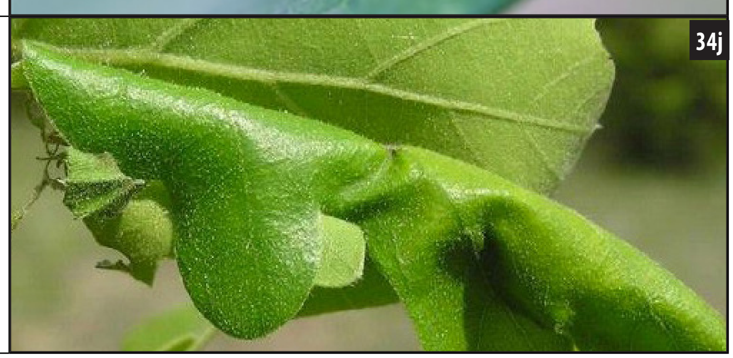
Table 6.1. Characteristic damage by common chewing insects.

Type of Insect	Illustration of Damage
Leafcutter bees remove smooth, rounded sections. (Figure 34f)	 34f
Blotch and serpentine leafminers feed on tissue inside the leaf, creating hollow areas that may be swollen or discolored. Insects or accumulated waste may be visible by holding damaged leaves up to the light. Leaf miners commonly infest holly and boxwood. Heavily mined leaves may drop prematurely. (Figure 34g)	 34g
Fall webworms (FWW) build tents on the ends of branches, whereas Eastern tent caterpillars (ETC) build tents in the crotches of tree branches. ETC and FWW use silk to create communal nests. ETC feed on wild cherry and related species from March through April. Two generations of FWW spin tents on the ends of branches of many tree species in June and August. (Figure 34h)	 34h
Bagworms spin silk coverings with pieces of host plant foliage attached. The structure provides protection from desiccation and predators. Skeletonized feeding damage by this small caterpillar is visible on the leaf surface. The camouflaged bagworms are often undetected until damage becomes severe. (Figure 34i)	 34i
Leaftier and leaf roller caterpillars use silk to fold or roll leaves and create individual shelters on foliage in which they feed. (Figure 34j)	 34j

Sap Feeders

General decline of an entire plant or plant part can appear as yellowed or wilted foliage, general loss of vigor, or dieback. These general symptoms can indicate many problems, including sap-feeding insects. Many sap feeders are small and feed on the undersides of leaves, so they are easily overlooked. Often, the effects are subtle and symptoms are slow to develop. Table 6.2 presents examples of common damage that may result from sap feeders.

Table 6.2. Characteristic damage by common sap-feeding insects.

Type of Insect	Illustration of Damage
Saliva injected during feeding by some insects can cause distorted growth or discoloration. Injury may be mistaken for chemical injury or disease. Examine the undersides of the leaves for presence of insects. Normal new growth may indicate that the injury occurred some time ago. (Figure 35a)	 35a
Fine spotting (stippling) on leaves may be caused by leafhoppers, plant bugs, lace bugs, or mites. Saliva injected during feeding destroys chlorophyll at the feeding site, but the toxins do not diffuse throughout the leaf. Continued feeding by increasing numbers of pests can cause the entire leaf to lose color and drop prematurely. If stippling symptoms are present on the newest growth, then the infestation may still be active. Look for pests on undersides of leaves. (Figure 35b)	 35b
Thrips tear at leaf tissue to puncture cells and feed on their contents. Injury appears as thin scratches or flecking of the leaves. Thrips can produce distorted growth by feeding in buds or along veins in developing foliage. Black varnish-like spots of waste accumulate on the lower leaf surface where these insects feed. (Figure 35c)	 35c
Scale insects are destructive pests of landscape trees and shrubs. They resemble growths on plant leaves or bark, but they can be scraped off with a fingernail. Armored scales live under crusty, waxy coverings that resemble rough spots on bark. They spend their lives on woody tissue. Soft scales resemble larger bumps, so they are much easier to detect. In addition, they produce large amounts of nutritious excrement called "honeydew." Over time, buildup of honeydew supports the growth of the dark sooty mold fungus. Sap removal by scale insects gives heavily infested plants the appearance of drought stress. (Figure 35d)	 35d

Gall Makers

Galls are abnormal growths that may be found on most plant parts, from catkins to leaves (Figure 6.36). Most are caused by tiny wasps, aphids, flies, or mites. Unlike scale insects, they cannot be easily scraped off.

Many gall makers attack woody plant species, resulting in galls on twigs or branches (Figure 6.37). However, most insect galls do not affect plant health. The number of galls on a plant can fluctuate naturally from season to season.

Borers and Girdlers

Plant decline or foliar wilt along a single branch can mean infestation by borers or girdling insects.

Borers tunnel into woody tissues, often disrupting plants' ability to move water and nutrients. Damage produced by borers varies with the type of insect. Borer damage is often apparent as holes or splits on the outside of woody tissue. Longitudinal slits with splintered margins that form along finger-sized branches are typical of periodical cicada egg-laying damage (Figure 6.38). Significant damage can occur after brood emergence in an area. Many borers produce exit holes. These insects usually attack trees that are injured, dying, or suffering from transplant shock. However, some can infest healthy trees. Multiple exit holes are typical of the adult stage of an insect leaving the tree after completing its development. Several beetle families produce small holes while entering the tree to lay eggs. Exit holes of roundheaded borers are typically one-eighth to three-eighths of an inch wide and scattered randomly on branches or trunks. Scattered small holes are emergence sites of shothole borers or bark beetles, while D-shaped emergence holes, such as those made by the emerald ash borer, are characteristic of flatheaded borers (Figure 6.39). Tunneling insect larvae such as the petiole borer can cause sudden, premature leaf drop. Petioles generally turn black, and a small, white worm can be found in the leaf stem.

Girdlers are beetles that chew around a twig so that it breaks easily (Figure 6.40). The beetle's eggs are laid in the portion of the twig that falls to the ground. This damage increases stress to the tree and creates sites for potential disease development.

Figure 6.36. Some insects can cause gall formation on leaves.

Figure 6.37. The horned oak gall represents an example of insect galls on woody tissue.

Figure 6.38. Longitudinal slits along finger-sized diameter branches are typical of periodical cicada egg-laying damage.

Figure 6.39. D-shaped emergence holes are characteristic of flatheaded borers.

Figure 6.40. Girdling insects chew around twigs or branches and increase the likelihood of breakage.

Wildlife

Determining what wildlife species is causing a problem can be difficult. Wildlife species can cause a wide range of damage to plants, through feeding or other activities. Wildlife damage can be broken into two broad categories: aboveground damage from feeding, trampling, or antler rubbing and belowground issues. The following sections discuss various types of wildlife damage. Use any and all observations including plant damage and the types of habitat located around the damaged plant to help determine the species responsible.

Damage Type

Aboveground Damage from Feeding

Each group of wildlife species referenced in this section is divided by feeding behaviors and resulting damage.

Small mammals (rodents): Chewed bark and cambium tissue on small trees and shrubs are most frequently caused by mice, rabbits, squirrels, muskrats, or beavers. Look for teeth marks. These will be clean cuts, and plant tissue will not appear. torn (Figures 6.41 and 6.42). Frequently, teeth marks will be left in the plant material. These teeth marks can help gauge the size of the animal that caused the damage. Water sources close by may indicate issues from muskrats or beavers. Beaver damage is unique and easily identifiable due to their ability to chew into large trees and cause extensive damage to plants near ponds or streams. Other damage common from this group includes damage and removal of berries, fruits, or vegetables. Teeth marks left in berries or vegetables may help to gauge the size of the culprit, when there are no tracks or scat to aid in identification.

Figure 6.41. Clean cuts from a larger mammal, the beaver.

Medium-sized mammals: This group includes species like raccoons, skunks, opossums, armadillos, foxes, coyotes, and groundhogs. These species can range in size from several pounds up to the size of a medium-sized dog. (Coyotes can reach about 40 pounds.) Unfortunately, this is the most wide-ranging group in terms of the damage they can cause to plants or landscaping. Fruit-bearing trees, gardens, or landscapes may all be affected. Damage to plants may result when these mammals dig holes in the ground when searching for food or establishing dens. Some species may directly remove seeds, bulbs, fruits, or vegetables.

Large mammals: Deer, elk, black bears, cattle, and horses may tear and cut branches, leaves, or the whole plants of sprouting fruits and vegetables. Livestock culprits aren't actually considered wildlife but can cause damage similar to deer and elk. Large mammals are usually easier to identify because of their size and the amount of "evidence" they leave in the area. Tracks and/or scat are often present within the area, as well as extensive damage to plants that occurs in a very short period of time. Deer and elk are capable of consuming large quantities of hundreds of species of plants year-round. Damage will occur more frequently on plants or sections of plants where new growth is occurring. Bud damage occurs most frequently during winter months by both deer and elk, which can cause severe damage and potential death for the plants.

Figure 6.42. Clean cuts on a pine seedling caused by a rabbit.

Birds: Birds can cause damage to plants by either tissue removal or pecking damage. The removal of edible plant material such as fruits is the most common (Figure 6.43). Berries may have tears or damage from pecking. Tooth marks will not be present in this type of damage. Other types of birds, such as woodpeckers, may damage plants by pecking bark material. Sapsuckers, often confused with woodpeckers, create horizontal lines of holes in tree bark (Figure 6.44). These birds remove sap from holes to use as a food source during winter months.

Turtles: Damage from turtles is uncommon, but box turtles can feed in vegetable gardens. Look for damage close to the ground, with torn pieces of plant material or dime-sized or larger chunks missing out of vegetables.

Figure 6.43. Berry damage from birds (indicated by the white arrow).

Belowground Issues

Damage to plants can be directly or indirectly caused by wildlife. This is especially true when damage occurs below the soil surface. These issues are harder to diagnose as they are often out of sight. Roots of trees and bushes may be girdled by vole feeding during winter, when vegetative material is scarce. This belowground damage often goes unnoticed until the following spring, when plants show decline or poor vigor. In order to determine whether voles are active in the area during winter, monitor vole burrows.

Mole tunnels may disturb plant roots, but tunneling is usually only aesthetic and is not directly harmful to plants. Moles can be beneficial by managing grubs in lawns and increasing soil aeration. Checking for tunnels or soil mounds will indicate whether there are moles present within the area. Expect any plant damage to occur within close proximity to these tunnels.

Tools for Identifying the Cause of the Problem

Tracks and Scat

One of the easiest ways to determine potential species causing plant damage is to look for tracks or scat near the damage. This will help narrow down the possibilities of what may be causing the damage, but presence of tracks or scat does not mean the animal that left them is causing the damage. It is just a tool to help determine what species are in the area, and this information is added to the list of other "clues" to help narrow down the potential list of causative species.

When trying to determine the species that left a track, pay close attention to the size of the track, the number and position of fingers and toes, whether claws are visible, and, if there are multiple sets of tracks, the spacing between prints (Figure 6.45). Apply this information to a mammal or bird field guide, which will have a section on tracks. Alternatively, there are several good resources for track identification online including the Internet Center for Wildlife Damage (refer to Additional Resources section for link).

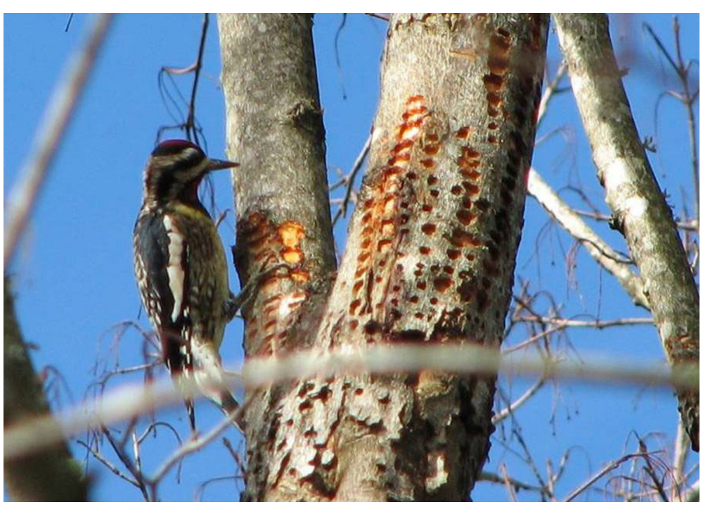


Figure 6.44. Sapsuckers damage trees by making lines of holes.

Figure 6.45. Example of tracks that may be left as evidence.

Scat is the fecal matter or droppings of wild animals and is a reliable sign that wildlife has been present in the area. When examining scat, avoid touching or wear rubber gloves to protect against potential diseases. Take note of scat size, width, and shape (Figure 6.46). Characteristics, such as a tubular or rounded shape, flat or pointed ends, and singular or multiple droppings, will help guide the identification of the species. See "Scat Identify Key" resource in the Additional Resources section to help identify scat.

Trail Cameras

Trail cameras offer an affordable and easily implemented option to determine causes of wildlife damage. Cost of cameras can be as little as $25 depending on features and brand. In most situations, the cheaper versions are capable of taking the quality pictures needed to identify wildlife culprits. Set the camera up in a manner that maximizes the chances of the nuisance wildlife triggering the device. Place a camera in the area that is experiencing the issue, preferably close to the plant(s) being damaged. Cameras should be placed at an appropriate height for the size of animal thought to be causing the problem. For example, if squirrels or rabbits are suspected, direct the camera to focus closer to the ground. With deer or elk, cameras should be placed about hip height. Even though a certain species is captured in a picture, this may not be the species that is causing the problem. Use pictures to help narrow down the potential list of causative species.

Resources and Reference Material

References can be helpful when attempting to identify wildlife species and damage. These resources include field guides and internet sources like the Internet Center for Wildlife Damage.

Abiotic Causes

Abiotic plant injury may be caused by environmental or physical conditions. These problems are noninfectious, meaning they are not caused by living organisms. In many cases, vigorous plants are healthier than those under stress. Thus, it is important to consider the age-old horticulture recommendation of "the right plant for the right place." For plants to thrive, they must have light, water, and nutrients in the proper amounts and temperatures within a range that supports growth. Plants grown in a location similar to their native habitat, especially in areas with minimal disruptions, will generally suffer less abiotic injury than those introduced from more exotic locations or those planted in areas with human-impacted habitats. While plants differ greatly with regard to optimal environmental conditions, the injuries observed when conditions are not met also vary greatly. Besides natural causes, plants sometimes suffer injury from chemicals or constraints humans bring into their growing space, such as herbicides, deicing salts, and synthetic materials around stems and roots. All of these noninfectious factors may contribute to plant injury.

Weather

Several aspects of weather may affect plant growth, including temperature, sunlight, and rainfall. Damage that results from weather conditions may be exhibited as a wide range of symptoms.

Late-summer fertilization (especially nitrogen) and abundant soil moisture encourage perennials to continue to grow well into autumn and delay cold acclimation. Plants that fail to adjust to cooler temperatures may exhibit winter damage to buds or stems. This damage appears as partial dieback to stems as growth resumes in spring or as lack of vegetative and/or flower bud growth.

Figure 6.46. Raccoon scat is dark and tubular.

Figure 6.47. Broad-leaf evergreens such as magnolia may exhibit leaf burn as a result of winter injury.

Broad-leaf evergreens (such as holly, magnolia, cherry laurel, and boxwood) may exhibit another type of winter damage called leaf burn or leaf scorch (Figure 6.47). On sunny days, these plants photosynthesize with open stomata. Cold, winter winds, combined with low water availability due to frozen soils, cause desiccation of leaves via rapid loss of water through stomata. In severe cases, this leaf burn may affect a large portion of the plant's canopy, causing deformity or even death. Fleshy stems with little bark coverage may also be affected. Milder cases of leaf burn may be expressed only on the leaf margins and may only cause temporary unsightly brown leaves that are replaced in spring with new growth. It is important to keep evergreens well-watered in late fall and winter as long as soils are thawed. A layer of mulch helps retain soil moisture.

Frost damage is another type of cold-temperature problem that can occur in spring as plants begin regrowth or as temperature-sensitive annuals are planted. Frost may occur when temperatures drop a few degrees or more below freezing. Sensitive plants exposed to frost may display blackening of young growing tips, leaves, flowers, or buds. Annual plants whose growing tips are damaged may be completely lost. Perennial plants usually regrow, but sensitive flower buds may be damaged, resulting in reduced flower and fruit production. Plants may be protected from frost by covering with light cotton or synthetic fabric material to catch warmth from the ground and hold it close to the plant. It is important that such material not only cover the plant, but also stretch down to the ground. Sometimes small plants are covered with solid objects such as flower pots or buckets; these objects should be removed to allow ventilation as temperatures warm. Coverings offer protection from light frost but are not effective when temperatures drop below 25°F.

Another aspect of cold-temperature damage may occur on tropical houseplants or certain vegetables. These plants are accustomed to growing under warm conditions, and as a result, low, non-freezing temperatures (40°F-50°F) may cause damage. Common houseplants such as peace lily, philodendron, and certain orchids, exhibit wilting and even death with prolonged exposure to low, non-freezing temperatures. Cold damage occurs with certain vegetables after prolonged storage under refrigerated conditions. Cucumbers, tomatoes, peppers, and watermelon may exhibit water-soaked tissue when refrigerated for long periods.

Hot temperatures, usually coupled with bright sunlight, may also cause damage to plants. For example, hot temperatures increase water demand in plants, causing them to release more water through their stomata than can be supplied by the root system. This results in temporary wilting, but plants usually recover overnight if there is sufficient soil moisture. Nevertheless, some scorching of leaves may result (Figure 6.48).

Plants are naturally adapted to certain light conditions (sun, part-sun, or shade). For example, shade-adapted plants will show symptoms such as yellowing, scorch, burn, or death when grown under sunny conditions. Plants germinated and grown

Figure 6.48. High temperatures can result in drought stress, which may be observed as leaf scorching.

Figure 6.49. Plants subjected to high soil moisture or flooding may exhibit a variety of symptoms, including yellowing of new growth and defoliation.

in one environment (greenhouse, house windowsill, nursery holding area) and then transplanted outdoors may scorch or burn when suddenly exposed to brighter light. It is important to gradually expose these plants to higher light conditions (called hardening off) before permanently planting them in a brighter location. Even houseplants abruptly moved to a bright window may exhibit some damage to leaves accustomed to lower-light conditions. Conversely, plants that are grown in high-light conditions and then moved to shade usually exhibit stunted growth and defoliation. New leaves produced in shade conditions are larger and thinner, and plants generally produce fewer flowers than similar plants growing in sun.

Figure 6.50. Decline refers to a decrease in plant vigor and can result from numerous abiotic issues.

Extremes in rainfall may also result in abiotic damage to plants. Severe low-moisture conditions or drought may cause symptoms such as wilting, yellowing, marginal leaf burn, and premature fall coloration of leaves. Insufficient rainfall is best remedied by irrigation. However, spotty or shallow irrigation may fail to meet plants' needs. A weekly, relatively deep irrigation equivalent to one inch of rain (wetting the soil to six to eight inches deep) is usually more beneficial to plants that frequent shallow irrigation. Newly transplanted plants with limited root systems may benefit from frequent shallow irrigation until roots are established. Too much rainfall or irrigation may also cause damage to plants. Plants under high soil-moisture or flooded conditions may exhibit wilting, yellowing of new growth, and defoliation due to damage to roots caused by low oxygen (Figure 6.49). Ensure that soils are well drained and aerated by incorporating organic matter; elevate soil in mounds or raised beds in areas of poor drainage.

Physiological Disorders

Physiological disorders are often characterized by gradual decline over time. Symptoms of decline include reduced growth, premature leaf coloration, winter injury, whole-plant dieback, water sprout production on woody plants, and increased susceptibility to insects and disease. Decline may be caused by a number of abiotic issues (Figure 6.50). Soils may lose structure and become compacted due to traffic, which impacts root health and subsequently foliage health. Packaging material, such as synthetic burlap or galvanized wire baskets, often constricts root systems, leading to decline.

Improper planting techniques may also result in decline or death of a plant. Prior to planting, all potentially girdling roots should be removed, so they do not wrap around the base of the plant. Plants should be installed at an appropriate depth and then maintained correctly. Improper maintenance, such as excess mulch or exposed roots, can lead to increased plant stress and an increased risk of decline. Symptoms of improper planting practices may appear within the first few years after planting. However, other symptoms may take five or more years to become visible.

Inappropriate temperature, rainfall, or sunlight may also result in decline, particularly if these conditions are mild or otherwise not extreme. This situation results in delayed symptom development but compromises plant health over time. Decline is best managed by good cultural practices. Proper fertilization, irrigation during drought, mulching, and proper pruning may help to slow or reverse decline. It is important to closely monitor pest situations on stressed plants, as they often develop compromised natural pest resistance.

Mechanical Damage

Plants often suffer physical damage from devices used in managing the landscape. Synthetic material left on plant roots may eventually constrict the root system. Synthetic burlap or twine should be completely removed from the root system before planting. It is common to stake trees after planting to prevent them from blowing over during strong winds. Trees staked too tightly are slower to establish new root systems than those that are allowed to sway slightly. The material used to secure the tree to the stake may also be problematic. Bare wires or twine tightly secured to the trunk or branches may be quickly overgrown by the plant, making it difficult to remove later and eventually causing constriction and girdling of the branch or trunk (Figure 6.51). Covering the section of twine or wire that touches the tree with flexible garden water hose or coarse fabric will delay growth around the fastener. In most instances, staking material should be removed after one growing season.

Mechanical damage may also be caused by wind, ice, or snow load. For woody plants, proper pruning, especially when plants are young, helps to develop strong trunks and branch angles that are better able to withstand weight and force. A discussion of proper pruning techniques is provided in Chapter 17, Care of Woody Plants.

Figure 6.51. Wires or other materials used to secure plants should be removed at the appropriate time to avoid constriction and girdling of the plant.

Another cause of decline is damage to the lower trunk by string trimmers or landscape equipment. Plants' phloem vessels are located just under the bark and can be easily damaged, especially on young trees. If damage occurs, photosynthates from the leaves fail to be transported to the root system. A weakened root system results in decline, and in severe cases, plants may fail to leaf out in spring. While it may seem logical to cover the base of the trunk with protective material, this practice also presents problems. Protective covers or wraps may retain moisture and invite decay. The best practice is to maintain a wide layer of mulch around the tree, making it unnecessary to trim or mow close to the trunk. However, mulch itself can be damaging when it is applied too deeply or too closely around the trunk.

Nutrition

There are 16 nutrients that are necessary for plant growth. Deficiencies or excess of any of these nutrients may cause symptoms such as discoloration (Figure 6.52), stunting, distortion, or burning. Sometimes, nutrients are present in adequate amounts but soil pH, when too acidic or too alkaline, limits the availability of nutrients to plants. Plant roots that are compromised by poor drainage, compacted soils, low soil moisture, or pest issues may also result in nutrient deficiencies due to the plant's inability to uptake nutrients. Symptoms of nutrient deficiency or toxicity are characterized in Chapter 1, Basic Botany. When nutritional issues are suspected, the first step is to complete a soil test (see Chapter 4, Soils and Fertility). Testing the soil will determine the level of important nutrients in the soil, as well as the soil pH. Recommendations from a soil test may help remedy the nutritional issue or, in rare cases, suggest the need for further analysis.

Figure 6.52. Nutritional deficiencies may result in a wide range of symptoms, including discoloration of plant tissue.

Figure 6.53. Chemical damage may be observed as chlorotic or necrotic spotting on leaf surfaces.

Chemical Damage

Patterns of chemical injury on individual plants differ, depending primarily on whether a chemical causes damage directly on contact or whether it is absorbed and moved throughout the plant. Direct-contact damage can occur on foliage, stems, and roots. Symptoms from shoot-contact chemicals occur over the general plant canopy. The injury does not spread with time or move to previously undamaged plants. Injury is characterized by chlorotic or necrotic spotting (Figure 6.53). Spots are usually uniform in size and evenly distributed over all or most plant surfaces, with a distinct margin between affected and healthy tissue.

If a chemical is applied directly to aboveground parts, the application pattern may be observed. For example, the pattern of spray droplets may be visible, or areas where spray accumulated along leaf edges may show the most damage. In the case of a toxic gas (volatile chemical), areas between leaf veins and along leaf margins, where water concentration in lowest, develop damage first. Examples of shoot/foliage contact chemicals are foliar-applied fertilizers; the agricultural herbicides paraquat, acifluorfen, and dinoseb; and herbicidal oils. (Very few, if any, contact herbicides are available to home gardeners.)

Toxic contact chemicals in the root zone, including excess fertilizer, can result in damaged roots or poor root development. Roots can be injured and root tips may be killed. Damaged roots are unable to obtain water; thus aboveground symptoms such as reduced growth, wilting, or chlorosis may be observed. In severe cases, wilting can occur even when the soil is wet. Lower leaves generally wilt first, followed by the drying of leaf margins (leaf scorch). Herbicides that inhibit root growth include the agricultural herbicides dinitroanilines, DCPA (Dacthal), and diphenamid. Excess nitrogen fertilizer can have the same results. Keep in mind that many other factors also injure roots or inhibit their growth, including nematodes, disease-causing pathogens, soil compaction, cold weather, salinity, and nutritional deficiencies or excesses.

Some chemicals can move throughout a plant after being absorbed. The effects of these mobile chemicals depend upon whether they are transported in the xylem or the phloem. Toxic chemicals transported in the xylem primarily cause symptoms in older plant foliage as they move upward from the crown. Examples of xylem-transported chemicals include urea fertilizer and the agricultural herbicides triazine, alachlor, and metolachlor. Chemicals transported through the phloem may move in many directions from the point of absorption; for example, it may move from the shoots to the roots or vice versa. Symptoms caused by phloem-transported chemicals occur primarily in the plant's new growth and meristematic regions. Affected young tissue is discolored or deformed, and injury may persist for several sets of new leaves. Examples of phloem-transported chemicals include the common garden herbicides 2,4D, dicamba, and glyphosate.

Diagnostic Assistance

In many cases, it may not be possible to determine the cause of a plant problem without additional assistance. Numerous resources are available to aid in this process. County-based Extension agents are local resources that can be utilized to assist homeowners with identification of the cause of a plant problem, as well as to provide recommendations regarding management of problems. In Kentucky, at least one agriculture and natural resources and/or horticulture agent is located in each of the 120 counties. Agents possess a broad range of knowledge on a variety of agricultural and horticultural topics. These individuals may provide various services to diagnose plant problems, including consultation, sample assessment, and/or site visits. Contact the local Cooperative Extension office for more information on services provided. To locate a local Extension office, visit https://extension.ca.uky.edu/county.

Diagnosis of a specific plant problem may require a specialist to assist in the identification process. The University of Kentucky and Kentucky State University both employ specialists that focus on specific areas of plant health. Specialists in the departments of plant pathology (diseases), entomology (insects), forestry (wildlife), and horticulture (abiotic) partner with Extension agents to provide homeowners and commercial growers with diagnoses and management recommendations for the wide array of plant problems. These specialists are accessible through local county Extension agents.

A wide range of diagnostic services are available to assist residents of Kentucky in determining the causes of plant problems and growing healthy plants. A county Extension agent can assist in determining which, if any, of these services are needed. Homeowners should work with the county Extension agent to submit samples. This ensures that appropriate samples are provided, improving response time and reducing the risk of an insufficient sample submission.

Plant Disease Diagnostic Laboratory: When a plant problem has been determined to be the result of disease, a sample of the affected tissue may be sent to one of the two University of Kentucky Plant Disease Diagnostic Laboratories. Diagnosticians review samples using microscopy, culturing, and/or molecular methods. Diagnosticians provide identification and management information. The University of Kentucky plant pathology fact sheet *Submitting Plant Specimens for Disease Diagnosis* (PPFS-GEN-09) provides helpful information for collecting appropriate samples.

Insect Sample Submissions: When insects have been determined to be the issue, plants with suspected insect injury, photos, or vials containing an insect sample can be submitted directly to the University of Kentucky Department of Entomology. Specialists review these samples and provide correct identification and management information.

Weed Identification: Extension weed specialists at the University of Kentucky Department of Plant and Soil Sciences are able to provide species identification, as well as weed management information. When herbicide injury is suspected, specialists in this program review samples to determine whether the problem is consistent with herbicide contact. However, the University of Kentucky does not provide herbicide residue testing.

Plant Identification: The Herbarium at the University of Kentucky Department of Forestry can provide identification of woody plants and wildflowers.

Soil Tests: The University of Kentucky Division of Regulatory Services provides soil testing for a minimal fee. Soil samples can be submitted through a county Extension office. Once soil is analyzed, a report is provided that includes recommendations to improve soil health.

Plant Tissue Analysis for Nutrients: Several private laboratories can provide an analysis of the nutrient composition of plant tissue for a fee. A county Extension agent can determine if this service is needed and provide additional information on submitting a sample.

Summary

The process of diagnosing plant problems can be a challenging exercise in critical thinking. Information about the problematic plant is collected by considering the identity of the plant and its history. Examination of the site may also provide additional information that may aid in the process. A thorough analysis of symptoms and signs is important for the diagnostic process. After collection, this information is used to determine whether the problem is the result of a living factor (disease, insect, or wildlife) or a non-living cause. It may be necessary to consult a variety of resources in order to draw conclusions from the information collected. If a probable cause cannot be determined after a review of the information collected, numerous services are available to assist in the diagnosis of a plant problem.

Appendix

Appendix A: Considerations for Diagnosis of Ornamentals in the Landscape

Additional Resources

University of Kentucky Department of Plant Pathology Publications https://plantpathology.ca.uky.edu/extension/publications

University of Kentucky Department of Entomology Publications https://entomology.ca.uky.edu/entfacts/

University of Kentucky Department of Forestry Wildlife Publications https://forestry.ca.uky.edu/wildlife-pubs

University of Kentucky Wildlife Damage Website https://forestry.ca.uky.edu/wildlifedamage

Internet Center for Wildlife Damage http://icwdm.org/

Scat ID Key https://icwdm.org/identification/feces/scat-id/

University of Kentucky Department of Horticulture Residential Publications http://www.uky.edu/hort/home-horticulture

University of Kentucky Cooperative Extension Service https://extension.ca.uky.edu/

Kentucky State University Cooperative Extension Service https://www.kysu.edu/academics/college-acs/school-of-ace/co-op/index.php

Considerations for Diagnosis of Ornamentals in the Landscape https://plantpathology.ca.uky.edu/files/ppfs-gen-15.pdf

Kentucky Cooperative Extension Service County Office Information http://extension.ca.uky.edu/county

Submitting Plant Specimens for Disease Diagnosis https://plantpathology.ca.uky.edu/files/ppfs-gen-09.pdf

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Chapter 07

Insects

By Jonathan L. Larson, Extension entomologist.

In this chapter:

Insects are the most biodiverse group of animals on earth. Amazingly, there are about one million total species of insects known currently, with the possibility of tens of millions more left to discover. When you include spiders, mites, scorpions, millipedes, centipedes, and other relatives, it's astounding to see the diversity of this group and how dominant they are across the planet. Not only are there many different species, but you can encounter these organisms almost anywhere on earth, from the bottom of the ocean to your own living room.

Insects and their relatives have a complicated relationship with humans. While most have no impact on human lives one way or the other, some can have negative impacts on us, while others are viewed as beneficial organisms. Insects that cause problems are collectively known as pests; only about one to three percent of the total population of insects would be considered true pests. Beneficial insects may provide goods or services that humans value. Honey bees for example, provide pollination services, helping farmers to produce things like apples, as well as goods like honey and beeswax. The vast majority of insects though are simply wild animals trying to survive.

As Master Gardeners, you will receive many inquiries about insects, particularly those that are plant pests. This could involve insect identification and making pest control recommendations. In order to successfully identify pests and provide help, it will be helpful to understand some of the basic natural history, anatomy, and biology of insects and their relatives.

Identifying Insects

Scientists have created a classification system for organisms that divides them into various groupings. These groupings are part of a tiered system, which can be best visualized as a pyramid. The base of the pyramid is the most generalized way of talking about a specific organism, currently this level is called "domain". The top of the pyramid is the most specific way of talking about a specific organism; currently this level is called "species" (Figure 7.1). In between these levels there are also (in order of increasing specificity) kingdom, phylum, class, order, family, and genus. When talking about insects and their relatives, we will be referring to them by their phylum name, Arthropoda, or more simply, the arthropods. This group represents almost 80 percent of animal life on the planet.

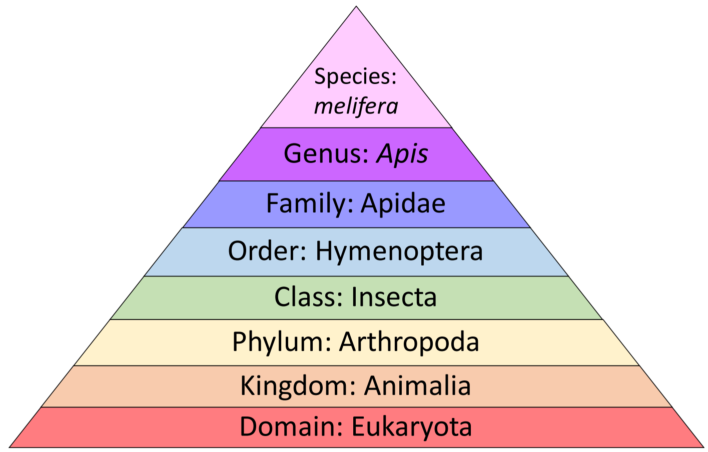


Figure 7.1. A pyramid showing the increasing specificity of terms referring to a European honey bee.

Arthropods

Representatives of the arthropods can look radically different from one another—think of comparing a monarch butterfly to a lobster. However, despite their differences, there are some traits that all arthropods share.

- All arthropods have jointed appendages. The name "arthropod" translates as "jointed foot."
- Arthropods all display bilateral symmetry. If a line is drawn down the middle of their bodies, the two sides should be a mirror image of each other.
- All arthropods have segmented bodies. Importantly, the different classes of arthropod are often separated by the number of segments their bodies have.
- Across the phylum, all representatives have an exoskeleton, a waxy outside layer that protects them, rather than having an internal skeleton like humans do.

Classes

There are multiple classes of arthropods that can be separated by certain physical traits, such as the number of body segments, number of legs or antennae, and the presence of other specialized anatomy.

Crustacea (Crabs, Lobsters, Shrimp, Crayfish, Isopods)

Members of this class have two pairs of antennae, two body segments, and five to seven pairs of walking legs (Figure 7.2). As a group, they tend to be found in bodies of water. Pillbugs and sowbugs (a.k.a. rolly pollies) are terrestrial, though they live in damp environments.

Figure 7.2. Crustacea.

Chilopoda (Centipedes)

Centipedes have one pair of antennae and one pair of legs per body segment (Figure 7.3). They tend to have a flattened profile and are predaceous. To subdue prey, they have a pair of venomous fangs. Contrary to what their name implies, they don't typically have one hundred legs.

Figure 7.3. Chilopoda.

Diplopoda (Millipedes)

Millipedes have one pair of antennae and two pairs of legs per body segment (Figure 7.4). They tend to have a tubular profile and are decomposers. Like their cousins, the centipedes, their name is a bit of a misnomer. It translates to "thousand feet" but most species have nowhere near that many legs.

Figure 7.4. Diplopoda.

Arachnida (Spiders, Ticks, Mites, Scorpions)

A very diverse class, containing predators, herbivores, parasites, and decomposers. All representatives have two body segments, four pairs of legs, and specialized mouthparts known as chelicera (Figure 7.5).

Figure 7.5. Arachnida.

Insecta (Beetles, Butterflies, Dragonflies)

While members of this class vary wildly in shape, size, color, and environmental role, they all share some traits. Insects have three body sections, three pairs of legs, and one pair of antennae (Figure 7.6).

Figure 7.6. Insecta.

Orders

After classes, organisms will be classified in an order. For the sake of this chapter, we'll focus on orders of insects to help you identify them in the future. Order level identification is often the level needed to help with pest problems. Not all orders are prevalent in Kentucky; some others can be found nearly anytime and anywhere.

There are about 30 orders of insects. This number fluctuates with new discoveries; entomologists may create new orders or fold one order into another, based on new genetic information. Previously, orders were compiled based solely on physical characteristics, but with the advent of genetic analysis, great shifts have occurred in our understanding of what is truly related to one another in the world of insects. Generally speaking, all members of an order will share certain physical characteristics and will develop in similar ways (Figures 7.7–7.18).

Anatomically, the most important traits that separate insect orders are the types of mouthparts, types of legs, and number of wings. Different orders will also progress through different types of metamorphosis as they mature. For more information on these anatomical and biological differences, see the second half of this chapter.

Figure 7.7. Odonata.

Odonata

Dragonflies and Damselflies

Odonata means "toothed," referring to the toothed parts of their mouths.

Big Eyes and Skinny

Odonates tend to have long, thin abdomens; heads that are mostly covered with compound eyes; and vein-filled wings.

Incomplete Metamorphosis

Odonates hatch from their eggs and develop through nymphal stages, gradually developing underwater.

Figure 7.8. Orthoptera.

Orthoptera

Grasshoppers, Crickets, and Katydids

Orthoptera means "straight wing," and these insects bear folded wings that form a straight line down the back.

Jumping and Singing

Most orthopterans have a hind pair of jumping legs and use songs to communicate.

Incomplete Metamorphosis

Orthopterans hatch from their eggs and develop through nymphal stages, gradually growing and developing wings.

Figure 7.9. Mantodea.

Mantodea

Praying Mantises
Mantodea means "prophet." There are three mantis species in Kentucky.

Predatory Attributes
Mantises have raptorial front legs and triangular heads with large eyes, both aiding in catching prey (usually other insects).

Incomplete Metamorphosis
Mantises hatch from their eggs and develop through nymphal stages, gradually growing and developing wings.

Figure 7.10. Blattodea.

Blattodea

Cockroaches and Termites
Blattodea means "cockroach." Termites were added to this order after recent genetic research.

Basic Legs and Antennae
Cockroaches and termites have simple walking legs. Cockroaches tend to be flattened, with a protected head. Termites are pale in color and live in colonies.

Incomplete Metamorphosis
Roaches and termites hatch from their eggs and develop through nymphal stages.

Figure 7.11. Dermaptera.

Dermaptera

Earwigs
Dermaptera means "skin wing," referring to the skin-like front-wing covers of earwigs.

Cerci and Ear-Shaped Wings
Earwigs are most recognized by the pincerlike cerci on their rear. When unfolded, their wings are ear shaped.

Incomplete Metamorphosis
Earwig mothers tend to their eggs over the winter. When they hatch, earwig nymphs will emerge.

Figure 7.12. Thysanoptera.

Figure 7.13. Hemiptera.

Thysanoptera

Thrips

Thysanoptera means "fringe wing," referring to the hairy-looking fringe on thrips' wings.

Slender with Hairy Wings

Thrips are small and pencil shaped, with fringed wings and asymmetrical mouthparts.

Strange Metamorphosis

Thrips are sometimes considered to have development that is both complete and incomplete metamorphosis.

Hemiptera

Aphids, Cicadas, Stink Bugs, Assassin Bugs, and More

Hemiptera means "half wing." Some hemipterans have half-leathery and half-membranous wings.

Piercing–Sucking Mouthparts

All hemipterans have needle-like mouthparts that can be used to siphon their food.

Incomplete Metamorphosis

Hemipterans hatch from their eggs and develop through nymphal stages, gradually growing and developing wings.

Figure 7.14. Neuroptera.

Neuroptera

Lacewings and Antlions

Neuroptera means "nerve wing," referring to the many veins in the wings of this group.

Slender with Vein-Filled Wings

Adults look vaguely like dragonflies but with long antennae, and their wings have many veins in them.

Complete Metamorphosis

Neuropterans are larvae when immature, looking considerably different from their adult form.

Figure 7.15. Coleoptera.

Coleoptera

Beetles

Coleoptera means "sheath wing," referring to the hardened top wing that protects the soft underwing.

Tough Wing Covers

Beetles have tough wing covers called elytra, along with chewing mouthparts and two pairs of wings.

Complete Metamorphosis

Beetles hatch from their eggs as larvae, sometimes referred to as grubs. They will pupate before reaching adulthood.

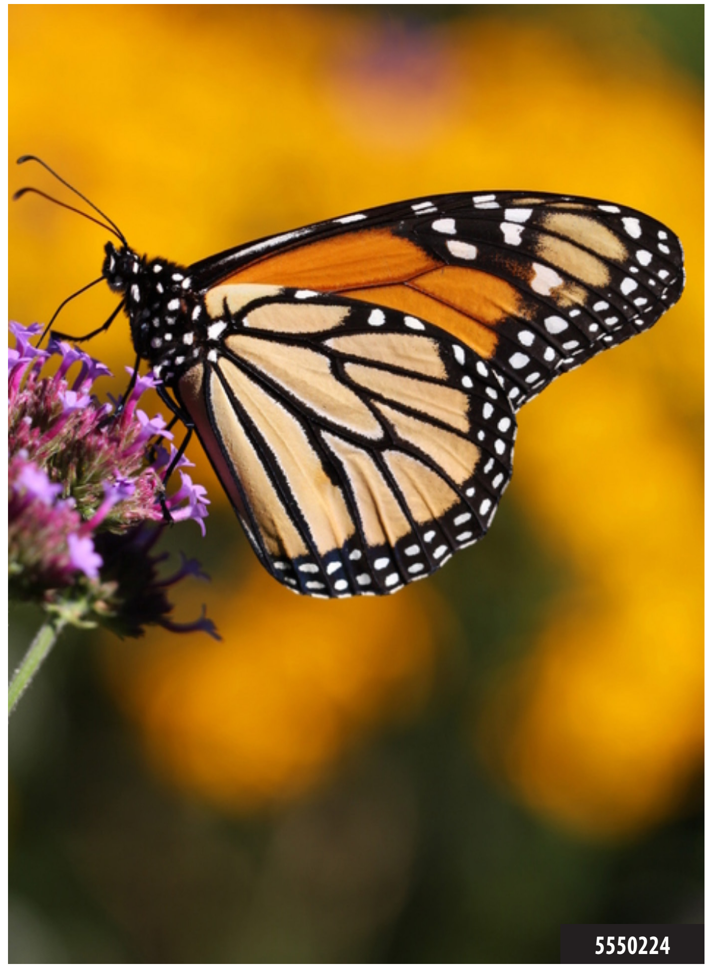


Figure 7.16. Lepidoptera.

Lepidoptera

Butterflies, Moths, and Skippers

Lepidoptera means "scale wing," referring to the scalelike coating on the wings.

Siphons and Scales

Lepidopterans have colored scales covering the wings and siphoning mouthparts that curl under their heads.

Complete Metamorphosis

Lepidopterans hatch from their eggs as larvae, usually referred to as caterpillars, which will pupate before becoming adults.

Figure 7.17. Diptera.

Diptera

Flies

Diptera means "two wings," as flies only have two full wings.

Two Wings and Aristate Antennae

All flies have two wings, and most also have aristate antennae and sponging mouthparts.

Complete Metamorphosis

Flies hatch from their eggs as larvae, usually called maggots, and they will pupate before they mature into adulthood.

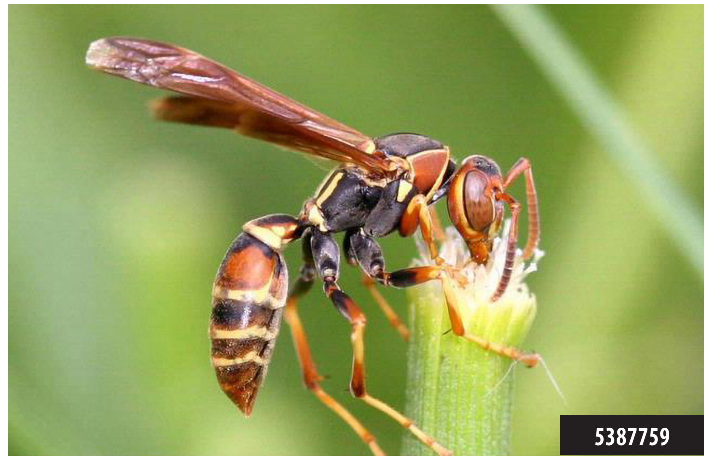


Figure 7.18. Hymenoptera.

Hymenoptera

Bees, Ants, Wasps, and Sawflies

Hymenoptera means "membrane wing," referring to the insects' four see-through wings.

Membrane Wings and Social Structures

Hymenoptera have chewing mouthparts and two pairs of membranous wings. Many live in social colonies.

Complete Metamorphosis

Hymenopterans hatch from their eggs as larvae and will pupate before reaching adulthood.

Inside of each order can be numerous families of insects. Family-level identification is also helpful when identifying a specimen, as the extra specificity may provide a more targeted management approach or reveal that something isn't a pest at all. Animal family names end in "-idae"—for example, Coccinellidae (lady beetles), Tettigoniidae (katydids), and Culicidae (mosquitoes). Most families also have distinct traits that help with quicker identification. To use Coccinellidae as an example, they are generally recognized by their bright warning coloration, spots, and domed appearance.

Beyond the family will be genus and species. Identification of insects to these levels usually requires the use of a dichotomous identification key and magnification equipment. Some species may be separated by something difficult to see, such as the number of hairs found on a specific part of the antennae. Other times, it's possible to recognize the species quickly and easily. For example, a Japanese beetle has a distinct enough appearance that it can be identified almost immediately. Genus and species names are combined to make an insect's binomial scientific name. To stick with Japanese beetle, its scientific name is *Popillia japonica*. Japanese beetle is this species' common name.

Common names are important, as they are what most people will use when discussing insects and they are easier to understand than Latin genus and species names. Common names can also be confusing though, as they vary by location and are sometimes applied to multiple insects. For example, the common name "potato bug" could refer to either a Colorado potato beetle or to a Jerusalem cricket, depending on whom you ask. Similarly, the insects that fly in the summer and glow could be called lightningbugs or fireflies, depending on where you are in the state of Kentucky. These confusing situations are why you might hear an entomologist using the more specific scientific names instead of common names.

Other common name issues can arise from the terms "fly" and "bug." Flies and bugs are both specific kinds of insects. Fly is the term broadly applied to the order Diptera, while bug or true bug is applied to the order Hemiptera. However, common names may borrow these terms and apply them to insects outside of those two orders. The way to tell if "fly" or "bug" is being used to describe an actual fly or bug is to look for a space before the word "fly" or "bug". The word "firefly" is a good example of this. Fireflies are actually a type of beetle; therefore, there is no space before the word "fly." A house fly, on the other hand, is a true fly, and there is a space before the term "fly" when writing the name out. With the term "bug," you can see this with a ladybug (a beetle) versus a bed bug (a true bug).

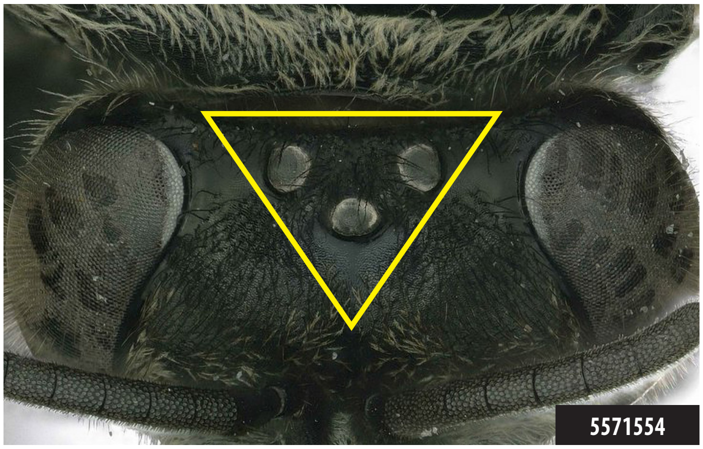


Figure 7.19. Insect ocelli, such as the ones inside of the yellow triangle here, are often in groups of three on top of an insect's head.

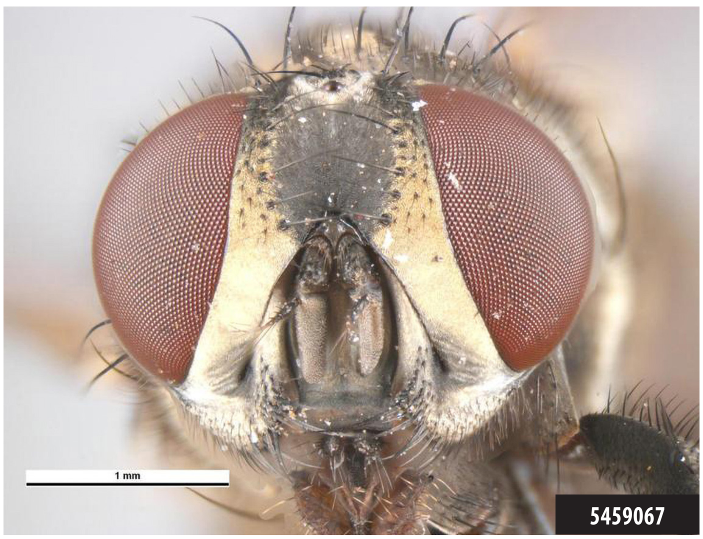


Figure 7.20. Compound eyes, like the two red ones on this house fly, can collect visual information from around the insect; most insects are considered to have poor vision, though.

Insect Anatomy and Development

As described before, insect anatomy is key to understanding how to identify insect specimens. Looking at the basic body plan of an insect, there are three body sections: the head, thorax, and abdomen. Each section will have specialized internal and external anatomical structures that help the insect be successful and help us to tell what it is.

Head

The head is where the insect receives most of the sensory information it needs to find other members of its species group, food, and shelter. This information is acquired through sensory organs housed on the head, namely the eyes, antennae, and mouth. Inside of the head is the first and largest of an insect's multiple ganglia, or brains.

Insect Eyes

Insects can have two kinds of eyes: simple eyes (also referred to as ocelli) and a pair of compound eyes. Ocelli are able to detect only light and darkness. Insects may use them to know what time of day it is. Ocelli often come in groups of three, arrayed in a triangle on top of the insect's head (Figure 7.19). Insects have a pair of compound eyes that gather more visual information (Figure 7.20). Each compound eye is made up of hundreds or thousands of lenses, each of which will send an image to the insect's brain. This multitude of images is compiled into a collage-like visual. Insect vision lacks depth perception, and they tend to be near-sighted. Insect compound eyes are capable of detecting ultraviolet light, though.

Insect Antennae

All insects have a pair of antennae, usually located on top of the head or at the front of the head. Antennae are used variously for smelling, touching, and even hearing. To facilitate smelling,

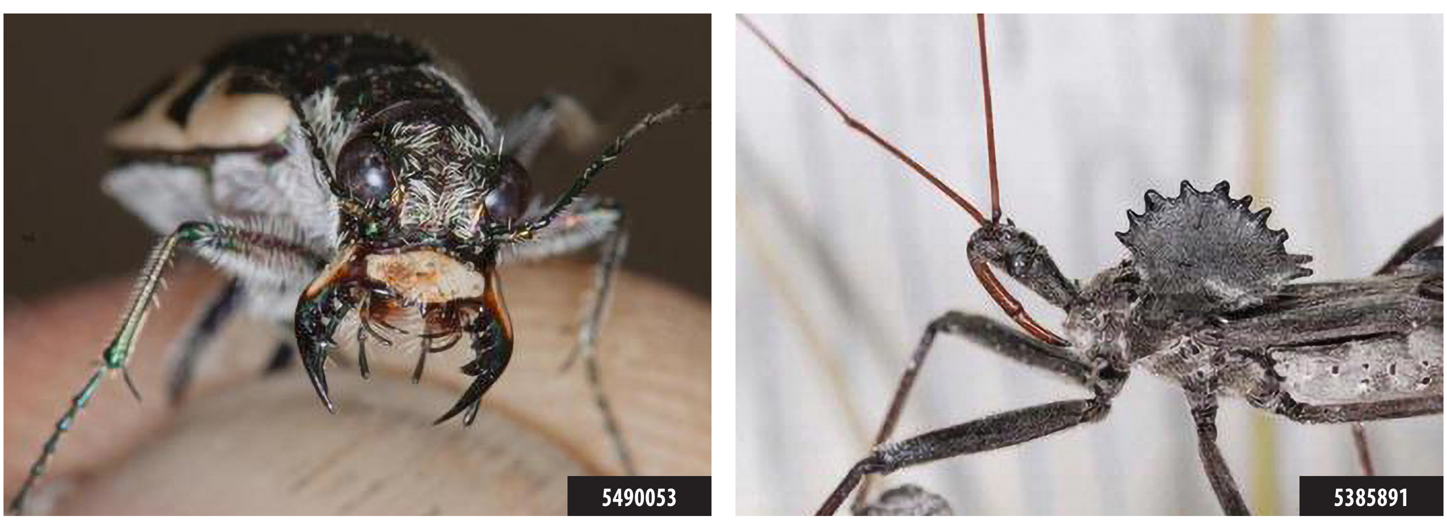


Figure 7.21. The two most common types of insect mouths are chewing (image of the beetle on the left) and piercing-sucking (wheel bug on the right).

the antennae are covered with small hairlike receptors that collect odorous cues. This allows the insect to detect food from afar, to confirm that something is food, and to detect pheromones produced by other members of its species. Antennae can be quite helpful for identifying insects to order and family, as there are lots of different shapes and forms of antennae (Table 7.1).

Insect Mouthparts

Anatomically, insect mouths are made up of multiple structures. There are mandibles, different kinds of palps, and pieces that function like lip covers, in a way. Taken as a whole, these pieces may be called the insect's mouthparts. Insects feed on a great diversity of food, and mouthparts can be specialized to help the insect consume whatever food it feeds on (Figure 7.21).

Chewing

The most common of insect mouths, chewing mouthparts feature two mandibles, opposing one another, that chew up food. Depending on the species, this could be for herbivory or for predation. Mandibles are usually toothed to facilitate chomping.

Piercing and Sucking

The second most common type of insect mouths, piercing and sucking mouthparts have been heavily modified to allow the insect to pierce a food source and then slurp the juices out of it. Piercing-sucking mouths can be used on plants by herbivores to draw out sap, on animals by parasites to draw out blood, or on other insects to consume their innards by predators. Hemipterans have piercing-sucking mouthparts, as do a few others like mosquitoes.

Chewing and Lapping

Chewing and lapping mouths are found on insects that chew pollen and drink nectar, such as honey bees. This type of mouth will have chewing mandibles but also a long tube or tongue to consume liquids as well.

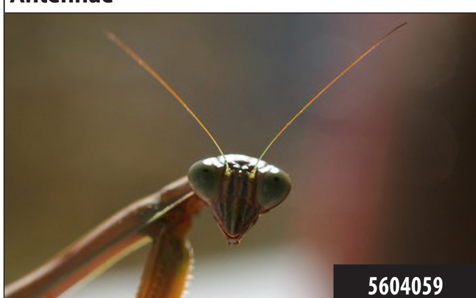
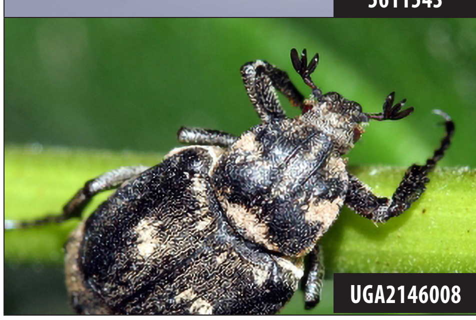
Sponging

Found on many Dipterans (flies), sponging mouthparts have a structure that helps them to absorb liquids from surfaces. Some sponging mouths may be paired with sharp cutting organs to help gain access to blood.

Siphoning

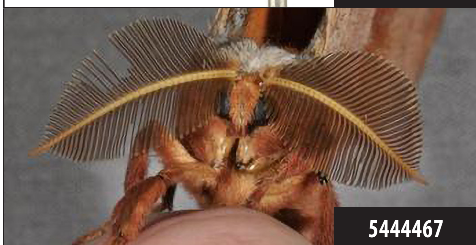
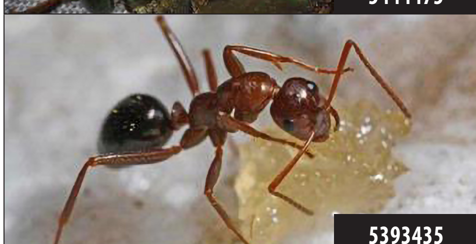
Moths and butterflies have siphoning mouths, simple, tubelike mouths that curl up under the head when not in use. They can be unfurled and dipped into things like flowers to drink up liquid food, such as nectar.

Table 7.1. Insect antenna types, and insects that most commonly have them.

Antennae	Type	Bearing Insects
	*Filiform* The most basic of insect antennae, simple and threadlike	Found in almost every order, and prevalent in Orthoptera, Mantodea, Blattodea, Dermaptera, and Neuroptera
	*Serrate* Antennal segments have small triangular projections that appear like saw teeth to humans	Found mainly on beetles
	*Lamellate* Start out thin but have finger- or page-like projections at the tip	Found mainly in scarab beetles

Continued from previous page.

Table 7.1. Insect antenna types, and insects that most commonly have them.

Antennae	Type	Bearing Insects
	*Pectinate* Long, fingerlike projections on one side of antennal segments, like a comb	Found mainly on beetles, sawflies, and parasitoid wasps
	*Plumose* Feather-like, usually with projections on two sides of the antennae	Most common on moths and mosquitoes, but may only be on males in certain species
	*Aristate* Small, feather-like antennae that sit on top of a bulbous structure	Found typically on flies
	*Setaceous* Very simple and thin, looks like an individual hair	Found on fast flying insects, dragonflies, water bugs, cicadas, etc.
	*Geniculate* Elbowed antennae, look similar to filiform with a joint in the middle	Most associated with ants and other Hymenopterans
	*Capitate* Antennae terminate in a bulbous tip, knobbed in appearance	Found on butterflies as well as some Neuropterans and beetles
	*Clavate* Clubbed antennae that gradually get thicker toward the tip	Found on beetles and moths most often

Thorax

The next body section is known as the thorax. The thorax itself is split into three sections: the pro-, meso-, and metathoraxes. One pair of legs is attached to each section.

The thorax starts where the first pair of legs are and ends with the last pair of legs. This section specializes in locomotion; not only are the legs attached here to facilitate movement but if the insect is winged, this is where the wings will attach as well.

Insect Legs

Depending on the order they belong to, insects may have different kinds of legs. Legs may also help facilitate identification. Insect legs are structurally similar to human legs, with a coxa ball joint, a first section called the femur, a tibia, and tarsi at the end.

Walking

Most insects will have at least one or two pairs of walking legs. These are very simple legs with no special adaptations. They help the insect to scurry along (Figure 7.22a).

Jumping

Grasshoppers, katydids, crickets, and fleas are most famous for having jumping legs. This type of leg looks like a walking leg, except the femur will be larger and packed with more muscles, allowing the insect to jump many times its own body length (Figure 7.22b).

Natatorial

Aquatic insects can have natatorial legs. These are usually flattened and oar shaped, and sometimes they will have a dense coating of hairs that also help to push water as they swim (Figure 7.22c).

Fossorial

These legs are designed for digging into soil. Part of the leg will be modified to scrape soil. Scarab beetles, mole crickets, and several other families of insects will have a pair of them (Figure 7.22d).

Clasping

These legs have been modified to allow an insect to grasp onto hairs or feathers. They are most associated with lice (Figure 7.22e).

Raptorial

These predatory legs have been modified so that the tibia and femur can close on one another, similarly to a bear trap. Mantises, giant water bugs, and mantis wasps are the insects most commonly associated with these legs (Figure 7.22f).

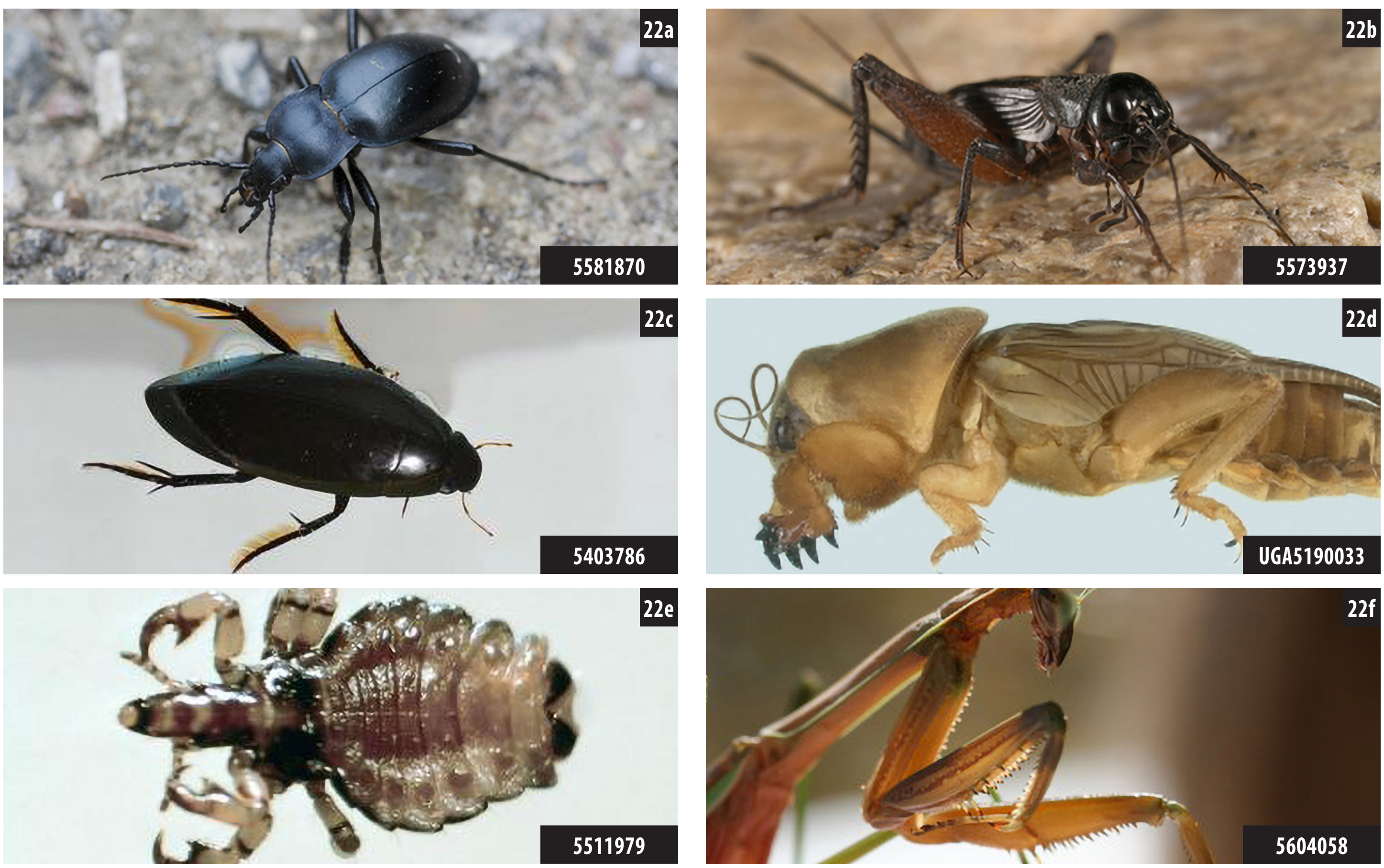


Figure 7.22. Insect legs are suited to the lifestyle of the bug they are attached to.

Insect Wings

Insects are the only invertebrates that have wings. Usually, they are clear and membranous, with noticeable veins inside of them. Some wings have been modified and can be helpful with identification. Lepidopteran wings are coated with scales and are opaque. The front wings of beetles, known as elytra, are hardened and leathery. They help to protect the softer, membranous hind wings.

Not all insects are winged. Some, like silverfish and firebrats, have never had wings. Others, like fleas and bed bugs, once had wings but over time they became greatly reduced, as these insects found other modes of movement and did not need the wings anymore. Only adult insects have wings.

Abdomen

The final body section is the abdomen. It can be made up of eight or more segments. Internally, the abdomen houses many important organs; much of the digestive tract, circulatory system, respiratory system, and nervous system are housed here. Most importantly, the insect reproductive system is in the abdomen. Externally, on female insects, an ovipositor may be noticed on some groups. These are often sword-like or stinger-like. Cerci may also be seen at the tip of some insects' abdomens. Cerci are tactile organs that serve as sort of rear antennae. Some cerci are short (like on cockroaches), while others may be quite long (mayflies). Earwig cerci are hardened and antler-like, helping to separate their order from others.

Insect Development

Insects use internal fertilization to reproduce. After mating, female insects can fertilize their eggs and then will usually lay them outside of the body. Depending on the type of insect, after an egg hatches, the insect will either be a nymph or a larva. Nymphs go through incomplete metamorphosis, and larvae go through complete metamorphosis.

Incomplete Metamorphosis

Also known as hemimetabolous development or gradual metamorphosis, incomplete metamorphosis involves a nymphal stage that looks similar to the adult form, except smaller and lacking wings (Figure 7.23). Gradually, the insect will develop through several nymphal stages, shedding their exoskeleton in between each. Hemiptera, Orthoptera, Mantodea, Blattodae, Dermaptera, and Odonata (amongst others) develop through incomplete metamorphosis.

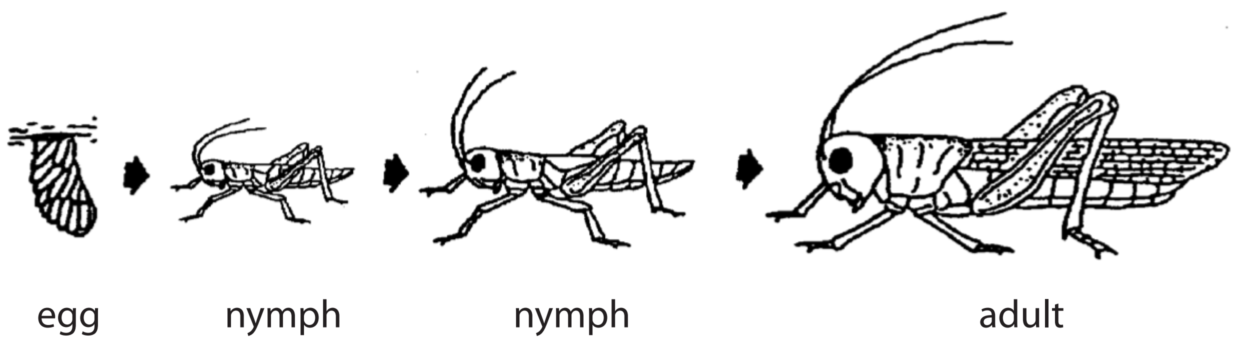


Figure 7.23. Stages of gradual metamorphosis.

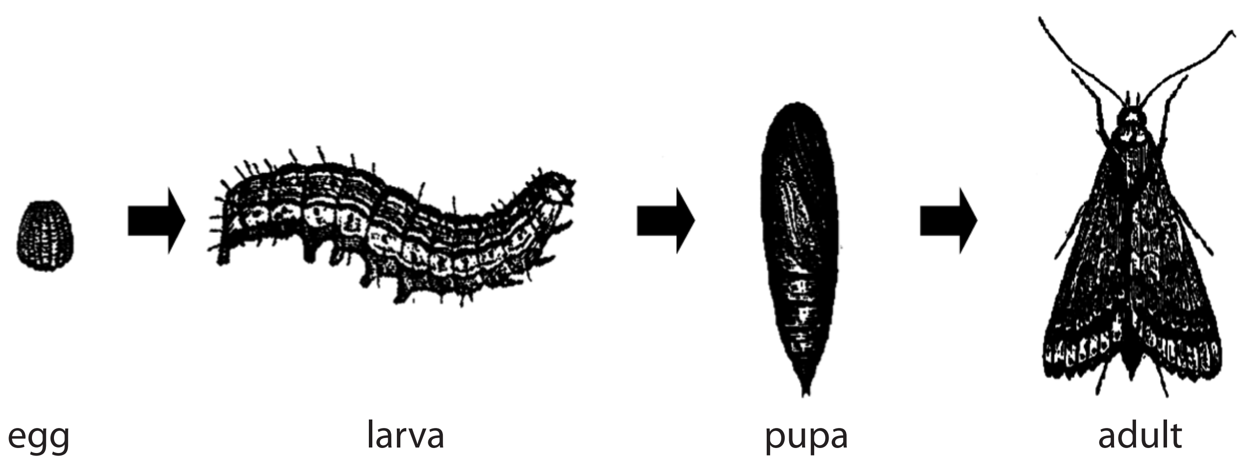


Figure 7.24. Stages of complete metamorphosis.

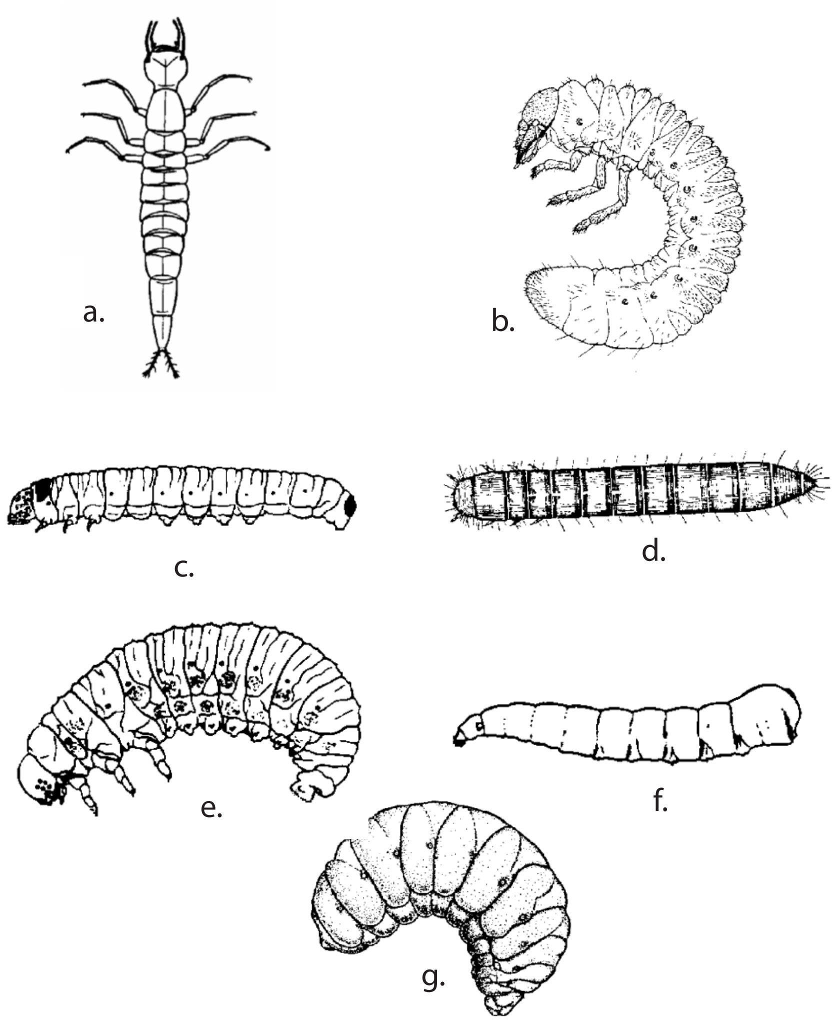


Figure 7.25. Basic larval types.

a. Predator (some beetles, lacewings). Characteristics include a streamlined body with hard exoskeleton, long thin legs, and big, often sharp, jaws at the front of the head.

b. White grub. This type has a distinct yellow-brown head with large jaws and a soft, white, curved body with distinct legs. This type is usually a root feeder, but some larvae of this type live in decaying organic matter. Japanese beetles and green June beetles have this larval type.

c. Caterpillar. This type has a distinct head; a long, cylindrical body with three pairs of segmented legs; and two to five pairs of fleshy legs along the abdomen. This is the larval stage of butterflies and moths. Many caterpillars are striped or brightly colored, but caterpillar larvae that bore in plants are usually white or cream-colored. Sawflies are similar but have fleshy legs on all abdominal segments.

d. Wireworm. This larval type has a round, cylindrical body that is hard and yellow or brown. It has three pairs of short, segmented legs behind the head but no fleshy legs on the abdomen. These larvae may live in the soil and feed on seeds or plant roots; some live in decaying logs. Some beetles have this form.

e. Leaf beetles. This type is similar to caterpillars but has no fleshy legs on the abdomen. Many leaf beetles feed on leaves and are camouflaged by color and markings. Some have white, thinner bodies and live in the soil, where they feed on plant roots.

f. Maggots. This type is headless, legless, soft-bodied, and white or cream-colored. They are the larvae of flies.

g. Legless grubs with distinct heads. Many feed in plants or seeds. Bees and wasps have this type of larva.

Figure 7.25. Stages of complete metamorphosis.

Complete Metamorphosis

Also known as holometabolous development, this is the most common type of metamorphosis that insects go through (Figure 7.24). In this type, the egg will hatch and a larvae will emerge. Larval insects usually look radically different from their adult form (Figure 7.25). Larvae may have special names, such as caterpillars (immature Lepidoptera), grubs (immature Coleoptera), or maggots (immature Diptera). Larvae lack wings and usually feed on different food than the adult form will; for example, caterpillars eat leaves usually, while adult moths consume nectar. Between the larval and adult stages, the insect will pupate. Pupae are an intermediate stage between immature and mature forms. Coleoptera, Diptera, Lepidoptera, Hymenoptera, Neuroptera, and many other orders use this type of development.

Growing Degree Days and Overwintering

Insects generally can't control their own temperature, and their development speed is determined by the temperature around them. Each species has different requirements, but there is usually a temperature they need to reach in order to begin or continue developing. For the insect to move from one stage of life to the next, that temperature needs to be reached or maintained for a certain number of days. We call these "growing degree days," and we can use temperature data to calculate them and predict insect emergence times. Simply put, the cooler the temperatures, the slower they develop, and the warmer it is, the faster they develop.

Winter presents an issue for insects; the cold could mean death, since they can't warm themselves. To deal with this, different types of overwintering strategies have been developed. Some insects will literally leave the cold area and migrate to a warmer location to spend the winter months. The monarch butterfly is a famous example. Some insects, like stink bugs or lady beetles, will stay in the cold location but huddle together in a protected area to avoid cool air temperatures. Other species have timed their development so that they spend the winter as an egg or as a pupa, usually in a protected area. These stages don't require food and don't move, ideal traits in the dead of winter. Finally, some insects can produce antifreeze compounds in their body to prevent full freezing.

Identifying Insect Pests by Damage

While most insects may not be pests, the ones that are can cause considerable damage and can be expensive to manage. There are multiple categories of pests, clustered based on what they are causing damage to.

- Plant Pests: Plant pests may attack crop plants being grown for food or ornamental plants grown for beauty.
- Urban Pests: Insects and other arthropods that enter structures and cause issues can be addressed as urban pests. Some may be structural pests, such as termites, that actually harm the structure itself. Others may be annoyances, such as home-invading ants. Finally, some may be stored-product pests, organisms that will attack foodstuffs in storage and consume them. Indian meal moth is a good example.

Figure 7.26. Chewing damage can look like this skeletonized leaf, where scarabs have consumed the green tissue and left the veins behind.

Figure 7.27. Sucking damage causes leaves to cup and curl, with pests often hiding in the cupped area.

- Health Pests: These pests may be human health hazards or veterinary issues. Fleas, mosquitoes, and bed bugs are common examples that can serve as vectors for disease or cause emotional distress.

For Master Gardeners, the plant pests are usually the insect pests you will deal with most often. These pests attack different parts of the plant, including leaves, flowers, fruit, stems, and roots. As plant pests feed, they often leave behind diagnostic symptoms that can help to deduce what pest you are dealing with.

Chewing Pests

If pests chew on leaves, they can create damage such as skeletonization, where the leafy tissue is consumed and veins are left behind (Figure 7.26); shot hole damage, showing small, irregularly shaped holes in leaves; and complete defoliation, where the leaves are gone or only the midrib is left. Each of these is associated with specific types of pests; scarab beetles tend to skeletonize leaves, shot hole damage is usually caused by flea beetles, and complete defoliation is usually from caterpillars or sawflies.

Sucking Pests

Pests with piercing and sucking mouthparts will pull fluids from the host plant. This can result in droopy, wilted-looking leaves; cupped leaves; leaf yellowing; and early leaf drop (Figure 7.27). Sucking pests also generally produce honeydew, a sticky fecal material found near the population of pests.

Mining and Boring Pests

The mature stages of these plant pests feed inside of part of the host plant. Leafminers create diagnostic mines in the leaves of host plants. These tunnels can be noticed from the outside. There are three types: serpentine mines, blotch mines, and linear blotch mines. The shape, paired with the host plant name, will usually reveal what species is the problem. Wood-boring pests can create distinctive piles of frass on the outside of infested trees or leave behind diagnostic exit holes when they emerge as adults.

Gall Makers

These insects use secretions to induce the larval host plant to form a "home" around the immature insects. These galls come in different shapes and sizes; some look like small fingers, and others like apples. They can appear on leaves or stems. Usually, they present no hazard to the plant.

Aside from these direct feeding or damage issues, some insects serve as plant pathogen vectors as well. This is similar to human health pests: the insect picks up a pathogen from one host plant and then moves it to another host plant, proliferating the disease. Sucking pests, such as aphids, thrips, planthoppers, leafhoppers, and mites, are most commonly associated with disease vectoring, though some specific bark beetles may also serve as vectors.

Insect plant-disease vectors may have pathogens on their bodies or inside their mouthparts, prompting transmission. Some may indirectly spread disease by damaging the plant and creating a wound that a pathogen will enter to infect the host plant. Others may purposefully move fungal pathogens from tree to tree in order to grow them and consume them.

Abbreviated Guide to Pest Management on Plants

Management of plant pests should be done through an integrated pest management (IPM) approach (See Chapter 10, Integrated Pest Management, for more information). This means thinking about ways to utilize all of the tools for pest suppression that are available, rather than relying on any one kind of management method.

- Pest problems can be prevented somewhat by making sure that the right plant is put in the right place. Choosing species or varieties not adapted for Kentucky can lead to higher stress for the plant, reducing defense and making the plant more attractive to arthropod pests. Further, when planting, consider selecting varieties that are pest resistant.
- Avoiding monocultures when planting creates more diversity for the landscape and can also help minimize pest populations. Diverse plants can also mean more natural enemies, such as predaceous insects, in the landscape.
- Using good cultural practices such as sanitation of gardens in the fall can help by removing overwintering habitat for pests like squash bugs. Sanitation can also include the removal and destruction of diseased or heavily infested plants. Other cultural practices include proper watering, fertilization, and pruning.
- Monitoring for pests by observing plants in the landscape, regular sampling, or setting out traps can alert us to when pest populations are rising and becoming a problem before severe damage has occurred. Monitoring also allows for pest identification, which can help to provide more specific pest management solutions.
- Natural enemy populations help to suppress but not eliminate pests. Adjusting expectations for the landscape from perfection to a more natural equilibrium allows for beneficial predators and parasitoids to exist and function in a healthier ecosystem.
- Insecticides can be deployed for pest outbreaks or for issues with invasive species that don't have a natural solution. Organic and biorational products can be sprayed, hopefully with less impact on non-target organisms such as pollinating insects.

By following an integrated approach, growers can reduce reliance on insecticides and keep themselves and the environment healthy.

Other Resources to Consider:

Books

Garden Insects of North America by Whitney Cranshaw
Tracks and Signs of Insects and Other Invertebrates by Charney and Eisman

Web Resources

Kentucky Pest News
https://kentuckypestnews.wordpress.com/
University of Kentucky Department of Entomology Factsheets
https://entomology.ca.uky.edu/entfacts

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Joseph Berger—Table 7.1: Geniculate, Figures 7.4, 7.13, 7.21b, 7.22b, 7.22c
David Cappert—Table 7.1: Lamellate, Figures 7.6, 7.12, 7.21a
Mohammed El Damir—Figure 7.17
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Pest and Diseases Image Library— Table 7.1: Aristate, Figure 7.20
California Polytechnic State University at San Luis Obispo
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Colorado State University
Whitney Cranshaw, Bugwood.org—Figures 7.8, 7.14
University of Georgia
Russ Ottens, Bugwood.org— Table 7.1: Capitate
Rebekah D. Wallace, Bugwood.org—Table 7.1: Setaceous, Plumose
Harvard University
Gary Alpert, Bugwood.org— Table 7.1: Clavate, Figures 7.3, 7.10, 7.11
South Carolina Department of Natural Resources
Allen Bridgman, Bugwood.org—Figure 7.9
USDA APHIS PPQ
Quin Bayne, Sawfly GenUS, Bugwood.org—Table 7.1: Pectinate
Tevan Brady, Exotic Bee ID, Bugwood.org—Figure 7.19
USDA Cooperative Extension Slide Series
Clemson University, Bugwood.org—Figures 7.15, 7.26
USDA Forest Service
Southern Research Station, Bugwood.org—Figure 7.7
US Geological Survey
USGS, Bugwood.org—Figure 7.2
William Fisher Photography
William Fisher, Bugwood.org—Table 7.1: Serrate

Chapter 08
Weed Management

By Chip Bubl, Extension agent, Columbia County, Oregon State University. Adapted by J.D. Green, Extension weed specialist, University of Kentucky.

In this chapter:

Every garden has weeds, and every gardener wonders what to do about them. Gardening involves lots of small decisions that can have a cumulative effect on those weed problems. This chapter will explore the origin of weeds, their adaptation and impact, and the techniques you can use to manage weeds in your landscape.

Understanding Weeds

To control weeds, you first need to understand them and be able to identify them.

Why Are Weeds a Problem?

The plants we call weeds are often aggressive, persistent plants—they are not shrinking violets. Weeds do have some redeeming qualities, but these qualities are often overwhelmed by the plants' "weedy" attributes.

The most useful definition of a weed is that it is a plant that is a hazard, nuisance, or causes injury to people, animals, or a desirable crop. A plant may be defined as a weed in some cases but not in others. For example, clover can be a valuable addition to a pasture and is tolerated in many lawns. But if you are a park manager faced with reducing liability due to bee stings, you may feel compelled to remove clover in some parts of the park. Another example is maple seeds. When they sprout in an herbaceous perennial flower bed, they are weeds, but they may well have come from trees that are part of the planted landscape.

Weeds can cause a range of problems in your garden or community, including the following:

- Competing with desirable crops
- Reducing the aesthetic qualities of a landscape
- Obstructing sight lines on roadways
- Interfering with water drainage from roads and low-lying communities
- Creating a fire hazard along railways and next to power substations
- Presenting allergy or poison hazards for humans or animals (through skin contact, ingestion, or inhalation)
- Harboring diseases, rodents, and insect pests
- Imparting off-flavors to water

Why Do We Have Weeds?

People have been cultivating plants for almost 10,000 years. When the first agriculturists tilled ground, planted seeds, and irrigated, they created an artificial environment that favored crops. They also selected and bred certain plants to improve the plants' food, fiber, or medicinal characteristics. The very practices that favored growth of these earliest crops inadvertently encouraged other plants that also liked plowed soil. Many of these plants became very aggressive competitors on farms and in gardens.

As agricultural practices and products spread, plants we now call weeds extended their range. Native plants that liked tilled ground joined the weed inventory and moved well beyond their original habitats. It is amazing how many of "our" weeds are equally well known in Asia, Europe, Africa, and South America. Table 8.1 shows the original home of some common weeds.

Many weeds traveled the world in feed and seed, on equipment, in ships' ballast, or in the bellies of domesticated animals. In addition, many plants that once had value as food, fiber, medicine, or ornamentals remained to become a nuisance long after their usefulness had diminished. Once weeds get a

Table 8.1. Origin of several common weeds.

Weed species	Origin
Canada thistle	Eurasia
Pigweed	Tropical Americas
Field bindweed	Europe
Common purslane	Western Asia
Common chickweed	Europe
Dandelion	Europe
Quackgrass	Mediterranean
Barnyardgrass	Eurasia
Crabgrass	Europe
Poison ivy	Native
Johnsongrass	Mediterranean
Common lambsquarters	Eurasia
Musk thistle	Eurasia
Yellow foxtail	Europe
Trumpet creeper	Native
Morningglory	Tropical Americas

foothold in a new area, they spread by wind, water, animals, in trade goods, and in equipment.

Plants that might be tame in their native landscape can become nasty when moved to new locations. The new environment might suit them better, or they might have left their natural enemies behind. Kudzu was originally introduced to help stabilize steep slopes and prevent erosion. It now grows uncontrolled in much of the southern United States and has become established in several Kentucky counties, where it is unsightly and chokes out native vegetation. Purple loosestrife was originally planted as a pond ornamental, but now it aggressively competes with native vegetation in wetland areas.

Nations establish quarantines to exclude new weed species. State departments of agriculture designate some weeds as noxious and implement programs to restrict their spread. There may be specific requirements for control of certain noxious weeds in some locations.

Once weedy species are established in a region, it is virtually impossible to eradicate or remove them completely. Instead, gardeners must live with them and work to lessen their negative impact. Various techniques offer a range of options to achieve that goal.

Weed Identification

If you can accurately identify a plant that is causing problems in your landscape, you have taken the first step toward good management. Fortunately, most problems are caused by a surprisingly short list of weeds. Often, a little time spent with a good reference (see "For More Information" section at the end of this chapter) will help you put a name to some of the challenging plants you encounter. You may find it helpful to give some of your worst weeds specific nonsense names until you get a more accurate identification. Then, it will be easy to mesh your new knowledge with your old identification.

Weed books usually first classify plants into two groups and a miscellaneous category:

- *Monocots* (Figure 8.1) include grasses, lilies, and the like.
- *Dicots* (Figure 8.2) are broadleaf species.
- "Other" weeds include mosses, horsetails, and ferns.

Plants are further subdivided within each major category by *family*—for example, the buckwheat, rose, and borage families. Within these family groupings are the *genera*, and within the genera are the *species*.

Scientific (botanical) names are in Latin and include the genus name followed by the species name. For example, common dandelion is known as *Taraxacum officinale*. The scientific name is used worldwide and eliminates the confusion caused when the same common name refers to several plants.

You don't have to be a botanical expert to work through a weed identification book, although it does help to learn some of the key characteristics of the major families.

Once you know a plant, you can gather important details about its life cycle and how it spreads within the landscape or garden. With practice, you can learn to distinguish weed seedlings from your planted vegetables and flowers.

Figure 8.1. Examples of monocots: bermudagrass *(Cynodon dactylon)*, crabgrass *(Digitaria* spp.*)*, and nimblewill *(Muhlenbergia schreberi* J.F. Gmel.*)*.

Table 8.2. Weeds classified by life cycle.

Annuals	**Common name**	**Botanical name**
Grass weeds	Annual bluegrass	*Poa annua*
	Barnyardgrass	*Echinochloa crus-galli*
	Crabgrass	*Digitaria sanguinalis*
	Yellow foxtail	*Steria glauca*
Broadleaf weeds	Annual sowthistle	*Sonchus oleraceus*
	Birdsrape mustard	*Brassica rapa*
	Carolina geranium	*Geranium carolinianum*
	Catchweed bedstraw	*Galium aparine*
	Common chickweed	*Stellaria media*
	Common lambsquarters	*Chenopodium album*
	Common mallow	*Malva neglecta*
	Common purslane	*Portulaca oleracea*
	Common ragweed	*Ambrosia artemisiifolia*
	Cressleaf groundsel	*Senecio glabellus*
	Hairy bittercress	*Cardamine hirsuta*
	Ladysthumb	*Polygonum persicaria*
	Mayweed chamomile	*Anthemis cotula*
	Nodding spurge	*Euphorbia nutans*
	Pineapple weed	*Matricaria matricarioides*
	Prostrate knotweed	*Polygonum aviculare*
	Shepherdspurse	*Capsella bursa-pastoris*
	Smooth pigweed	*Amaranthus hybridus*
Biennials	**Common name**	**Botanical name**
Broadleaf weeds	Bull thistle	*Cirsium vulgare*
	Common mullein	*Verbascum thapsus*
	Musk thistle	*Carduus nutans*
	Prickly lettuce	*Lactuca serrioia*
	Teasel	*Dipsacus sylvestris*
	Wild carrot (Queen Anne's lace)	*Daucus carota*
Perennials	**Common name**	**Botanical name**
Grass weeds	Bermudagrass	*Cynodon dactylon*
	Johnsongrass	*Sorghum halepense*
	Quackgrass	*Elytrigia repens*
	Velvetgrass	*Holcus lanatus*
Broadleaf weeds	Blackberry	*Rubus spp.*
	Buckhorn plantain	*Plantago lanceolata*
	Canada thistle	*Cirsium arvense*
	Creeping buttercup	*Ranunculus repens*
	Curly dock	*Rumex crispus*
	Dandelion	*Taraxacum officinale*
	Field bindweed	*Convolvulus arvensis*
	Hedge bindweed	*Calystegia sepium*
	Oxalis (woodsorrel)	*Oxalis corniculatus*
	Poison ivy	*Toxicodendron radicans*
	Red sorrel	*Rumex acetosella*
Others	**Common name**	**Botanical name**
	Horsetail	*Equisetum arvense*
	Star-of-Bethlehem	*Ornithogalum umbellatum*
	Wild garlic	*Allium vineale*
	Yellow nutsedge	*Cyperus esculentus*

Note: This list is not exhaustive, but it does include many of the most common weeds that gardeners should recognize.

Figure 8.2. Wild violet *(Viola* sp.*)*, an example of a dicot.

Figure 8.3. Common chickweed, an example of an annual weed.

Weed Life Cycles

Most gardens have a mix of annual and perennial weeds, plus a few biennials. When you understand the life cycle of troublesome weeds, you can begin to make intelligent decisions about control strategies. Later sections of this chapter examine some of those strategies. Table 8.2 lists some of our worst weeds by common and botanical names and their life cycles.

Types of Weeds

Weeds include annuals, biennials, and perennials.

Annuals

Annuals go from seed to seed in less than a year, often in periods as short as 45 days. Once they have thrown off their usually vast quantities of seed, the plants die. As you might suspect, annual weeds are numerous because their growth habit parallels our agricultural cropping pattern.

Annual weeds can be found in both winter and summer.

Winter annuals germinate in late fall through early spring and go to seed in spring and early summer. Some common examples include hairy bittercress, henbit, several mustards, annual bluegrass, and common chickweed (Figure 8.3). Clearly, the cooler temperatures and lower light intensity of winter are not an obstacle to these weeds. They prosper when other competitive weeds and plants are absent. A few winter annuals, especially common groundsel, seem to germinate in flushes throughout the year.

Summer annuals get started in the spring and summer and go to seed in the summer and fall. Many of our most annoying weeds are in this group, including crabgrass, pigweed, purslane, and lambsquarters. Most summer annuals germinate quickly, ahead of many flower and vegetable seeds. Others do not germinate until May or June and then grow aggressively and complete their life cycle without delay.

As discussed below, annuals have sophisticated mechanisms to ensure good year-to-year seed survival.

Biennials

Biennial species are less common. They take more than one year but less than two to complete their life cycle. Most start from seed in the fall or spring and grow through the summer, fall, winter, and next spring. They overwinter as *rosettes*. In the second summer, biennials flower and die. Examples include wild carrot (Queen Anne's lace), bull thistle, and musk thistle (Figure 8.4).

Perennials

These weeds often are the most difficult to manage. *Woody* species generally go dormant in the winter and begin growth in spring from aboveground stems. Aboveground parts of *herbaceous* perennials may die back, but their underground storage organs survive the winter. Many are deep rooted and continue to grow during summer droughts. The life span of perennials varies. They spread from seed and often from creeping roots, tubers, bulbs, and rhizomes. Tilling of perennial weeds often spreads them, and mulches may have little impact. Weeds in this group include quackgrass, poison ivy, Canada thistle, horsetail, and field bindweed (Figure 8.5).

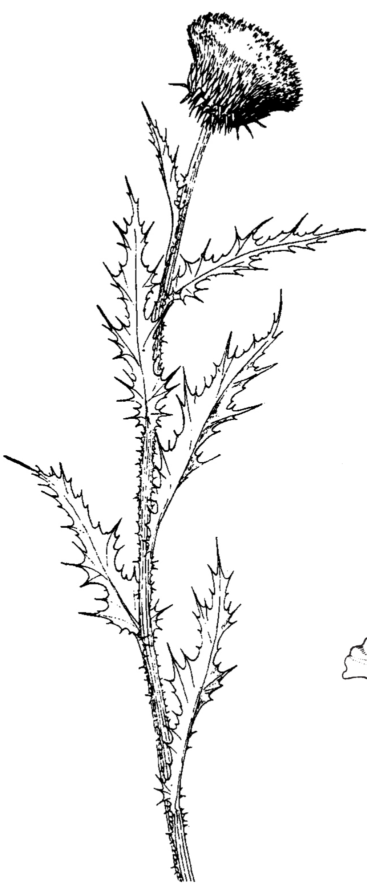


Figure 8.4. Musk thistle, an example of a biennial weed.

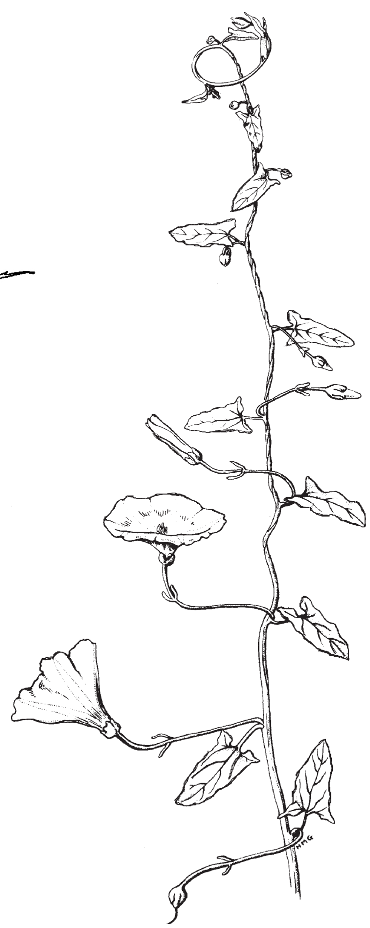


Figure 8.5. Field bindweed *(Convolvulus arvensis),* an example of a perennial weed.

Weeds and Your Landscape

Weeds can disturb the appearance of a landscape. Most garden soils contain a lot more weed seeds than the vegetable or flower seeds you plant. Studies on commercial vegetable farms show that viable weed seed populations in the top six inches of soil average 900 per square foot, with some fields having more than 7,000 viable seeds per square foot!

What is worse, weed seeds germinate very quickly when the ground is tilled. Two weeks after planting, it may be very difficult to find your flowers and vegetables amid all the weeds. Some poorly tended gardens may end up with 10 to 20 times more weight in weeds than in desired plants.

Weed Competition

Weeds compete directly with garden plants for light, nutrients, and water. A successful weed grows aggressively to capture whatever resource is in shortest supply. Crop plants may end up stunted and unable to produce a normal product. Paired test plots of vegetables that were either weeded or left untouched provide some eye-opening results (Table 8.3).

Research in England showed that a delay in weeding could reduce final yield by 3 percent per day, depending on the crop, weed species, and weed density. Some plants (onions, for example) need a certain leaf area to produce a marketable crop, while others (e.g., potatoes and artichokes) can send up new leaves and recover to produce a near-normal yield if weeds are removed early enough.

Some characteristics that help weeds compete include the following:

- Aggressive vegetative growth from seeds
- Abundant and rapid reproduction
- Good means of dispersing seeds
- Long-lived seeds and other plant parts
- Wide adaptability to soil types and climates
- Ability to time germination to coincide with favorable conditions
- Ability to thrive in disturbed or bare soil

Table 8.3. Vegetable yields in weeded and unweeded plots.[1]

	Yield (lb)	
Crop	**Weedy**	**Nonweedy**
Carrots	27.9	503.3
Beets	45.9	240.3
Cabbage	129.1	233.6
Onions	3.6	67.7
Tomatoes	23.2	164.2
Potatoes	52.7	148.3

1 Plot sizes not specified, but weedy and nonweedy plots were equal in size. With the exception of weed management, both plots were treated the same.

Rapid Root and Top Growth

Weeds grow quickly to capture sunlight, water, space, and nutrients. They often can alter their branching pattern, leaf size, and leaf orientation to win the battle for light. In soil short of moisture, weeds' root growth can stunt crop roots.

Sophisticated Reproductive Strategies

Not only do weeds produce tremendous numbers of seeds, but they also have ways to prevent all of their seeds from germinating during years with less favorable weather. Seeds can be buried in undisturbed soil for an amazing length of time and still germinate. Lotus seed in Manchurian lakebeds has germinated 1,000 years after the seed was produced. Common lambsquarters seed from Egyptian tombs also has been viable after many years. Table 8.4 shows weed seed production and survival rates. These survival rates are under optimal conditions, and most weed seeds are nowhere near these rates. Nevertheless, as the saying goes, one year of weeds leads to seven years of hoeing.

Chemical Warfare between Plants

Some weeds produce compounds in their leaves and/or roots that can kill or harm other plants. This phenomenon is called *allelopathy*. The compounds aren't effective on all the species with which a particular weed might be competing, but they at least can improve the weed's odds. Some weeds that have allelopathic qualities include quackgrass, Canada thistle, pigweed, kochia, purslane, and smartweed.

Managing Weeds

Weeds are part of the dynamic and shifting garden landscape. As discussed earlier, many weeds are especially adapted to a cultivated environment. A gardener should plan for weeds. It is possible to develop a fairly comprehensive weed management strategy that takes into account landscape objectives, weeds already present, available tools, and personal gardening philosophy.

Table 8.4. Weed seed production and seed survival in soil.

Weed species	Seeds per plant	Seed survival (yrs)
Spotted knapweed	1,100	7–10
Lambsquarters	72,450	40
Purslane	52,300	40
Dandelion	15,000	6
Pennsylvania smartweed	19,300	30
Canada thistle (per stem)	680	21
Pigweed	117,400	10
Barnyardgrass	7,160	3
Crabgrass	25,000	3

Note: Seed survival means that some viable seed remains. Generally, however, most seeds germinate or lose viability within three to 10 years or less, depending on soil conditions. A few, however, will hang on to aggravate future gardeners.

In the broadest sense, weed management has the following three objectives:

- Preventing introduction of new weeds
- Discouraging weeds so they can't compete with desired plants
- Preventing weeds from going to seed, thus reducing over time the weed seed burden in the soil

Prevention

Most garden soils already have many weeds, and other weed seeds can be blown in, but the alert gardener can take some steps to prevent introduction of new weeds. Examine any soil you plan to bring to your lot. Pay particular attention to the presence of Johnsongrass, Canada thistle, and Star-of-Bethlehem, which will cause years of agony if found in your landscape (Figure 8.6).

Watch container plants from nurseries, garden exchanges, and plant sales. They can be a source of several tough plants, particularly *Oxalis*, buttercups and the weedy veronicas. Remove any sign of these plants before placing new trees, shrubs, or flowers in your landscape.

Finally, cultivate a relationship with your neighbors that allows for a coordinated approach to creeping perennial weeds such as field bindweed, English ivy, blackberries, and Japanese knotweed.

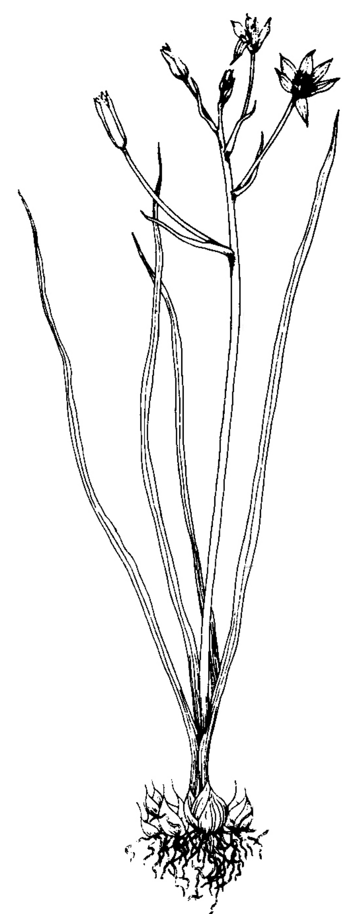


Figure 8.6. Star-of-Bethlehem *(Ornithogalum umbellatum)*.

Cultural and Mechanical Control

You can manipulate the landscape in ways that reduce weed success if you work from the premise that weeds thrive in disturbed ground. Cultural and mechanical control methods can help you reduce the impact and spread of weeds without herbicides.

Several are discussed in this section.

Rotation

Rotating vegetable crops can reduce weed infestations. Noncompetitive crops such as carrots and onions should follow more aggressive vegetables such as winter squash or corn. *Fallowing* (keeping part of the garden clean-tilled or in a summer cover crop) can help reduce weed problems for the next season.

Solarization is a way to reduce weed- and disease-infested garden areas. In July, thoroughly till and moisten the soil. Stretch clear plastic over the soil as tightly as possible. The heat captured under the plastic steams the soil, killing many weed roots and seeds. Leave the plastic on through August. The area can be planted in the fall or the following spring.

Weeding

Cultivating soil to control weeds has been practiced for thousands of years. Agricultural yields improved tremendously when cultivating equipment became widely available. Tilling and hand pulling normally are gardeners' first weapons in the weed wars.

Advantages—A germinating weed is very vulnerable to root disturbance from hoeing, hand pulling, or rototilling. It also helps break up soil crusts that may limit vegetable or flower seedling growth.

Disadvantages—Mechanical weed removal must be done early and often to be effective. Cultivating perennial weeds can spread reproductive underground portions of the plants, causing more weeds to grow, and tilling brings new weed seeds to the surface. Also, excessive cultivation destroys soil tilth and causes compaction.

When tilling, take care not to damage your plants' roots. For example, it generally is unwise to hoe close to shallow-rooted rhododendrons and blueberries.

Remember that some plant compounds are toxic to the skin. You should wear gloves when hand weeding. Also, a sharpened hoe makes for more effective weeding.

Bed Planting

Planted beds are areas designed with untilled areas between them. Soil working is reduced, and mulches are used extensively. Flower or vegetable crops often are planted close together to compete against weeds. Shading is effective in preventing some weed species from germinating. Transplants are used extensively.

Advantages—Less weed seeds are brought to the surface. Leaving untilled areas (either in sod or heavily mulched) also reduces the area that needs to be managed for weeds.

Disadvantages—Most of the tilling and weeding must be done by hand. Some gardeners plant too closely and crops are stunted, much as with weed competition.

Using Transplants

Transplants can be one of the best weed management strategies. Vegetables or flowers can be started in a cold frame or greenhouse and set out into the freshly worked garden.

Advantages—The transplant has a head start against germinating weed seeds and, if it is managed well in the transplanting process, it should effectively compete against many weeds.

Disadvantages—It takes time to produce transplants or money to buy them, and not all plants transplant well.

Mulches

Mulching should be part of any landscape planting because of the weed suppression it provides. When bare soil is covered, many weed seeds either won't germinate or can't grow through mulch.

Mulch materials may be organic (such as shredded bark or leaves, pine needles, compost, or newspapers) or synthetic (such as plastic or landscape fabrics). They can be applied in both winter and summer for year-round weed control. Mulch materials may be home generated or purchased, but purchased materials can be somewhat expensive.

Advantages—If used effectively, mulches significantly reduce time spent pulling weeds. Fewer weed seeds are brought to the surface than with hoeing or rototilling. Mulching correctly can cool the soil and help manage soil moisture. Plastic mulches can work well on well-drained and aerated soils and around some deep-rooted trees and shrubs.

Disadvantages—If organic mulches are applied in a layer of six or more inches, they may produce acids that can hurt plants. Plastic mulches can create a zone of lifeless soil that often leads to root disease due to their inability to "breathe" around shallow-rooted species, such as rhododendrons. Weed seeds can blow in and germinate in the organic mulch covering generally used over synthetic mulches to improve their appearance, thus reducing weed control. Plastic and landscape fabrics can give shelter to mice (voles) or rats.

Choosing the Right Mulch

Which mulch will work best depends on your landscape.

Woody landscapes—Twice-yearly applications of organic mulches such as bark go a long way toward reducing weed problems. As the material decays, it improves soil tilth and aeration around landscape plants. Fall applications of mulch can reduce winter and spring weed problems.

In general, plastic mulch is not the best choice for woody landscape beds.

Landscape fabrics are better than plastic mulches in a woody landscape bed, since water and air can pass through them. Laminated fabrics are more expensive, but they are porous, wick water through the fiber, and prevent roots from penetrating. When choosing a fabric, make sure it cannot be broken or stretched with your finger. Easily perforated fabrics are not effective.

Annual gardens—Plastic mulch does have a place in annual vegetable and flower gardens. It usually is used along with drip irrigation and bed planting. Make slits in the plastic, then place transplants in the slits next to the water source. Add fertilizer to the soil before transplanting or later through the irrigation system. Dispose of the plastic after the growing season.

Black plastic is preferred for weed control because it reduces light to the soil, thus preventing weed growth. Clear plastic sometimes is used where weeds are few, since it warms the soil faster than black plastic but does not control weeds. Be sure to stretch the plastic tightly over the soil surface to get the benefits of soil warming as well as weed control.

Landscape fabrics can be used in the same way as plastic. Since they allow moisture to pass through, they don't require a drip system. However, they are thicker than plastic and tend to cool the soil instead of warming it. This cooling can be a problem for crops such as tomatoes, peppers, and melons, which require very warm soil.

For most vegetable and flower gardens, organic mulches are the best choice, because they tend to improve the soil as they break down. In the summer, many gardeners use organic mulches to conserve moisture and control weeds. It is best to apply these mulches around heat-loving plants such as peppers after the soil is warm.

Winter organic mulches can be pulled back or tilled in before planting in the spring.

Organic mulches can cause nitrogen deficiency as they decompose, and leaves from a few trees can inhibit growth of some plants and seeds if they are part of organic mulches. Walnut trees are one example.

Effect of Water Management and Irrigation

Weeds need water to germinate and grow. When a garden is irrigated with sprinklers, the entire area is usually watered and must be weeded. When water is directed only to desired plants, such as with drip irrigation, much of the garden stays dry, so that in those drier areas, weed problems are much reduced. Drip systems are excellent tools for reducing weed growth. They are often combined with bed planting and/or plastic mulches in vegetable and annual flower plots to control weed growth.

Advantages—They are fairly easy to set up, and they have come down in cost.

Disadvantages—Despite improvements and reduced cost, drip systems still can be costly to install and complicated to maintain. In some cases, they might not provide an adequate moisture zone for desirable plants.

Competitive Plantings of Groundcovers, Herbaceous Perennials

In permanent landscapes, it often is best to eliminate bare areas under trees and shrubs by planting them with groundcovers or herbaceous perennials. Many species do well as understory plants and can provide both foliage and flowers (e.g., hostas, ferns, and daylilies).

For lawns, more tolerant gardeners now can choose mixes that include certain broadleaves (e.g., yarrow) with good lawn character. These mixes tend to repel some of the weedier broadleaf species.

Use caution when selecting groundcovers for these areas. Some plants, such as creeping euonymus (winter creeper), English ivy, and periwinkle (vinca minor), can become weedy escapees.

Advantages—The landscape can be more visually interesting, and over time, the need for weeding is reduced.

Disadvantages—Establishing plants can be costly. Herbaceous perennial weeds such as Canada thistle, bindweed, and quackgrass can cause problems. Some shallow-rooted plants, such as rhododendrons, don't like aggressive understory plantings. Lawns planted in both grass and broadleaf species do not look exactly like traditional lawns. Also, they may not tolerate the herbicides usually recommended to get rid of undesirable plants.

Cover Crops

Cover crops are generally grown in winter on annual vegetable and flower beds. Fast-growing crops such as winter grains are the most competitive with weeds. The cover crop may be a winter-hardy grain, a legume, or a combination of both. Cover crops are by no means 100 percent successful in weed suppression, so there may be some weeds to contend with.

Advantages—Cover crops smother winter weed growth. They capture excess fertilizer, improve soil tilth, and when turned under, increase organic matter. They are also generally inexpensive. In warm areas, some cover crops can be cut and left on the surface as a weed-suppressing mulch during the growing season, and some crops, such as tomatoes, can be transplanted through the residue. The residue enhances the environment for beneficial soil insects.

Disadvantages—Gardeners in most areas have to till in the cover crop before they can plant a spring/summer garden, which can delay planting in a wet spring. Rye grain used as a cover crop might reduce germination of some small-seeded vegetables such as lettuce. Also, slugs and other insects may prosper if the residue isn't turned under.

Chemical Control

Herbicides are another tool for managing weeds. The extent to which you choose to use them depends on your personal philosophy, garden objectives, and particular weed problems. Herbicides may have a place in your garden or landscape areas, but you should always know what the alternatives are and what makes the most sense given your situation.

All herbicides have detailed label instructions on mixing, application timing, weeds controlled, plants around which they can be used, and other significant issues concerning their safe and effective use. The label is the legal document administered by the EPA that defines the use of a product and your responsibilities as a consumer. It is crucial that you read the instructions on the label before you purchase a product and follow them as you mix and apply it.

Herbicides control weeds by interfering with critical plant functions, thus resulting in the death of plants. Not all herbicides act in the same manner.

You need to understand some important terms and concepts before purchasing and applying herbicides.

Selective and Nonselective

A *selective* herbicide controls certain plants and not others. For example, many lawn herbicides control broadleaf plants, such as dandelions, without damaging grasses. A few products control some (though not all) weedy grasses without harming turf. Other selective herbicides affect germinating seeds and sprouting herbaceous plants but not established woody trees and shrubs. A handful of products control grasses without damaging broadleaf species.

If an herbicide is selective, the label will provide extensive information about plants around which it can safely be used and weeds and plants it is likely to affect. In addition, there will be instructions on when to use the herbicide to obtain desired results and avoid problems.

Nonselective herbicides can potentially damage any type of plant. Some last a long time, having a residual effect; others do not. The label details how the herbicide acts.

It is important to remember that some products may be selective at certain rates but lose that selectivity as the amount of herbicide applied increases.

Systemic and Nonsystemic

Most herbicides are *systemic*, which means they circulate from the point of initial absorption to other parts of the plant to have their effect. They may be sprayed on the leaves and move to the roots or vice versa.

Nonsystemic or *contact* herbicides affect only the part of the plant they touch. When a contact product is sprayed on leaves, it generally kills those leaves but does not travel to the root system. They may control young annual or biennial weeds, but while they may cause established perennial weeds to lose leaves, the weeds will resprout. Very few contact products are available for home landscapes or gardens.

Foliar-active and soil-active

Herbicides also are classified by the way they move into plants. Many common products are *foliar-active*, meaning they enter through leaves. For example, glyphosate (e.g., Roundup) must enter through green tissue. If this product is applied to bare soil, it has no effect on germinating seeds. Also, glyphosate cannot be picked up by roots in most soils.

Soil-active products are absorbed through roots or through the growing tips of germinating seeds.

A number of products are both soil-active and foliar-active, although one absorption route is usually more important. Again, the label will describe how to apply the herbicide.

Preemergent and postemergent

Finally, it is important to know when to use an herbicide relative to the growth of the weeds and the crop. A *preemergent* herbicide is applied before weeds sprout. The desirable plants (landscape trees and shrubs, vegetables, flowers, bulbs, etc.) may or may not be present. Careful label reading is important!

A *postemergent* product is used after weeds are up and actively growing. Selectivity of postemergent herbicides may depend on crop age, application rate, or other factors. It's important to understand application timing as it relates to both weed and crop growth. Again, read and follow the label.

Herbicide interactions

Herbicide results are influenced by a number of factors. A plant with a waxy leaf (such as poison ivy) or a hairy leaf (such as stinging nettle) may not absorb an herbicide as well as a plant with a smooth leaf. Likewise, a plant with narrow, upright leaves may be hard to cover adequately with a spray mixture, or a weed's growing point may be protected under the soil surface.

Environmental conditions can affect an herbicide, rendering it useless against the target plant or causing unintended damage to nontarget plants. In general, as temperature increases, herbicides work more effectively.

Some herbicides can become volatile (gaseous) at certain temperatures. For example, some formulations of 2,4-D and some of its related chemistries can volatize off leaves shortly after application if temperatures climb into the mid-80s. Since small amounts of this herbicide can visibly distort sensitive plants, high temperatures and high humidity combined with a little wind can cause serious problems in your own or neighboring landscape areas and surrounding gardens.

Wind drift by itself can be a problem when using any herbicide. As you pump a sprayer, the pressure increases, which in turn creates a smaller spray droplet. The smaller the droplet, the more likely it is to become airborne and move away from where you want it to land. Again, this drift can cause unintended consequences and problems for neighborhood landscapes.

Moisture in modest quantities is needed to move soil-applied herbicides such as pendimethalin into the soil. However, if a downpour occurs shortly after a soil-applied herbicide is applied, the chemical may wash downslope instead of entering the soil. This runoff can damage lawns or other plants in its path. When you use foliar chemicals, there must be enough time between application and rain to allow the plant to absorb the herbicide. Eight hours of dry weather is normally enough.

While eight hours is ideal, significant plant damage can occur in considerably less time. There are many stories of misapplying herbicides and then trying to wash them off, only to find that the plant was already damaged.

Sometimes, herbicides work poorly in dry weather. Drought-stressed plants conserve water by reducing transpiration through leaves. In this condition, they are less able to absorb herbicides. Several systemic products have specific statements on the label about their reduced effectiveness when plants are drought stressed.

Specific herbicides

Always read the label to determine whether or not the application site is appropriate for the product considered for use. Many of the herbicides listed below are not labeled for use in vegetable gardens.

Note: All herbicides listed may not be available in your area or suitable for your situation. Consult with your local Extension agent for current herbicides recommended for use in Kentucky.

2,4-D—This systemic, foliar, postemergent herbicide affects broadleaves, especially herbaceous annuals, biennials, and perennials. It is a common component in lawn products, since it doesn't damage established grass. It is sold under numerous trade names and is often combined with other closely related chemicals—mecoprop (MCPP), dichlorprop (2,4-DP) and/or dicamba—to broaden the spectrum of weed control.

Glyphosate—Glyphosate is a systemic, nonselective, foliage-applied herbicide. It potentially affects any plant with which it comes in contact. Glyphosate is absorbed through leaves, green bark (usually a very young tree or shrub), or freshly cut stems. The chemistry of glyphosate is such that it becomes tied up on soil particles. Little chance exists that glyphosate can be picked up by roots unless they are somehow exposed to it.

Glyphosate tends to follow the flow of sugars in plants. If it is applied to an actively growing woody plant, the chemical tends to move to the new leaves (where the sugars are headed) and stunt the terminal growth. In that circumstance, it may not move to the root system in sufficient quantities, and the plant survives. Thus, it is best used on perennial plants as they begin flowering or in the fall as they start storing sugars for winter.

Glyphosate can be used on some grasses almost any time they are green and on annuals when they are actively growing. It works faster (in seven to 10 days) in warm weather. It also can be effective in colder weather, but results might not be evident for a month or more. It is sold under several brand names.

Triclopyr—This product is systemic and predominantly foliage absorbed. In some cases, it can be absorbed through bark. Triclopyr is active against broadleaf plants, especially woody species. It has no effect on established grass. It often is used on blackberries and poison ivy. It is sold alone or sometimes mixed with 2,4-D for control of brush and other harder-to-control broadleaf weeds. Read the label carefully to see whether the formulation is an ester or an amine. Avoid applying ester formulations in hot weather to reduce potential volatility and drift.

Oryzalin and pendimethalin—These preemergent herbicides act on germinating seeds. They are most effective on annuals.

It is very important to read the labels for oryzalin and pendimethalin carefully. These products differ in their need for mixing into the soil, the weeds they control (some, but not all, grasses and broadleaves), and the plants around which they can be used.

Pendimethalin is sold as Pendulum, Pre-M, and several other names. Oryzalin is marketed as Surflan and Weed Preventer. Plants sensitive to these herbicides cannot be planted for several months after use.

Fluazifop—Fluazifop controls many grass species but does not harm most broadleaf plants. It is applied after grasses emerge and are rapidly growing. It takes seven to 14 days or more to see results. It is sold as Grass-B-Gon and other brand names.

Sethoxydim—Sethoxydim controls grasses and does not harm most broadleaf plants. It is applied after grass has emerged and is growing rapidly. The most common trade name is Poast.

Weed Management for Specific Situations

Your particular landscape or situation determines how you manage weeds.

Lawns

Choose grass species suited for your area. A vigorous lawn reduces weed invasion. Good fertility, watering, and mowing will keep your turf in top condition. Plan an annual program of overseeding weak areas, especially shade areas. Work to reduce insect damage to your lawn; weakened areas offer little competition to encroaching weeds.

Lawn blends that contain grass-cover combinations may provide a stable plant community that resists invasion by more weedy species. These combination lawns do not have the feel of pure grass, however, and some people find them unacceptable. Other homeowners swear by them.

If the grass you plant can tolerate a mowing height of 1¾ inches or more, the shade cast by the grass will inhibit germination of many broadleaf weeds. Use a fertilizer low in phosphorus to avoid stimulating clover (assuming you don't want clover in your lawn). Some broadleaf weeds can be managed by hand pulling, but smaller species may be hard to control in this way.

Weedy perennial grasses such as quackgrass, bermudagrass, and nimblewill can be very invasive. Once these plants establish, you have few options short of complete renovation. Some gardeners spot-spray the patches with glyphosate and then overseed them.

Summer annual grasses such as crabgrass are generally part of most well-maintained lawns, and can be more prominent in closely mowed turfgrasses.

Usually, lawns are weakest in shady areas and where drainage is a problem. Annually overseed lawns in those areas to maintain a viable turf. Moss often grows where grass is weak.

Many homeowners use broadleaf herbicides, either alone or in combination with fertilizer ("weed and feed"). To reduce the amount of herbicide used, it generally is much better to spot-spray weedy areas rather than apply herbicides over the entire lawn each time you fertilize.

Herbicide-treated lawn clippings should be used cautiously as mulch or in compost. Unintended damage to nontarget plants can occur. For example, clopyralid-containing products can persist for more than a year.

If young children or pets use the lawn, be cautious with herbicides!

Renovation

Lawn renovation often is done to reestablish turfgrasses where weedy grass species have taken over. The weedy species must be killed (especially perennials) before a new lawn is planted.

A single rototilling generally spreads rather than controls problem grasses, but repeated tillage over three to four weeks can give acceptable control in dry weather.

Some homeowners use glyphosate to kill an existing weedy lawn, and then they dethatch and overseed. Repeat applications of glyphosate are sometimes necessary before seeding. They don't use rototilling unless the lawn needs to be reshaped. With good temperatures and water, a new lawn can be up and growing in three to four weeks.

Woody Landscape Areas

Weeds in landscape beds can be managed with a mix of techniques that include mulching, water placement, competitive planting, hand pulling, and herbicides applied as both spot and broadcast treatments.

Mulches should be your first line of defense against weeds. They reduce the germination of weed seeds and protect the soil. Organic mulches such as bark probably are the most effective and cause the least problems. Hoeing in mulch is easy and disrupts most annual weeds. Landscape fabrics may be used around annual and perennial flowers but should not be used around woody plants, where they often encourage surface root growth. Perennial weeds generally are not deterred by organic mulches and may defeat landscape fabrics as well.

Drip irrigation puts water around desirable plants but doesn't water everything, and the dry areas will have much less potential for weed growth.

When bare areas are planted with robust plants, weeds struggle to compete.

Complex landscapes that cover most of the ground generally have fewer weed problems as the plants become established—which can be a great reason to buy more plants! It does help to have a plan and know which species will work best. In some cases, competitive plantings may limit your herbicide choices.

The herbicides most commonly used in woody landscapes are isoxaben, pendimethalin, oryzalin, trifluralin, and spot application of glyphosate. Be sure you understand how these products work to avoid damaging desirable plants.

Annual Flower and Vegetable Gardens

Annual vegetable and flower gardens can be weed nightmares. Working the garden in the spring offers an opening for weed seeds. Their aggressive growth can quickly dominate a garden.

Weeds are best managed in flower and vegetable gardens by a combination of hoeing, hand pulling, use of vigorous plants that shade the ground as they mature (including extensive use of transplants), drip irrigation, mulches, and relentless attention that keeps weeds from going to seed. Winter weeds can be managed by mulches or cover crops.

In general, herbicides are not a good option for home vegetable gardening due to the complex of different plants that are grown.

Some gardeners use glyphosate before the first spring cultivation to control persistent perennial weeds, especially quackgrass. Trifluralin (Preen or Treflan) is labeled for use around some (but not all!) flowers and vegetables. Oryzalin has some home-garden labels for flowers. Read the labels carefully and follow instructions if you use herbicide products.

For More Information

University of Kentucky Cooperative Extension Service publications:

Weeds of Kentucky Turf (AGR-12)

Weed Control for Kentucky Home Lawns (AGR-208)

Other resources:

McCarty.LB, et.al. *Color Atlas of Turfgrass Weeds*. Ann Arbor Press. 1991.

Haragan, Patricia Dalton. *Weeds of Kentucky and Adjacent States: A Field Guide.* University Press of Kentucky, 1991.

Chapter 09

Vertebrate Pest Management

By Dave Pehling, Extension analyst, Snohomish County, Washington State University. Adapted for Kentucky by Thomas G. Barnes, Extension wildlife professor and wildlife Extension specialist, University of Kentucky. Revised by Matthew T. Springer, assistant Extension professor and wildlife Extension specialist, University of Kentucky.

In this chapter:

Most people enjoy watching wildlife around the home, whether it is birds at a feeder, butterflies on flowers, or the occasional deer or turkey wandering through the yard. In some instances, wildlife come into contact with humans and are in the wrong place at the wrong time. For the gardening enthusiast, this encounter can create conflict. With weeds, insects, and other types of garden pests, you can just spray a chemical and solve the problem, but vertebrate pests are considerably more difficult to deal with. Few poisons or repellents are available for use. Also, vertebrate pests share similar physiology with humans, so chemicals designed to kill mammals can potentially also harm us and our pets. Consequently, there is no standard approach to dealing with wildlife problems. Each situation must be examined in terms of:

- species of animal causing the damage
- severity of damage
- season and duration of damage
- legal status of the animal
- biological and ecological considerations
- wildlife value
- available types of prevention and control methods (non-lethal and lethal)
- economic considerations

These factors can help you evaluate the situation. Not every conflict between humans and wildlife requires action—the goal is to solve a problem, not kill animals. Often, a bit more human tolerance is all that's needed; the situation may resolve itself, evident in the old saying, "Plant four seeds; one for the mouse, one for the crow, one to rot, and one to grow." Even if you tried to kill all the wildlife in the group causing the problem, it would be almost impossible to control the entire population. The types of wildlife you are dealing with have very high reproductive rates, live short lives, and have high death rates. They are usually adaptable and opportunistic in their general habitat requirements, and we often create excellent habitat for them around our homes and in our gardens. For example, rabbits like nothing better than to eat from a well-tended, fertilized bean patch rather than eat grass and clovers.

Problems with Home Remedies

People are ever-resourceful, so when it comes to wildlife conflicts we attempt to make our lives easier by designing and developing new products, sometimes based on sound information and sometimes not. A perfect example of these new products is deer or wildlife "whistles" meant to keep deer or other creatures away from cars or structures by using high-pitched sound. Research conducted in Europe has shown these whistles have little effect.

In some cases, gardeners and homeowners take matters into their own hands and develop their own "home remedies." Most such inventions may work for a short time, but be aware that laws govern the types of chemicals you can put out to control wildlife. For example, many people will use mothballs to move bats from a structure or from part of a building, such as an attic. Most of them do not realize that mothballs are carcinogenic to humans and that to obtain a concentration strong enough to repel bats would probably create a hazard for the human occupants as well. Consequently, mothballs are not labeled for use as a bat repellent.

Many states are becoming serious about the use of such home remedies due to the toxic chemicals they contain and the harm they can do to the environment, people, and pets. Some states interpret using a home remedy as an illegal use of a pesticide. Some will also invoke animal cruelty laws if wildlife show signs of suffering and that suffering can be traced back to an individual homeowner. For example, most homeowners recognize that antifreeze attracts wildlife and that if wildlife drink it, it will kill them. What they do not realize is that an animal dying as a result of this activity mimics an animal dying of rabies.

It takes time for the animal to die and it wanders around the neighborhood. Someone will most likely discover this animal and make efforts to help it. While this is most probably a case of cruelty to animals, it is most definitely a violation of federal and state pesticide laws. If the homeowner who enticed the animal to the antifreeze were caught, the case would be treated quite seriously by the legal system.

It is better to use a product that has been tested and undergone scrutiny than to use something you or your neighbor heard of through the grapevine. Unfortunately, many of the chemicals that are labeled for wildlife control are "restricted use" products, which mean you must have a specific license to use them. You must also realize that the directions on the product's label are the law, and failure to follow the label is illegal.

Prevention is the Best Solution

The best long-term solution to solving conflicts between humans and wildlife is to prevent them in the first place. The second-best solution is to keep the animals from the site and to minimize any damage they might do. The solution of last resort may be to capture and remove or kill the offending animal.

A homeowner or gardener should first take stock of his or her property and at a minimum take some common-sense precautions, like making sure the trash cans have lids that fit tightly; not keeping dog or cat food out at night; inspecting the home to ensure that all holes and entrance routes are sealed; not putting wildlife-attracting meat or fat scraps in the compost; and picking up boards, debris, and other items from the ground to minimize use by snakes, skunks, or other burrowing creatures. Clean up at the bird feeder—excess seed attracts not only birds, but also chipmunks, squirrels, and rabbits. Finally, look at your perimeter fences and check for signs of where animals are moving from surrounding properties. Seek to make these travel routes uninhabitable.

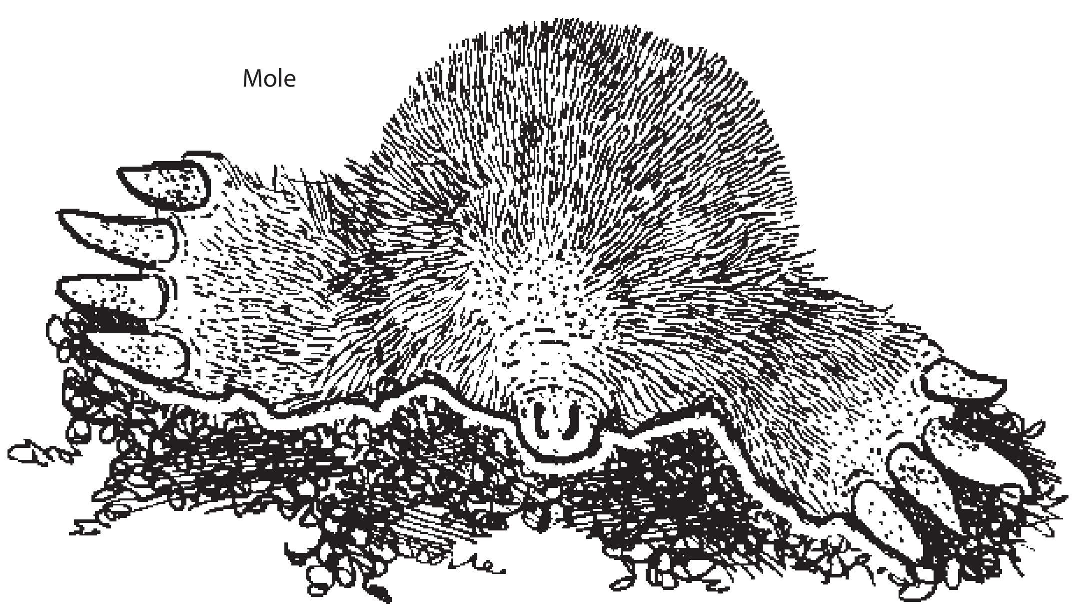
The next step in preventing damage is to examine your garden and landscape to see where barriers can be erected around the vegetable garden or over the grape arbor/berry patches, which is where netting would be appropriate. You can also look to see if you have favorite perches where birds roost (trees or structures) and net them off. Or, you can use some other type of structural deterrent (like porcupine wire or angled boards) to keep the birds from perching near the gardens.

If you are determined to live-trap and release wildlife from the garden, consider the following:

- You can't release them on public land such as a park, wildlife management area, forest, nature preserve, or any other public land.
- You must obtain written permission from the landowner to release wildlife onto private land.
- It is not necessarily more humane to release the animal, as they are often at a disadvantage when released. Members of the same species may be aggressive to them or they may become easy prey. Released animals may be injured in confrontations with these newly encountered individuals in the area they were released. The injuries may not be limited to the animal that was released, as those individuals that were present are just as likely to be injured in a confrontation. On top of that, you do not know if the animal you are relocating is potentially carrying a disease. Unnatural movement by relocation can help diseases like rabies to be quickly spread across the landscape, causing substantially more harm to the species you are trying to protect.
- Wildlife have incredible homing instincts. Unless an animal is taken many miles from the point of capture, it will return to its original habitat.

Given these general guidelines, specific animal groups and potential control options are presented in this publication.

Mole



Moles

The much-maligned mole may be the greatest source of stress among homeowners. It is probably the number one lawn pest that people complain about. While moles do little actual economic damage except to golf courses and other expensive turf areas, many people consider it to be a significant problem. Moles are insectivores, not rodents, so they do not eat plant material. Their primary diet is earthworms and grubs. If you have a problem with grubs in your lawn, it is not wise to spray an insecticide to kill them, because the moles could switch their prey to something else and actually cause more damage.

Ninety percent or more of a mole diet is earthworms, and the remaining 10 percent is other soil insects. If you have a grub problem, treat that problem, and if you have a mole problem, treat that problem.

Most damage occurs when moles' shallow burrowing activity, which is generally in the spring and fall, creates ridges or hills of fine dirt in the lawn. It isn't necessarily true that moles are difficult to control. The key, whether trapping or using the poison earthworm baits, is to find the active tunnels that moles use most often. These tunnels are usually long and straight, not branched. If you place your foot over a section of the burrow, it will usually be pushed up the next day.

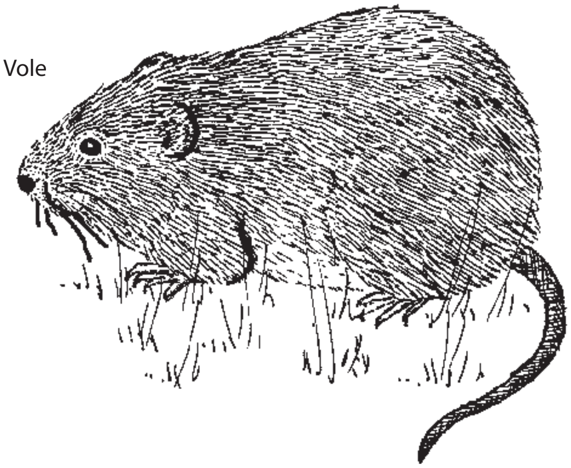
The best time of year to use either baits or to trap is spring and fall, when moles are more active in surface runs rather than deep runs and chemicals do not break down as quickly as in summer heat. (The chemicals in the earthworm baits are very heat sensitive.) Fumigation or gas cartridges are also available for control, but they are generally not effective. The mole runs are so extensive that it is difficult to get enough gas into all areas of the burrow system to kill the animals. More information on using traps to control moles can be found in the UK Cooperative Extension publication *Managing Mole Problems in Kentucky* (FOR-42) at http://www2.ca.uky.edu/agcomm/pubs/for/for42/for42.pdf.

The final option is to use a castor oil-based repellent. These repellents have been shown to be somewhat effective; however, they must be continually reapplied because they disperse into the soil. Also, they do not solve the problem; they only delay dealing with the long-term issue of actually controlling the animals. Furthermore, these products can be quite expensive. In the long run it will be more cost effective to remove the offending animals.

Voles

Often damage by voles is mistaken as mole damage, because meadow voles can create extensive burrow systems, particularly in lush, thick grass lawns. Voles, or meadow mice, are small, compact mammals with stocky bodies; small, rounded ears; short legs; and short tails. When fully grown, voles are four to five inches long. Their long, coarse hair can be blackish, grizzled, or reddish, and they spend most of their lives just below the soil surface. Voles are plant eaters, so if you find bulbs, tubers, shrubs, or other plants gnawed on at ground level or just below it, the culprit is likely a vole, not a mole. You might find one-inch diameter holes in the turf, indicating the entrance to a burrow system. Prairie and meadow voles feed on tree bark, primarily during the fall and winter. However, pine voles characteristically attack trees of all sizes in all seasons. Most pine vole damage occurs belowground, where the animals feed on rootlets and the bark of larger roots. Voles breed from January through October in Kentucky and can produce an entirely new generation in about 60 days. Vole numbers fluctuate from year to year; under favorable conditions, populations can increase rapidly. Voles often experience population booms and busts on about a four-year cycle. It is during the boom years that lawn and shrub damage is usually the worst.

Vole



Vegetation management is the key to managing vole populations. Because voles like thick, heavy mulch and grass, the key is to not provide this type of habitat. However, limiting this habitat can conflict with other objectives, such as applying mulch around landscape plants. To reduce the potential for vole damage, mulch should be pulled away at least 36 inches from the base of the plant material, and if possible, the ground should be kept clear of any vegetation or mulch, because bare ground minimizes vole activity around plants. A thick, lush lawn, particularly with fescue as the grass species, creates ideal habitat for prairie or meadow voles. Lawns should be dethatched to reduce potential vole problems.

To protect individual landscape plants, place hardware cloth cylinders (quarter-inch mesh) around the lower trunks and bury the cylinder's lower edge six inches deep. Tree guards that control rabbit damage do not discourage voles, since voles feed mostly underground. In fact, voles have been known to nest under loose-fitting guards! For very small vole populations, trapping may be sufficient control. Use ordinary mousetraps baited with peanut butter or apple. The traps must be placed in the runs and then covered with boards. Check traps daily and reset as needed. This method is very time-consuming but is often the only solution, as there are no chemicals labeled for vole control in the landscape.

Chipmunks

These small squirrels are not ground squirrels, although that is a name commonly used for them. Kentucky has no ground squirrels. Chemicals sold in Kentucky that are labeled for use on ground squirrels are illegal to use for chipmunks. While chipmunks are avid climbers, they spend most of their time on the ground or in underground burrows that can be up to six feet long and two to three feet deep. The entrance is typically a hole from one inch to one-and-a-half inches in diameter. No soil is mounded around it, and it closely resembles the entrance hole for a vole. Chipmunk entrance holes are often around or at the base of structures like a rock fence, a concrete wall, or sidewalk, and often the entrance is concealed with leaves or other debris.

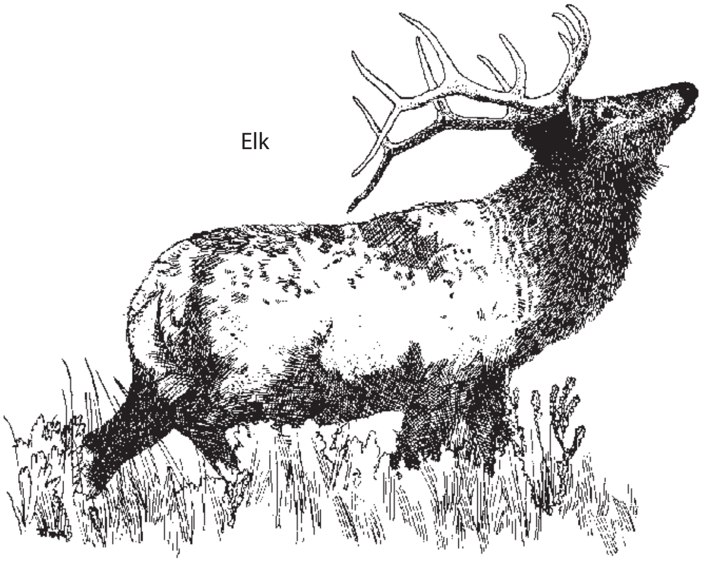
No chemicals are labeled for chipmunk control in Kentucky, and homeowners are left with either excluding the animals or trapping them. The best material to exclude chipmunks is quarter-inch hardware cloth. It should be buried at least six inches deep to prevent the animals from burrowing under it. The most common trapping method involves using rat snap traps (which are much like a common mousetrap) or small live traps. Live trapping is usually an all-encompassing activity, because homeowners trap and release not only the animals from their yards but from surrounding yards as well. Therefore, snap trapping is the preferred alternative. To be successful, two traps should be used per entrance hole. The traps should be placed adjacent to one another and perpendicular to the hole, and they should be buried so they are level with the surrounding environment. There is no need to bait the traps at the entrance hole. Once in place, some sort of structure should be placed over the top so that birds, pets, and other animals do not inadvertently step in the traps. Another viable alternative is to use PVC pipe six inches in diameter. Cut it into one foot sections and place a trap in each pipe. Bait the trap with a mixture of peanut butter, oatmeal, and apple. For more information on chipmunk control, see the UK Cooperative Extension publication *Managing Chipmunk Problems in Kentucky* at https://www2.ca.uky.edu/agcomm/pubs/for/for41/for41.pdf.

Cottontail Rabbit

A well-fertilized garden and lawn is a buffet for cottontail rabbits. They love flowers, vegetables, and shrubs or trees that provide ample nutrition. They often feed on bark and stems during winter, when they cause a lot of damage to gardens and orchards, especially in peak population years. In spring and summer, they develop an appetite for flowers (particularly tulips) and vegetables. Rabbit-damaged trees and shrubs are easily identified by characteristic tooth marks. Rabbits clip tender young shoots and terminal buds as well as gnaw on the trunk. The gnawing marks are larger than vole marks and appear as clean, knifelike cuts at a 45° angle.

Because rabbits can't climb and jump more than several inches, the best method of solving rabbit problems is to place a mesh two-foot fence buried six inches deep around gardens and flower beds where rabbits have been observed. Individual trees and shrubs can be protected with hardware cloth cylinders that are at least two feet tall and buried six inches deep. Rabbits can also be deterred using a single high-tensile electric fence with the wire placed four inches above the ground. Make sure the system is well grounded and the vegetation under the wire has been removed to ensure good contact between the wire and animal. If the rabbits jump this fence, a second wire can be placed two inches above the lower wire. Live-trapping rabbits is not all that easy in the garden because there is such an abundance of food, and it is generally ineffective. There are a number of commercially available chemical repellents for rabbits that are labeled for homeowner use. The only two available for use on human edible crops are Hinder and those made with capsaicin (hot pepper). Generally speaking, repellents that make the plant taste bad are more effective than those that repel by making the area smell bad. To be effective, these repellents must be reapplied after a rain or heavy dew, and they are expensive and labor-intensive to use. Always be sure to read and follow the label when using any chemical repellent.

Chipmunks



Deer and Elk

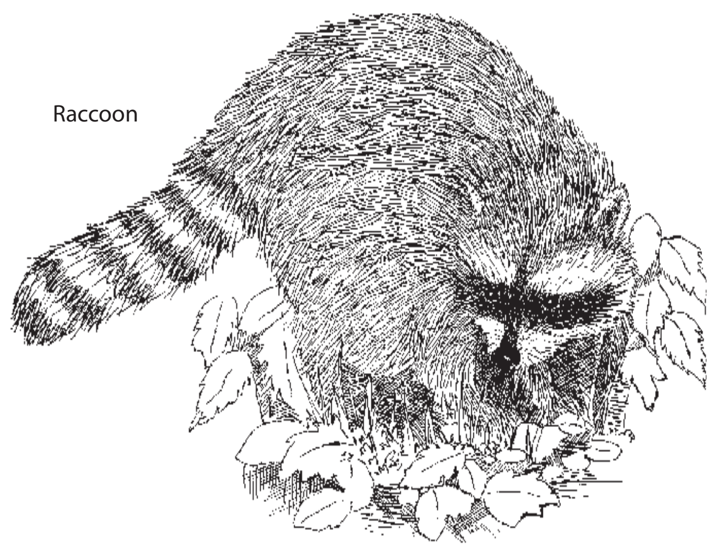
Kentucky has abundant deer and elk populations in both urban and suburban environments. They are difficult for homeowners to deal with, because hunting is usually not a control option in these environments. These two large mammals can cause considerable damage, not only from their browsing of plant material, but also from their movements and behavior. Furthermore, since fencing is really the only viable management option that works, homeowners need to determine if they can deal with potentially unsightly fences around trees, shrubs, gardens, and other plantings. While repellents can provide some temporary relief, they are not viable management options in the long run. One potential solution is to select deer-resistant landscape material. However, if a deer or elk population is stressed and hungry, it will devour these plants as well. More detailed information on managing deer problems is available in the UK Cooperative Extension publication *Managing White-Tailed Deer Problems in Kentucky* (FOR-57) at http://www2.ca.uky.edu/agcomm/pubs/for/for57/for57.htm.

Black Bear

Bears are the largest omnivore within Kentucky, and their range and population is currently expanding. Found mostly in the southeast and eastern counties, they can cause large amounts of damage quickly within your garden or other landscaping. Bee hives, sweet corn, all types of berries, and orchard trees are especially attractive to bears. Because these species are quite adept at climbing, the best control is to use electric fencing around any areas you want to protect. The wires should start at six inches from the ground and be spaced about every eight to 10 inches up to four feet off the ground. To ensure this method is effective, you need a power source capable of providing an adequate shock to the animal; it is suggested to be between 6,000 and 10,000 volts. In addition, all vegetation must be kept clear of the fences to prevent the wires from grounding. These can be temporary fences that can be removed once the crop has been harvested or permanent versions. Other types of fences, such as a chain-link fence, may help deter bears, but they become much more effective by adding a single strand of electric wire on the top. Hinder and hot pepper-type repellents are labeled for use on human edible crops, but no research has shown them to be effective at keeping bears from consuming crops.

Skunks

Skunks are another small omnivore common within Kentucky that can be problematic when maintaining gardens and landscaping. Skunks will feed on many types of produce within gardens, including corn and various types of berries. Fencing is a feasible option to help keep them out of gardens, as they are not adept at climbing. A chicken fence that is two to three feet high should suffice in keeping them from entering specific areas. One of the major problems skunks can cause has to deal with their diet, specifically their love of larvae. They will dig up larvae from the soil, usually creating numerous holes from three to four inches deep within flower beds or lawns. This behavior is not all bad, as they are removing species that are often viewed as pests. One of the easiest ways to deal with this type of skunk damage is to treat your lawns to control the pest species itself. If there are no larvae present, the skunks will not dig to find them.



Raccoons and Opossums

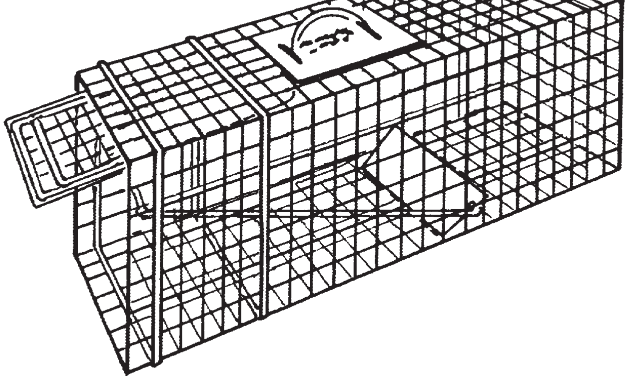
These two mid-sized omnivore mammals cause most problems when they get into the garden and raid fresh produce just before it is ready to be picked. Sweet corn is especially attractive. Because these species are quite adept at climbing, the best control is to use a two-strand electric fence around the garden. The wires should be at six and 12 inches from the ground. To make sure this method is effective, you must have a charger that supplies sufficient electricity to provide an adequate shock, and all vegetation must be kept clear of the fences to prevent the wires from grounding. These temporary fences can be removed once the crop has been harvested. Other types of fences, such as a chain-link fence, can work, but adding a single strand of electric wire on top makes them more effective. Hinder and hot pepper-type repellents are labeled for use on human edible crops and may deter the animals long enough for the vegetables to be harvested. If using hot pepper-type repellents, remember that they should not be sprayed on the actual vegetable you will be eating but on the surrounding vegetation.

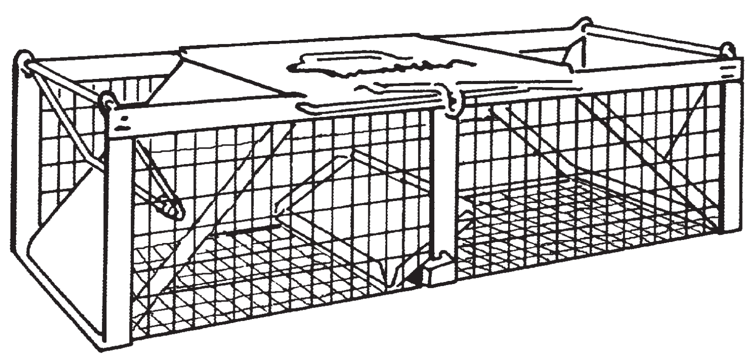
Gray squirrel

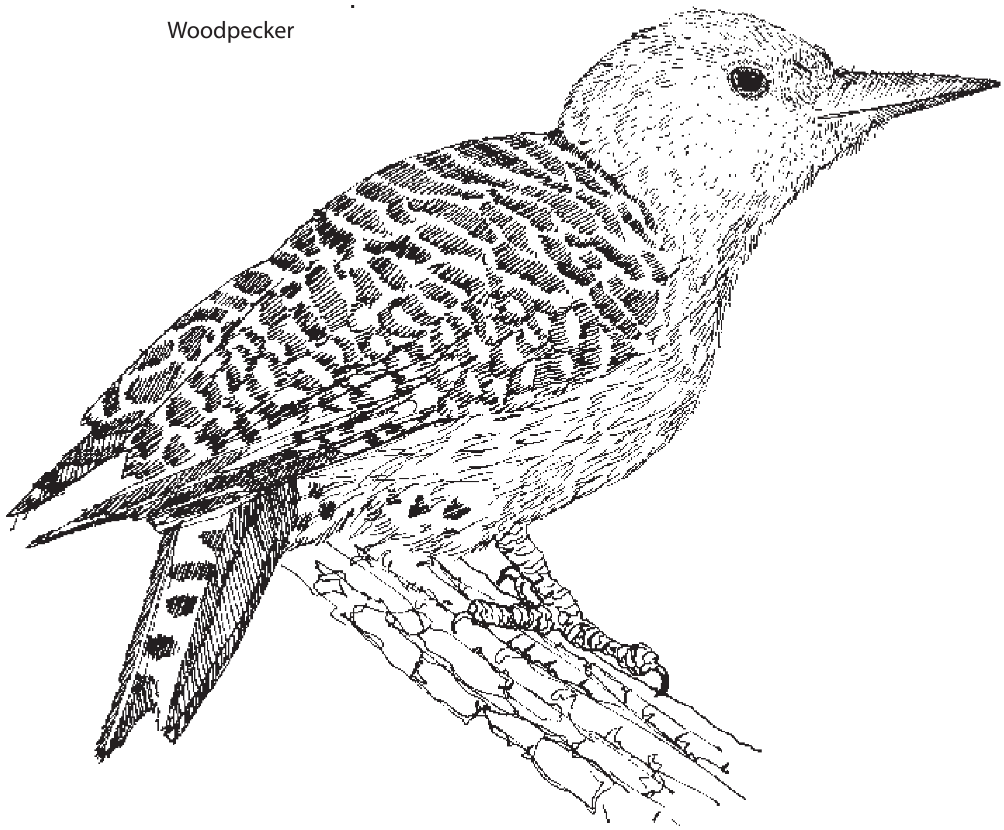
Tree Squirrels

Both the fox and eastern gray squirrel are common in Kentucky, and both can cause problems for gardeners by digging up plants, bulbs, or seeds; eating from fresh vegetables; gnawing off small branches and twigs; stripping bark; and raiding bird feeders. If they get into a house or another structure, they can cause significant property damage. Squirrels are easy to live trap if the traps are baited with sunflower seeds, corn, peanut butter and oatmeal, or other fruit-nut material. However, once squirrels are trapped, they are vicious. Dealing with them in a live trap can be troublesome and even hazardous. Furthermore, you may have many more squirrels than you first realize. Twenty-four squirrels were trapped in a single week at a residence in Lexington, Kentucky, and the population was still not depleted. If you do want to catch and release the animals, pay strict attention to the laws and regulations outlined previously. To more humanely move the animals, cover the trap in heavy canvas while transporting them (this method might also save one of your fingers!). If you have squirrels digging up bulbs, plants, or seeds, the best method is to place hardware cloth just under the soil so they can't dig through the cloth and access the plant material that is underground. The cloth should be staked firmly, and it should be much larger than the immediate area to prevent the squirrels from getting at the edges and tearing the cloth out of the ground. Electric fencing, as discussed for raccoons and opossums, will also work to deter squirrels from a vegetable garden, and commercial repellents are available as well. If you want to treat birdseed to deter squirrels, a hot pepper-type repellent is available that can be placed on the birdseed. If you do feed birds, make sure you clean up any and all extra food that drops so that you discourage other animals. Squirrels can be kept out of fruit trees and other trees by placing six-foot sheet metal or plastic barriers at the base of the tree. At certain times of the year, squirrels will clip twigs and branches of trees for no apparent reason other than to sharpen their teeth. Don't worry about this damage; it generally doesn't harm the tree.

Cage traps







Woodpecker

Birds

Birds, primarily crows, starlings, woodpeckers, pigeons, house ("English") sparrows, and robins, can cause problems in gardens by their roosting, nesting, and feeding habits. Bird management may present special issues, because woodpeckers, robins, and songbirds are protected by law. Because of where Kentucky is located geographically, the state has tremendous control issues with populations of both summer- and winter-roosting birds. The first step in dealing with this problem is to select proper tree species for the landscape. For example, species with much branching, like the Callery pear, white pine, pin oak, and those of Zelkova, attract roosting species in the winter because the birds can congregate closer and keep warm. For these species, the first line of attack is to trim up to 30 percent of the canopy and "open" it so that branches do not overlap and more air moves through the canopy. Another option is to place bird netting over the tree. The final method would be to disperse the roost by using a bird distress tape call along with pyrotechnics. For more detailed information on dispersing a roost, see UK Cooperative Extension publication *Managing Urban Pest Bird Problems in Kentucky* (FOR-62) at http://www2.ca.uky.edu/agcomm/pubs/FOR/FOR62/FOR62.pdf.

If you have woodpeckers tapping on siding or trees in the spring, it is usually a result of courtship. Cedar siding is especially attractive and prone to damage. It is illegal to harm these birds. The best method is to place another material in the areas where they are drumming or cover the area with bird netting to create a different sound. If this method doesn't work, a special sticky repellent available at hardware and lawn/garden stores can be applied to deter them. Sometimes an infestation of carpenter ants or solitary bees can attract woodpeckers. If this is the case, take care of the insect problem and the woodpecker problem will also disappear.

Perhaps the biggest threat to home gardens from birds is the damage to strawberries, cherries, blueberries, apples, grapes, and hazelnuts. If you want any of these crops for harvest, you will most certainly have to place bird netting over them. It is the cheapest, most environmentally friendly, and most effective method of keeping birds from crops. Another alternative is to use the chemical repellent methyl anthranilate, which is derived from grape skins, to deter the birds. However, using this repellent is very expensive, and, as with all repellents, you must reapply it after dew or rain.

Various scare devices, including but not limited to fake snakes and owls, scarecrows, hanging flashers, balloons, loud noise, and ultrasonic or subsonic devices, may work for a day or two, but the birds quickly become accustomed to them and quickly return to their habitual behavior.

For More Information

A list of UK Cooperative Extension publications on managing vertebrates follows:

Managing Muskrat Problems in Kentucky (FOR-51)
Managing Beaver Problems in Kentucky (FOR-50)
Managing Skunk Problems in Kentucky (FOR-49)
Bats: Information for Kentucky Homeowners (FOR-48)
Snakes: Information for Kentucky Homeowners (FOR-46)
Managing Tree Squirrel Problems in Kentucky (FOR-45)
Managing Woodchuck Problems in Kentucky (FOR-44)
Managing Rabbit and Vole Problems in Kentucky Orchards (FOR-43)
Managing Mole Problems in Kentucky (FOR-42)
Managing Chipmunk Problems in Kentucky (FOR-41)
Controlling Woodpecker Damage (FOR-38)
Coyote Managing Coyote Problems in Kentucky (FOR-37)
Managing Urban Pest Bird Problems (FOR-62)
Managing Commensal Rodent Problems in Kentucky (ID-115)
Kentucky's Endangered and Threatened Species (ID-103)

Chapter 10

Integrated Pest Management

By Jonathan L. Larson, Extension entomologist.

In this chapter:

Pests can be insects, weeds, vertebrates, and diseases. Any organism that causes harm to crops, livestock, or humans can be considered problematic and therefore must be managed. In Extension, we practice and teach that pest management is best accomplished through a holistic approach called integrated pest management, or IPM.

What is IPM?

The history of IPM traces back to research done in the early 1900s that focused on how to best use early insecticides in ways that wouldn't harm beneficial natural enemies such as lady beetles. That way, growers could receive the benefits of both pesticides and biological control. By the 1970s, IPM became more formalized as a philosophy of pest management that focuses on utilizing the best set of tools to suppress a pest population, rather than relying on any one method.

In many ways, IPM as we know it is a response to the heavy use of insecticides such as DDT in the middle part of the twentieth century. Some always define IPM as the avoidance of insecticides and other pesticides. IPM does not necessarily exclude pesticide use or consider pesticides the "weapon of last resort."

Another issue, in modern times, is that IPM is sometimes conflated with organic agriculture. IPM is not inherently organic, as some IPM programs include the use of synthetic pesticides that would not be allowed on an organic site. What is most accurate to say is that integrated pest management is located between the traditional "spray 'em all" approach and the "never use pesticides" perspective; it is a judicious use of all possible tools that will help to suppress a given pest.

Developing an IPM Program

Monitoring

The foundation of success for IPM is a good monitoring program. Monitoring for insects, weeds, and diseases allows populations to be caught when they are easiest to manage, and suppression will be more successful. In a more traditional approach, action might not be taken until a high amount of damage has occurred and pest populations are difficult to manage. Other times, a preventive application of pesticides may be applied without verification that the target pest is even present. By monitoring, those methods can be minimized or avoided.

Monitoring can be achieved in multiple ways:

- Regularly inspect plants, paying close attention to new growth. Check flowers, leaves, fruits, and stems. Not every plant has to be inspected necessarily. Designating certain plants in the garden or field as the check plants for a row or patch can save time while still allowing for monitoring.
- Plants should be checked for signs (the actual pest organism) and symptoms (the evidence a pest leaves behind). A hand lens or magnifying glass can help to magnify signs and symptoms for easier identification. Depending on the pest, it may be prudent to check at night rather than during the day to confirm the problem.
- Insect pest populations can sometimes be monitored with traps. Yellow sticky cards, yellow bowl traps, pheromones traps, and bait traps can be deployed and checked regularly for the presence of pests. Once a certain number are trapped, a treatment regime might be recommended.
- Diseases and weeds can often be tracked via weather and climate models. For example, fire blight has parameters for its emergence that can be tracked and predicted. The University of Kentucky provides prediction model tools, such as those available online at http://weather.uky.edu/plant_disease.html, to help growers monitor for conditions that lead to disease.

Monitoring also includes creating records and maps of pest problems. By keeping track of pests on an annual basis, this allows for more predictability in the garden, and maps can help focus management efforts on hot spots.

Despite the power monitoring gives growers, it is often the most neglected aspect of pest control. It takes time and dedication—both of which can be in short supply! It is important when teaching about pest management to emphasize how important monitoring is.

Identifying Pests

Monitoring for pests is only half the battle though. Once a pest has been captured or seen, or its damage has been observed, it is necessary to figure out its identity. Identification tips have been covered in other chapters in this manual for various types of pests. Identification is necessary for IPM, as it allows for more specific approaches to pests and tailoring solutions to the situation at hand. Identification also helps to rule out possible abiotic problems and guarantee a pest problem.

If identification proves a bit difficult, Master Gardeners, Extension assistants and agents, and Extension specialists may be able to help.

Economic and Action Thresholds

Monitoring for pests allows us to act based on established thresholds for specific pests. There are different types of thresholds: economic and action. Economic thresholds are usually established for large-scale agriculture. These thresholds are calculated to determine the population level at which a pest is causing enough damage to make a suppression method economically sensible.

These economic thresholds don't always apply to the lawn and landscape or to the home garden, where aesthetics may be important or there are only a few plants of a given crop. In these situations, it may be prudent to act on action thresholds. These are sometimes known as aesthetic thresholds, and there is a lower tolerance for the pests in these models. Indoor pests, such as bed bugs or rats, may also have action thresholds. In these instances, just seeing one pest may be enough to begin management.

Evaluating Results

The final step in monitoring is evaluation. Continuing to monitor after a management plan can establish efficacy and suggest new possibilities if the original plan didn't work. It can also help to track issues such as pesticide resistance, which is covered later in this chapter.

Methods of Pest Management

When it comes to suppressing pest populations, IPM relies on a variety of strategies. Some of these are preventive in nature, hoping to reduce the conditions most favorable to pests, while others are reactive to monitoring results or damage in the field.

Cultural Methods

Cultural management alters the current cultural practices to reduce pest pressure or damage from pests. This can include changes to irrigation, fertilization, and sanitation in efforts to prevent or stop pests. These are some examples that may help in the future.

Right Plant, Right Place

One mantra that can help to curtail pest problems before they start is this: "Put the right plant in the right place." Site traits can dictate which plants might best survive in that environment. Soil pH, soil type, moisture retention, growing zone, and more can all impact what the best plant to choose might be. Ignoring these conditions can mean a plant is set up to be stressed and fail from the moment it is planted. Stressed plants suffer from more pests and are easier for pests to harm.

Choosing Resistant or Tolerant Varieties

Beyond choosing a plant best suited for the site, some plants have also been bred to be *resistant* or *tolerant* of certain pests. A resistant plant has been bred to support little to no pests on it. A tolerant plant cultivar has been bred to be able to host pests, sometimes for extended periods of time, without exhibiting symptoms. Plants can be resistant or tolerant to insects and pathogens.

Irrigation and Fertilization

Tending to a plant's water and fertilizer needs can help the plant to stay healthy. A healthy plant can rebuff pests or can sustain more damage without displaying symptoms. This means understanding what the needs of a landscape or garden plant will be and meeting those.

There can also be too much of a good thing. Overfertilization can stress a plant and open it to pest infestation. Fertilization can also sometimes attract pests; insects in particular can be attracted to plants overfertilized with nitrogen. Overirrigating can stress a plant but also creates ideal conditions for pathogens to thrive.

Sanitation

Sanitation is most frequently a preventive pest suppression strategy. Sanitation can be going through a garden in the fall and removing all debris from the growing season. Doing so removes overwintering habitat for multiple pests and may even remove eggs and pupae that were there for the winter. Sanitizing pruners and other gardening tools in between uses can cut down on the spread of pathogens. Use rubbing alcohol, a disinfectant such as Lysol, or a solution of one part bleach to nine parts water. If you are pruning diseased plants, make sure to disinfect tools between each plant. Weed control during the growing season cuts down on alternative hosts and harborage for pests. Finally, the pruning or removal of infested plants can sanitize the garden of pests.

Table 10.1. Plant families for rotations.

Plant Family*	Representative Members
Apiaceae	Carrot, celery, fennel, parsley, parsnip
Asteraceae	Chicory, endive, globe artichoke, lettuce
Brassicaceae	Bok choy, broccoli, Brussels sprout, cabbage, cauliflower, collard, kale, kohlrabi, mustard, radish, rutabaga, turnip
Chenopodiaceae	Beet, spinach, Swiss chard
Cucurbitaceae	Cucumber, melon, pumpkin, squash
Fabaceae	Bean, pea, vetch
Liliaceae (Alliums)	Chive, garlic, leek, onion, shallot
Solanaceae	Eggplant, pepper, potato, tomatillo, tomato

*A more complete list of families and representative genera is in Chapter 5, Plant Diseases.

Crop Rotation

Continuously growing the same plants, or even related plants, in a given area is a recipe for pest problems. Insects will infest the location and disease propagules will be able to persist, as a host is constantly provided. Taking at least a growing season to switch between, for example, potatoes and leafy greens, could break the reproductive success of the potato pests and lead to fewer issues in the future. Crop rotation is often seen in Kentucky in large-scale agriculture with the switching between corn and soybeans. This highlights another benefit of rotation; plants need different nutrient levels, or some may even fix nitrogen. Switching between corn and soybeans can replenish soil and reduce stress levels for future plantings. See Table 10.1 for suggested rotations to utilize.

Physical Methods

Physical management of pests focuses on creating conditions that are unsuitable for pest entry, dispersal, survival, or reproduction.

Barriers to Pests

Row covers are among the most common methods of pest exclusion through physical control. Row covers are sheets that cover rows of plants or individual plants. They can ensure that pests such as squash vine borer, cucumber beetles, flea beetles, whiteflies, aphids, leafminers, and cabbage loopers physically can't feed on or lay eggs on plants. It is important to check under covers frequently for intruders. Pests that do get in are protected from their natural enemies and can do a lot of damage. Remove covers if it gets too hot underneath or if plants are in flower and need pollination.

Similar options can include plant collars that protect seedlings from cutworm damage. Use toilet paper tubes or cut the ends out of tin cans or paper cups to form a tube. Place a tube over each seedling. Bury the edge of the tube one inch deep. Sticky barriers can be used to catch climbing insects as they make their way up a plant's stem. This technique is effective against adult root weevils on ornamentals, ants on fruit trees, and climbing caterpillars and beetles. Rather than applying the sticky adhesive directly to the plant, first wrap the stem or trunk with a three- to four-inch-wide band of paper, plastic, or cotton. Then apply the adhesive to the wrap. Add more adhesive as soon as the trap is covered with insects, dust, or debris.

Physical Removal

If pests penetrate a barrier to entry, it is still possible to create conditions unsuitable for their survival or dispersal. One option is simple handpicking. Plucking pests, weeds, or diseased plant material and removing them from the growing setting can make it more difficult for the pest to proliferate and stop further damage from occurring. Some pests can be dislodged from a plant with a forceful stream of water. Small insects in particular can be susceptible to physical removal with water. Both of these methods will take time and effort to keep up with pests but should eventually lead to lower populations.

Finally, some growers may be able to vacuum pests off plants for physical control. It works best with insects such as whiteflies and spider mites that congregate in groups and do not scatter when disturbed. Use a handheld, wet-dry vacuum to suck these pests from infested plants. For best results, vacuum early in the morning, when pests are lethargic. Seal the vacuum contents in a bag, freeze overnight if possible, and discard.

Mechanical Methods

Mechanical and physical controls are often lumped together, but there is a distinction. Whereas physical control tries to exclude pests, mechanical control involves destroying a pest or its ability to procreate.

Pest Destruction

One of the most common methods of mechanical control is mowing. Mowing removes large parts of weeds and may kill them outright or reduce their ability to procreate. Rototilling is another mechanical method. Tilling will destroy some pests in the soil, such as tomato hornworms. It can also bury and kill others, or it can destroy overwintering shelters, exposing pests to the elements. One of the more extravagant methods of pest destruction is flaming. Both weeds and insects have been managed using fuel-powered jets of flame.

Trapping

Pest traps come in lots of shapes, sizes, and even smells. Traps are often promoted for use in monitoring for pests, but they can in some instances mechanically destroy certain pests. In other cases, traps are less mechanical management and are more of an opportunity for physical removal from the garden or field. Traps can include the following:

- Pheromone traps—Insect pheromones can be used against them by designing a lure and then a trap to hold pests. Again, these are most often deployed as a monitoring tool, although there is an amount of mechanical control that also occurs as insects get stuck in the trap.

Ground beetle larva (left) and adult · *Green lacewing larva (left) and adult* · *Big-eyed bug* · *Lady beetle larva (left) and adult* · *Syrphid fly larva (top) and adult* · *Tachinid fly* · *Assassin bug* · *Damsel bug* · *Spined soldier bug* · *Minute pirate bug* · *Robber fly*

Figure 10.1. Some beneficial predatory insects common to Kentucky.

- Snap traps and glue traps—These options are used for mechanical destruction of rodent and insect pests. They snare the pest, either with a snapping arm that is triggered by the pest or with glue from which the pest can't escape. Insect-specific traps can include blue or yellow sticky cards that are frequently used in greenhouses or high tunnels.
- Bait or habitat traps—Some traps may contain food or are themselves shelter for pests. These can concentrate pests in one spot, allowing for mechanical destruction or physical removal from the area. One example is an apple-cider vinegar trap to capture vinegar flies; the odor lures them into the container, and they fly into the trap, never to leave. Newspapers and boards can also be set out as shelter for pests like squash bugs. They will hide inside of piles of papers or cardboard or under the boards, allowing a gardener to come out in the morning and dispatch them all in one place.

Biological Methods

Biological methods, or biological controls, are foundational to integrated pest management. At the outset of IPM development, the focus was on maintaining populations of beneficial organisms and avoiding negative impacts from insecticides. To define biological control, it is the use of an activity by one species that reduces the negative impacts of another.

Predators, Parasitoids, and Parasites

The common image of biological control is to use a beneficial predator against a pest. This is a robust and well-researched area, but these are not the only "natural enemies" that can be deployed against pests. There are other categories into which these can be separated.

- Predators: These are animals that attack, kill, and consume multiple prey items throughout their lifetimes. Some predators may specialize more than others, only feeding on specific groups of prey (such as the mealybug destroyer, which specializes on mealybugs). See Figure 10.1 for some Kentucky examples of predaceous insects used in biocontrol.

Table 10.2. Garden flowers that attract beneficial insects.

Common Name (Botanical Name)*	**Predators Attracted**	**Parasitoids Attracted**
***Apiaceae* (carrot family)**		
Angelica *(Angelica archangelica)*	Lacewings, lady beetles	—
Anise *(Pimpinella anisum)*	—	Wasps
Blue lace *(Trachymene coerulea)*	—	Wasps
Caraway *(Carum carvi)*	Bugs, hover flies (syr-phid flies), lacewings	Wasps
Coriander *(Coriandrum sativum)*	Hover flies	Tachinids, wasps
Dill *(Anethum graveolens)*	Hover flies, lady beetles	Wasps
Lovage *(Levisticum officinale)*	—	Wasps
White lace flower, bishop's weed *(Ammi majus)*	Bugs, hover flies, lady beetles	Tachinids, wasps
Yarrow (*Achillea* spp.)	Bugs, lady beetles	Wasps
***Asteraceae* (daisy family)**		
Blazing star, gayfeather (*Liatris* spp.)	Bugs	Wasps
Chamomile *(Anthemis nobilis)*	Lady beetles	—
Coreopsis (*Coreopsis* spp.)	Lacewings, lady beetles	Wasps
Cosmos *(Cosmos bipinnatus)*	Hover flies, lacewings, minute pirate bugs	—
Golden marguerite *(Anthemis tinctoria)*	Lady beetles	Tachinids, wasps
Goldenrod *(Solidago altissima)*	Bugs, lady beetles, sol-dier beetles	Wasps
Marigold, signet *(Tagetes tenuifolia)*	Minute pirate bugs	Wasps
Mexican sunflower *(Tithonia rotundifolia)*	Hover flies, minute pirate bugs	—
Sunflower (*Helianthus annuus* and *H. debilis*)	Hover flies, lady beetles	Wasps
Tansy *(Tanacetum vulgare)*	Hover flies, lady beetle larvae	Wasps
***Brassicaceae* (cabbage family)**		
Broccoli *(Brassica oleracea)*	Hover flies	Wasps
Candytuft *(Iberis umbellata)*	Hover flies	—
Mustards (*Brassica hirta* and *B. juncea*)	Big-eyed bugs, hover flies, minute pirate bugs	—
Sweet alyssum *(Lobularia maritima)*	Hover flies	Tachinids, wasps
***Dipsaceae* (scabiosa family)**		
Cephalaria *(Cephalaria gigantea)*	Hover flies	Wasps
Pincushion flower *(Scabiosa caucasica)*	Hover flies	Wasps
Scabiosa *(Scabiosa atropurpurea)*	Hover flies	—

Table 10.2. Garden flowers that attract beneficial insects.

Common Name (Botanical Name)*	**Predators Attracted**	**Parasitoids Attracted**
***Fabaceae* (legume family)**		
Alfalfa *(Medicago sativa)*	Bees, bugs, lacewings, lady beetles	—
Clover (*Trifolium* spp.)	Bees, bugs, lacewings, lady beetles	—
***Hydrophyllaceae* (waterleaf family)**		
Fiddleneck *(Phacelia tanacetifolia)*	Bees, bugs, hover flies	—
***Polygonaceae* (buckwheat family)**		
Buckwheat (*Eriogonum* spp. and *Fagopyrum* spp.)	Hover flies	—

*This list includes only some of the many plants whose pollen and nectar attract beneficial insects.

- Parasitoids: These are animals that attach to or live inside one host, which they will eventually kill. Parasitoid insects often inject their eggs into a host, which then usually ceases to be a functional pest. One example is the aphid wasp; it injects an egg into an individual aphid, which serves as a nursery and food for the growing baby wasp. As a result, the aphid feeds less and doesn't reproduce.
- Parasites: Often confused with parasitoids, parasites are animals that infest a host that they typically won't kill, though they may make it sick enough that it causes less of an issue as a pest.

When using these biological control agents, there are different ways to deploy them or utilize them.

- Classical biological control: This is usually done when dealing with an invasive species. The government will dispatch personnel to the invasive species' native range to find predators and parasitoids that coexist with the pest and bring them back to study. They will be checked to make sure they won't also become invasive before possibly being released to manage the invasive pest. One famous example is the use of vedalia beetle to control cottony cushion scale.
- Augmentation biological control: This is the purchase and release of things like predators and parasitoids. For example, one could go to an online retailer and purchase 1,000 lady beetles to release in the garden in the hopes of having them help manage aphids. The most successful stories of augmentation biological control have come from greenhouses or using small or immature biological control agents rather than adults in the field. For example, predatory mites can be released to manage spider mites in a garden.
- Conservation biological control: Agricultural areas or cultural practices can be modified to do less harm to native populations of beneficial organisms. Such conservation biological control could include the creation of naturalized areas, where flowers and insects could live near a field or garden. Any beneficials in these areas may spill over into ag production and

provide benefits. Also, there could be alterations to pesticide use to reduce non-target impacts that harm beneficials. For example, using a granular insecticide rather than a liquid one can keep residues away from non-targets. Table 10.3 highlights some plants that may entice beneficials to dwell near your garden.

Microorganisms

Viruses, bacteria, nematodes, and protozoans are also natural enemies that may help to manage some pest populations. While they aren't as visible as predators and parasitoids, they do persist in nature and provide suppression, even without our input. There are some microorganisms that have been "weaponized" and may be applied to a growing area to provide further pest management. Microorganisms can be used against insects, weeds, and pathogens, though some of the most commonly used ones help with insect pests.

- Bacillus thuringiensis (B.t.) is a bacterium containing a toxin that poisons some insects. When ingested by a susceptible insect, it paralyzes the insect's gut, causing the insect to stop feeding and die within a few days. It is most effective on the youngest life stages. B.t. can be applied but is also deployed through GMO crops, to manage insects feeding on crops like field corn. There are multiple strains of B.t. that can be purchased. Here are a few examples:
    - B.t. *kurstaki* works on caterpillars, the immature forms of moths and butterflies.
    - B.t. *israelensis* is active against mosquito and fungus gnat larvae.
    - B.t. *san diego* is active against Colorado potato beetles and elm leaf beetles.
- Parasitic nematodes, also known as entomopathogenic nematodes, are microscopic roundworms that can infest and kill larval and pupal stages of certain soil-dwelling insects. Once a host has been destroyed, nematodes may burst forth from its body and then infest other nearby hosts.
- Fungi, such as *Beauveria bassiana*, can be applied to infest aphids, thrips, and other soft-bodied insects.

Biological control happens naturally without human intervention, but as shown, there is also opportunity to enhance what goes on naturally. There are some considerations to be kept in mind if biological control is to be a featured part of an integrated pest management plan:

- Biocontrol can have a high upfront cost when first purchasing biological control agents, especially when compared with traditional pesticides.
- Biological control relies upon monitoring and proper pest identification in order to release or apply the biocontrol agent when populations are most susceptible and to ensure the correct natural enemy is purchased.
- Unlike what might be seen after a pesticide application, biological control will never fully eliminate a pest population. There will be background levels of pests present that growers will have to be comfortable with.

But, if properly utilized and supported, biological control methods result in fewer pesticides being applied into the environment, can provide season-long suppression of pests, and may be more cost-effective in the long run.

Chemical Methods

One question that some people ask about IPM is how pesticides can fit into an integrated program. Pesticides, such as fungicides, herbicides, and insecticides, can be an important part of an integrated pest management plan. While reliance on pesticides may hinder IPM, it is also a mistake to discount the effectiveness of these chemicals. Why are pesticides a popular first choice for pest control?

1. Pesticides are readily available and tend to be easy to use.
2. Pesticides tend to be effective at controlling pests.
3. Pesticides usually work relatively quickly, with little lag time between application and control.
4. Large areas can be easier to treat with a pesticide than with methods like physical or mechanical control.
5. Pesticides are also relatively cheap when compared to alternative options such as biological control.

It is also fair to point out that, in some cases, a pesticide may be the only viable option for success against a particular pest.

But there are consequences that may arise from the use of pesticides as well. Pesticides can pose a hazard to the applicator, as well as anyone else who may be exposed to residues after the application. Further, pesticides can have impacts on the environment; this can come from misapplication or through circumstances like drift. When this happens, ground and surface water may be contaminated; fish, birds, and other invertebrates may be killed; and non-target insects and plants may be damaged. By carefully considering the situation and needs where a pesticide may be deployed, we can make decisions that help to minimize the chances of these negative outcomes and successfully control pests.

The ultimate goal when using pesticides is to choose the least toxic material that will satisfactorily manage a pest in the most economical way possible. All pesticides have an inherent *hazard*; they pose a potential to harm. However, hazards can be avoided by minimizing *risk*, which is a combination of hazard and exposure. To reduce risk, we must consider things like the following:

- The pesticide's formulation, or the mixture of ingredients, which can dictate the way the product is applied. Common formulations include aerosols, dusts, granules, and wettable powders. A more complete list of formulations can be found here: http://npic.orst.edu/factsheets/formulations.html. Choosing different formulations can reduce the risk of pesticides. For example, choosing an insecticide granule rather than a liquid spray can cut down on exposure to residues for bees in the landscape.

- The pesticide's active ingredient, or the chemical in the product that manages the target pest. Different active ingredients pose different levels of hazard. A pesticide's label should dictate what non-target organisms may be at risk if exposed to the product, allowing for informed choices between different active ingredients.
- The application methods used for pesticides. By changing the time of day that a pesticide is applied, risk can be greatly reduced. For example, treating at dusk avoids non-target pollinators. Other options include spot treatments of small areas rather than treating entire landscapes, reducing dosages, and employing low-volume applications.

Another part of using pesticides as part of IPM is recognizing the potential for pesticide resistance. Resistance occurs due to the pressure being placed on populations of pests by pesticides. A random mutation may occur, or the pest could be naturally predisposed to resistance, but either way, a population will slowly be able to withstand applications of products that had previously been effective at killing them. As part of an IPM program, pesticide rotation must be practiced. Rotation describes using a different ***mode of action*** against pest populations that have already been treated. Modes of action are the ways in which an active ingredient kills the pest. By switching between different modes of action, we are targeting different systems inside of the pest and reducing the chances that resistance may arise. This is part of ***pesticide stewardship***, a way of making sure that pesticidal tools are effective for longer periods of time.

By taking all of these factors into consideration, nuanced decisions about pesticides in an IPM plan can be made. Rather than relying on "one-size-fits-all" pesticide applications, pesticides should be deployed in the least disruptive way possible. They don't have to be consider the final option for an IPM program.

PAMS

There is a somewhat new way of recontextualizing the many methods of pest management that are a part of IPM. It is called PAMS, which stands for prevention, avoidance, monitoring, and suppression. Some growers and educators find PAMS helpful to create a sequential plan of action, as opposed to the list of options that IPM sometimes becomes.

- Prevention: Prevention is the practice of keeping a pest population from infesting a field or site and should be the first line of defense. Prevention typically uses cultural methods, in particular sanitation, alternative host removal, and proper irrigation, to prevent conditions that favor pests.
- Avoidance: Avoidance may be practiced when pest populations exist in a field or site but the impact of the pest on the crop can be avoided through cultural practices. This includes choosing resistant and tolerant cultivars, crop rotation, and altering planting dates.
- Monitoring: Monitoring and proper identification of pests through surveys or scouting programs, including trapping, weather monitoring and soil testing where appropriate, should be performed to see if prevention and avoidance have been successful, or if further action is needed. Monitoring involves the many tools and traps listed earlier in the chapter.
- Suppression: Suppression of pest populations may become necessary to avoid economic loss if prevention and avoidance tactics are not successful. The primary suppressive tactics that growers can employ include cultural, physical, mechanical, biological, and chemical control. This includes the options outlined above.

To learn more about PAMS, see this link: https://www.canr.msu.edu/ipm/uploads/files/NRCS/PAMSapproach2010-9-1new.pdf

PAMS does not replace IPM as much as it offers an alternative perspective on teaching IPM to growers. The more sequential nature utilizes all the same tactics that are usually taught with IPM, but it just puts them in a slightly different order.

For More Information:

https://ipmworld.umn.edu/
https://ipm.ca.uky.edu/
http://npic.orst.edu/

Photos by Ric Bessin and Blake Newton, Entomology, University of Kentucky.

Chapter 11

Pesticides and Pesticide Safety

By Lee Townsend, Extension entomologist, University of Kentucky.

In this chapter:

Pest is not a biological term for an organism's environmental role as are the words *plant*, *herbivore*, *predator*, and *scavenger*. It is a term for an organism that is either causing damage or is somewhere where it's not wanted. Pests can include plants, insects and their relatives, and microorganisms that cause plant diseases. Often, pests are a problem because we use cultural practices or create conditions favoring organisms that they feed on, compete with, or infect.

Key pests are present and often cause enough damage to require regular control (for example, Japanese beetles on roses). Occasional pests require control during some years because of favorable weather conditions (such as fireblight on crabapples). Sporadic pests do not require control most years but may be very damaging in certain circumstances (such as periodical cicadas on newly established trees).

Some natural forces act on all organisms, causing their numbers to rise and fall from year to year. You may not be able to alter the effect of natural forces on a pest population, but you can be aware of their influence and take advantage of them whenever possible. These natural forces include climate, natural enemies, geographic barriers, food and water supply, and shelter.

Unfortunately, natural controls may not act quickly or completely enough to prevent unacceptable injury or damage. That is when other control measures must be used. Those measures include host resistance, biological control, cultural control, mechanical control, sanitation, and chemical control, or pesticides.

The active ingredient in a pesticide product is a chemical that, when used according to label directions, can reduce or control a pest problem. A pesticide application should be thought of as a temporary solution to a pest problem, not the way to solve it. Ideally, a pesticide helps to reduce losses or damage until the conditions leading to the outbreak change or those conditions can be corrected.

Accurate identification is the first step in an effective pest management program. (See Chapter 7, Insects, in this manual for more information.) Identification is the key to all kinds of information about the pest, including its life cycle, behavior, and recommendations for effective management. Incorrect pest identification is a leading cause of pest control failures and improper use of pesticides.

Your county office of the Cooperative Extension Service can help with pest identification and control recommendations. Diagnostic labs in plant disease, insect, and weed identification are also available, along with help in how to take useful pest samples. Most of these diagnostic services are free.

Types of Pesticides

Herbicides

Herbicides are pesticides that kill plants. Selective herbicides are used in lawns, landscapes, and gardens to control unwanted plants without damaging desirable plants. Nonselective herbicides are used to kill all plants in an area. Selective (and in some cases nonselective) products are used as spot treatments to control weeds in turf and ornamental landscapes to remove undesirable species growing near desirable plants.

A herbicide's mode of action is the way it affects a plant. Some herbicides damage leaf cells, causing them to dry up; others reduce the nutrient uptake. A few interfere with the plant's ability to grow normally or to conduct photosynthesis. The mode of action often dictates when and how a herbicide is used. Herbicides must adequately make contact with and enter the plant. Then, a sufficient amount of the herbicide must move to the site of action to produce the desired effect.

To inhibit germination or seedling growth, use preemergent herbicides. To control weed seedlings, these herbicides must be applied to the soil before the seedlings break through the soil surface. In order to come into close contact with germinating weed seeds, these products require rainfall or incorporation into the soil. Some products do not move within the plant, so injury symptoms occur only at the site of uptake. In contrast, systemic herbicides enter through the roots and move up. Their effects are most obvious where the product tends to accumulate.

Postemergent herbicides are applied to the foliage of growing weeds. Those that become active upon contact kill the plant by destroying leaf and stem tissues. They require thorough spray coverage. In contrast, systemic postemergents move within leaves and other green parts to growing points, where they act. These products vary in their ability to move within a plant.

Factors that affect how well these herbicides work include characteristics of plant leaf surface, plant size and age, water stress, air temperature, humidity, and herbicide additives. Differences in the amount of herbicide uptake within the plant often explain the year-to-year variation in herbicide effectiveness.

Plants that can rapidly degrade or deactivate a herbicide can escape its toxic effect. However, plants under stress (such as hot or cold temperatures, high humidity, or physical injury) may be affected by herbicides that they normally tolerate. Also, misapplication, especially at excessive rates, can overwhelm the ability of the plant to degrade or deactivate the chemical and result in plant injury.

Fungicides

Fungicides are pesticides that destroy or inhibit the growth of fungi. Contact fungicides, sometimes called protectant fungicides, remain on plant surfaces after application and do not enter plant tissue. In order to be effective, contact fungicides must be on the plant's surfaces before infection begins.

Systemic fungicides are absorbed into the plant and moved up within the water-conducting tissue (xylem); downward mobility is limited. Systemic fungicides sometimes can suppress the fungus after it has infected the plant.

Fungicide labels usually provide a range of application rates and intervals. Fungicides can be used as a preventive (usually at low rates and/or with long intervals between applications) when a disease outbreak has not yet occurred but when weather favorable for disease is expected. Fungicides may also be used, often at higher rates and/or at short intervals, after an outbreak has occurred and disease pressure is high. Such applications cannot cause sick tissue (yellow or brown leaves, rotted roots) to become healthy again, but they can protect uninfected tissue and new growth. These applications are only effective if the turf is actively growing.

Insecticides

Insecticides can be classified as either broad-spectrum insecticides, which can kill a variety of insects (caterpillars, beetles, aphids, etc.) or as selective insecticides, which affect a limited range of species (for example, caterpillars only) and can help to preserve beneficial species.

Stomach poisons kill insects with chewing mouthparts after they feed on treated plant tissue, while contact insecticides must be absorbed into the body to kill the target. Contact insecticides often are used against sap-feeding pests that do not eat plant tissue and require thorough spray coverage. An insecticide may work as a stomach poison against caterpillars or beetles and as a contact insecticide against aphids or scale crawlers. These products are broken down by moisture, sunlight, or microorganisms, so their residual effect is limited. Consequently, correct timing of applications is important.

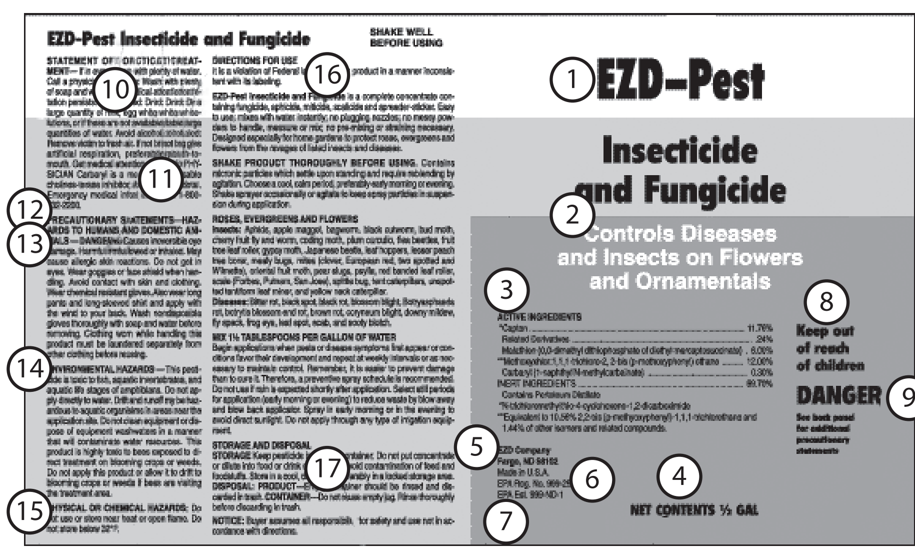
Systemic insecticides are absorbed into plants through the roots or foliage. They can be particularly effective against sap-feeding insects such as aphids and may provide control of some borers and leaf miners. Uptake of a systemic insecticide by the roots and movement to the pests' feeding site may take several weeks, so this type of insecticide may have to be applied several weeks before the pests are active. Systemic insecticides can remain in the plant at effective levels for a long period of time and may have an impact on beneficial insects.

While many insecticides affect the insect's nervous system, products with different modes of action are being used—those that target muscles, insect development and metamorphosis, or parts of the nervous system that are distinctive to insects.

The active ingredients in organic insecticides typically come from plant extracts (pyrethrins, neem), products from soil microorganisms (Bt, spinosyn), or plant fatty acids (insecticidal soaps). The spectrum of pests affected and the length of control following an application of organic insecticide may be limited

The Pesticide Label

The pesticide label is the way the manufacturer tells you how to use a product safely and effectively. Always read the label before you buy and use a product. Check the directions-for-use section to be sure that the plants, insects, or pathogen, and the site that you intend to treat are listed. Be sure you understand how and when to apply the pesticide with appropriate equipment.



(See the next page for explanations of numbered sections on pesticide label example.)

(Continued from previous page)

Pesticide Label Sections Explained

1. The product name or trade name appears in large print at the top of the label.
2. Type of pesticide—the label must identify the type of pesticide or the types of pests that it controls.
3. The ingredient statement must include the concentration and common (generic) and/ or chemical name of each active ingredient in the product and percentage of inert ingredients.

Many pesticide products, even though produced by different manufacturers, contain the same active ingredient. By purchasing pesticides according to the common name you will be sure you are getting the correct active ingredient no matter what the brand name is. When comparing two different products with the same active ingredient, be sure to compare the amount of active ingredient in each product. Often, different products will contain the same active ingredient but the concentration will vary. Make comparisons based on use rates of pesticides containing the same amount of active ingredient.

For example, Sevin is a brand name of a common insecticide used in the garden and landscape. Its common name is carbaryl; the chemical name is 1-naphthyl N-methylcarbamate. Being able to recognize the common name may allow you to find the pesticide you want under a different brand name. It may be sold as a 50% wettable powder (WP) or a 25% WP. The actual concentration of the active ingredient in the spray tank will be the same, regardless of the amount in the product. The use rate of the 25% WP per gallon of water will be twice that of the 50%WP.
4. The net contents tell how much product is in the container in units of liquid or dry measure.
5. Name and address of the manufacturer.
6, 7. The EPA registration number is unique for each pesticide product. It identifies the manufacturer and product and indicates that the product has been approved by the EPA for the listed uses. The EPA establishment number identifies where the product was produced.
8. All products must bear the statement "Keep Out of Reach of Children."
9. The signal word indicates the acute toxicity of the product.
10. The statement of practical treatment lists the first-aid treatment that should be given in case of accidental exposure to the pesticide.
11. The note to physician lists treatment information and antidotes and often provides an emergency phone number for further information.
12. Precautionary statements identify potential hazards and recommend ways that the risks can be minimized or avoided. Types of precautionary statements include "Hazards to Humans and Domestic Animals," "Environmental Hazards," and "Physical or Chemical Hazards."
13. Hazards to humans and domestic animals. The signal word is listed followed by statements indicating which route(s) of entry (mouth, skin, lungs, eyes) are most likely to be harmful and must be particularly protected. The label will then provide specific action that can prevent overexposure to the pesticide. Protective clothing and equipment required to handle or apply the pesticide will be listed.
14. Environmental hazards warns of pesticide risks to wildlife, birds, fish, bees, and the environment and provides practical ways to avoid harming them. Some examples are "This product is highly toxic to bees exposed to direct treatment or residues on plants," "Do not contaminate water when cleaning equipment or when disposing of wastes," and "Do not apply where runoff is likely to occur."
15. Physical or chemical hazards lists any special fire, explosion, or chemical hazards the product may pose.
16. Directions for use begins with this statement: It is a violation of Federal law to use this product in a manner inconsistent with its labeling. The instructions list what pests the product will control and the plants, crops, or sites the product is intended to protect. The directions also provide information on when, where, how, and in what form the product should be applied, proper equipment to be used, correct dosage, mixing directions, compatibility with other often-used products, minimum time between the application and entry into the treated area for unprotected persons, and possible problems with plant injury.

Harvest interval: When used on fruits or vegetables, there may be a period of time that must elapse from application until the residue drops to a level at which the crop can be safely harvested. It is a mistake to assume that a residue can be washed off if the crop is harvested before the waiting period is complete. The harvest interval is often listed as a number in parentheses following the crop name.
17. Storage and disposal directions: This section of the label will tell you how to store and dispose of the product correctly. Pay attention to specific temperature conditions that are listed.

What pesticide label signal words mean:

Signal Word	Toxicity	Approx. Lethal Human Dose
Danger-Poison/Danger	Highly toxic or harmful to skin/eyes	A few drops to a teaspoon
Warning	Moderately toxic	1 teaspoon to 1 tablespoon
Caution	Low toxicity to relatively nontoxic	1 tablespoon to 1 pint or more

Exceptions to Label Instructions

Federal law allows pesticides to be used in some ways not specifically mentioned in the labeling. Unless it is a violation of the state law, you may do the following:

- Apply a pesticide at any dosage, concentration, or frequency less than that listed on the labeling
- Apply a pesticide against any target pest not listed on the labeling if the application is to a plant or site that is listed
- Use any appropriate equipment or method of application that is not prohibited by the labeling
- Mix a pesticide or pesticides with a fertilizer if the mixture is not prohibited by the labeling
- Mix two or more pesticides if all the dosages are at or below the recommended rate

Pesticide Formulations

A pesticide formulation is a mixture of chemicals (active ingredient + inert ingredients) that control a pest. Different formulations are developed for safer, easier handling, mixing, or application; reduction of drift off-target; or specific application equipment.

Liquid

Emulsifiable concentrates (EC or E) package the active ingredient with a solvent and an emulsifier so it can be mixed with water and applied with a sprayer. ECs are easy to pour and measure, but the solvent can damage the leaves of some sensitive plants (the solvent has "phytotoxicity"). Also, an EC formulation is easily absorbed if spilled on the skin.

Flowables (F) contain the active ingredient on very fine particles in a milkshake-like liquid. A flowable is easy to pour and measure accurately, but it does not dissolve in water. The small particles are suspended, so the diluted spray must be agitated regularly to keep the particles from settling to the bottom of the tank. Flowables have no solvent, so there is less chance of leaf burn.

Dry

Dusts (D) are fine clay or talc-like products with a low percentage of active ingredient. A dust is ready to apply and requires no mixing or cleanup. However, it is hard to treat the lower surfaces of leaves and large amounts drift off target.

Granules (G) have an active ingredient that is on or in small clay particles that are applied with a spreader or shaker can. Granules are designed to let the pesticide fall to the soil surface rather than stay on the foliage.

Wettable powder (WP or W) formulations are made by putting the active ingredient in a fine powder. They are like a dust formulation but with a much higher percentage of active ingredient. WPs are mixed with water and sprayed on trees or plants. This type of formulation needs continuous agitation in the spray tank to maintain it in suspension. Inhalation and skin/clothing exposure is a problem.

Soluble powder (SP) is an active ingredient in powder form that dissolves in water.

Other

Ready-to-use (RTU) products are sold in aerosol cans or hand-pump sprayers. No mixing or cleanup is necessary. This approach is efficient when a small number of plants need to be treated.

Baits (B)are made by adding the active ingredient to an edible or attractive substance. Baits are often used to control slugs, snails, or small ground insects and rodents.

Figure 11.1. Hose-End Sprayer

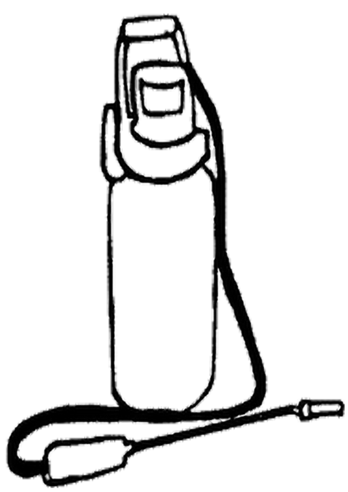


Figure 11.2. Compressed Air Sprayer

Application Equipment

Pesticide application equipment comes in all shapes, sizes, types, and prices. Select equipment that fits your needs and situation. Following are various types of application equipment:

Hose-End Sprayer—These small, inexpensive sprayers are designed to be attached to a garden hose (Figure 11.1). With some sprayers, a small amount of pesticide is mixed with water—usually no more than a pint—and placed in the receptacle attached to the hose. With others, a pesticide concentrate is already in the container, which is connected by a tube to the hose opening. When the water is turned on, the suction created by the water passing over the top of the tube pulls the concentrate up and into the water stream.

Potential problems include poor spray distribution, drift onto the applicator, and drift onto non-target areas. Metering of the concentrate into the water stream can be inaccurate, since it is determined by the water pressure. These sprayers put out an excessively high volume of spray for most needs, using excessive pesticide. All hose-end sprayers should be equipped with an anti-back siphon device to prevent the pesticide from being drawn back into the water system if there is a drop in water pressure.

Compressed Air Sprayer—The spray is mixed in a small tank, generally one to three gallons (Figure 11.2). A hand-operated pump supplies pressure during application. A uniform spray concentration can be maintained because the pesticide is mixed with a known quantity of water. Frequent agitation of the spray mixture is necessary when using a dry formulation (WP, W, D, G, or F). The applicator has excellent coverage control, so this sprayer is a good choice for treating flowers, shrubs, and small trees, but the spray will not reach into tall trees.

Hand-Pump Sprayer—These sprayers can be used to treat individual plants or small groups of plants. Many ready-to-use formulations are available for this type of container.

Calibrating Sprayers

Label instructions for spraying pesticides on plants usually are based on mixing specific volumes of product and water (for example, one fluid ounce in one gallon of water) and wetting the plants to the dripping point. Sprayer calibration is not necessary. Over-treating can occur if more product per gallon than specified on the label is added or if the foliage is wet excessively, both of which can injure leaf tissue, so the applicator should decide how much application to spray.

Label instructions for treating turf or soil, in contrast to those for plants, are usually based on a specific amount of product, such as three fluid ounces in two to five gallons of water per 1,000 square feet. Calibration is required for turf and soil application—so that the area can be treated evenly at the recommended rate, the applicator needs to know both the sprayer output (ounces per minute) and the amount of time needed to treat a specific area.

Sprayer calibration is relatively easy and should be done before the start of each growing season. The delivery rate will vary with the air pressure in the tank and size of the sprayer nozzle opening. Pressure in the tank will drop as you spray, so be sure to pump frequently in order to maintain a uniform delivery rate. Also, check regularly to make sure the nozzle opening has not become plugged.

Here is the procedure for calibrating a sprayer:

1. Fill the tank with water and pump up the tank pressure. Use a stopwatch as you spray water into a pint jar to determine how long it takes to deliver a known amount. Suppose it takes 30 seconds to deliver one-half cup of water, or one minute to deliver one cup (eight fluid ounces per minute).. Mark the delivery time on the sprayer for future use.
2. Mark off a known area on a driveway or hard surface so you can see the water deposit (for example, ten feet by ten feet) and measure the time it takes to spray the area evenly and thoroughly at a normal walking speed, which will tell you how long it takes to spray 100 square feet. If it takes 30 seconds to spray 100 square feet, it will take five minutes to spray 1,000 square feet. At eight fluid ounces per minute, you will use five cups, or 40 ounces, of water. If the label calls for three tablespoons of pesticide for 1,000 square feet, those three tablespoons must be mixed with 40 ounces of water to achieve proper spray coverage.

Mixing Pesticides

Pesticide *compatibility* exists when two or more pesticides can be mixed together without causing adverse effects such as jelling, forming of clumps in the tank, or the pesticides remaining unmixed.

Synergism occurs when mixing of two or more pesticides increases their activity. Synergism may increase control or result in the need for less chemical. It may also be more harmful to a nontarget organism. A synergistic effect can also be undesirable, causing death or damage to the organism that is being protected. No chemicals should be mixed together unless the label specifically says they are compatible.

When mixing of two or more pesticides results in reduced effectiveness, it is called *antagonism*.

In some cases, pesticide labels include information about tank mixes and recommend or caution against specific combinations. Pesticides can be mixed unless prohibited by the label, but the applicator assumes responsibility for any problems that occur.

Some Application Precautions

Before adding pesticide, always check application equipment for leaking hoses or connections and plugged, worn, or dripping nozzles. Before spraying, clear all people, toys, and pets from the area to be sprayed. To minimize drift, apply pesticides only on days with light breezes. If moderate winds (more than 10 mph) arise while you are working, stop immediately. Reduce drift by spraying at a low pressure and using a large nozzle opening. Generally, early morning and late evening are the safest times of day to spray to reduce chance of drift.

Vaporization is the evaporation of an active ingredient during or after application. Some pesticide vapors can cause injury. High temperatures increase vaporization, so choose pesticide formulations that do not evaporate easily, and spray during the cool part of the day. Some products, such as 2, 4-D, are very volatile under favorable conditions. These products should not be used near highly sensitive plants such as grapes and tomatoes. Do not apply when it is windy or when temperatures following application will climb above 85°F.

Cleaning Equipment

Thoroughly clean all equipment immediately after use. Do not store diluted pesticides in the spray tank. If you have excess pesticide, spray it over an area or on specific plants that are permitted by the label, first checking the label to determine what the safe areas are. Thoroughly clean all spray equipment inside and out with clean water, and don't forget to flush hoses and nozzles. Use caution to ensure that the cleaning water does not damage crops. Do not dump the rinse water in a confined area where it will be concentrated and may become a pollutant. Instead, spray the rinse water over a broad area, further diluting the pesticide. Never rinse pesticides down the drain!

Storage and Disposal

Use and store pesticides away from children and animals.

The best solution to the problem of what to do with excess pesticides is to avoid having them—buy only the amount needed for a year or a season. Calculate carefully how much diluted pesticide is needed for a job and mix only that amount, and use all the mixed pesticide in accordance with labeling instructions.

If you must store pesticides, store them in their original containers in a locked cabinet. They should be protected from temperature extremes, because some can be damaged upon freezing and others can be altered by heat. Do not store pesticides in the home!

To dispose of empty containers, first rinse them out, pouring the rinse water into the spray tank. Rinse three times, allowing 30 seconds for the water to drain between each rinse. Before disposing of the cans, wrap them in newspaper and secure them. The empty containers are best placed in refuse cans destined for a sanitary landfill. If possible, break the containers before disposal. Do not burn paper containers.

Never re-use empty pesticide containers other than to refill them with the original pesticide. Never allow children to play with empty containers.

Common Reasons for Control Failures

If the pesticide doesn't work, ask yourself these questions:

1. Was the pest identified correctly? If it wasn't, the wrong pesticide may have been used or applied at the wrong time.
2. Was the correct rate of pesticide application used? Lack of calibration or faulty equipment can cause control failures.
3. Was the application timed correctly? Sometimes the pests are too large to be controlled by a pesticide or they're in a less susceptible stage. In other cases, the damage is already done and killing the pest has no impact on the problem.

Safety

Safe use of pesticides involves self-protection and knowledge of proper techniques for mixture, application, cleaning of equipment, storage, and disposal. You also need to be able to recognize the symptoms of pesticide poisoning.

Use safety precautions as described in this section and treat all pesticides with respect, taking care to always follow label directions.

Tips for Safe Handling and Mixing

Here are some tips for safe handling and mixing of pesticides:

- Wear rubber gloves and any other protective equipment, such as eye protection, required by the label.
- Keep children and pets away from the area where you are mixing pesticides.
- Close container caps when you are finished using the pesticide.
- Do not leave containers unattended while applying pesticides.
- Keep a separate set of tools, including measuring spoons and cups and stirring paddles, for mixing and applying pesticides. Use plastic or metal items, not glass or wood.
- Open and mix pesticides outdoors or in a well-ventilated space.
- Mix only the amount of pesticide you will use.
- Have an absorbent material available to clean up a liquid spill, such as cat litter (best), sawdust, or sweeping compound. These materials can also be used to clean up other spills too, such as paints, solvents and fuels. Spread the absorbent on the spill, then sweep it up and put it into a heavy-duty plastic bag. Do not wash down spills with water.
- Any material used to clean up the spill should be properly disposed of, including a broom.
- Small quantities of spilled homeowner pesticides and cleanup materials may be placed into a heavy-duty plastic bag and securely sealed and disposed of in household trash. Immediately wash your hands and any exposed areas of your skin with soap and plenty of water. Shower if necessary.

Personal Protection

The minimum protective equipment to wear during the mixing and application of any pesticide is long pants, a long-sleeved shirt, shoes with socks, and rubber gloves. A hat is needed if you are spraying tree foliage or where you may be exposed to drift from above.

After using any pesticide, wash your hands and arms thoroughly with soap and water. If you have been doing a lot of spraying or dusting, remove your clothes, take a shower, and put on clean clothes. Clothing worn while applying pesticides should be laundered separately from the family wash. After cleaning pesticide-contaminated clothing, the washer should be run once without laundry but with detergent.

Know Symptoms of Pesticide Poisoning

It's important to be aware of the early symptoms and signs of pesticide poisoning. These symptoms are general and similar to those of flu or heat stress. They include fatigue, headache, and dizziness. Exposure to concentrated pesticides can also cause blurred vision, excessive sweating and salivation, nausea and vomiting, and stomach cramps or diarrhea.

First-aid procedures vary somewhat depending upon the pesticide, so see the pesticide label for instructions. In general, however, you want to stop the exposure and wash or flush the area to remove or dilute the pesticide.

Specific information on poisons and chemicals is available from the Kentucky Regional Poison Center of Kosair Children's Hospital, (800) 222-1222 and online at https://kypoisoncontrol.com/.

Other Safety Issues

Pesticides and the Environment

Pesticides can harm the environment if they are not used correctly. Most pesticides break down quickly and remain in the environment only briefly before being changed into harmless products. Some, however, break down slowly and stay in the environment for a long time. They can build up in some plants and in the bodies of animals and people.

Responsible pesticide users know and follow good practices that achieve effective pest control with very little risk of environmental impact.

Anyone who uses a pesticide must ask the following questions:

- How could this pesticide affect the immediate environment where it is being used?
- What is the danger that the pesticide will move out of the use site and cause environmental harm elsewhere?

Off-Target Pesticides

Fine mists of herbicides can drift to nearby gardens or landscape plants and either injure them or leave unacceptable residues. The natural enemies of pests can also be killed by pesticides. To protect beneficial insects, avoid excessive use of insecticides—spray only when pest activity is increasing or high. Use selective products and spot-treat infested areas when possible.

Life in streams or ponds can be contaminated by accidental spraying of ditches and waterways, runoff from sprayed landscapes, or careless disposal of containers. If more than one pesticide will control the pest, choose the one that is the least hazardous to the environment and most useful for the situation.

How to Protect Pollinators From Pesticides

Most people who are active in caring for their lawns and landscaped plants are aware of (and concerned about) the decline of insect pollinators. Reasons for the diminishing numbers of honey bees include combinations of habitat loss, parasites (such as mites), diseases (including bacteria and viruses), and pesticide exposure. Even sub-lethal exposures to pesticides can negatively impact insect pollinators in many ways, such as negatively affecting their orientation and feeding behaviors and their ability to reproduce and increasing their susceptibility to diseases.

The most important action to protect pollinators is to not apply pesticides to plants with open flowers. Encourage pollinators by establishing a variety of plants with different bloom colors and shapes that flower at different times throughout the season. This will provide continuous food (nectar and pollen) sources and nesting habitats for many types of insect pollinators.

Follow steps such as these to reduce exposing pollinators to pesticides:

- Mow all grass areas before applying insecticides. This will remove most of the flowering plants and will reduce bee foraging in treated areas.
- Apply insecticides when the air temperature is below 55°F; bees are less likely to be actively foraging then.
- Use buffer strips between treated turf areas and flowering plants.
- Spot-treat infested areas rather than broadcasting applications.
- Whenever possible, use insecticides or formulations that are least toxic to bees.

Insecticides should be the last resort in managing insect pests. While we want to maintain the visual appeal of our yards and landscapes, most insects that feed on our flowers, ornamentals, and turf are not harmful to the plant. Low numbers and light to moderate damage should be tolerated, when practical. Both homeowner and commercial use of insecticides should involve careful, responsible, and prudent applications of compounds that are toxic to beneficial insects. Some pesticide labels feature a "pollinator protection box" (or bee icon) that alerts applicators to specific use restrictions.

Integrated Pest Management

Integrated Pest Management (IPM) is an approach to pest control that incorporates, in a coordinated strategy, techniques including cultural practices, resistant varieties, use of natural enemies, and selective pesticide application.

Key IPM principles include the following:

- Control a pest only when it is causing or is expected to cause more harm than is reasonable to accept.
- Rather than to try to eradicate the pest, use a strategy that will reduce the pest numbers to an acceptable level.
- Cause as little harm as possible to everything except the pest.
- Be aware of weather conditions before and after application. Weather can impact pest control. Rain can wash off pesticide residues before the product can work, and poor growing conditions can prevent herbicides from being effective.

Credits

Compressed air sprayer: http://ag.arizona.edu
Pesticide label: http://www.ag.ndsu.edu

Chapter 12

Your Yard and Water Quality

By Van Bobbitt, former Cooperative Extension Master Gardener and urban horticulture coordinator; Robert Fox, Cooperative Extension project associate, King County; Holly Kennell, Cooperative Extension agent, King County; Curt Moulton, Cooperative Extension county chair, Pierce County; George Pinyuh, retired Cooperative Extension agent, King and Pierce counties; and Mary Robson, Cooperative Extension agent, King and Pierce counties; all of Washington State University. Adapted for Kentucky by Brad Lee, Extension specialist for water quality, and Richard Durham, consumer horticulture Extension specialist and state Master Gardener coordinator, University of Kentucky.

In this chapter:

We generally view gardening as a wholesome activity that enhances our environment. But pesticides, fertilizers, and erosion from gardens and landscapes can contaminate lakes, streams, rivers, oceans, and groundwater. Since the quality of our water resources affects our quality of life, we must learn how gardening practices can contribute to water contamination and how to reduce the threat to water quality.

We have long been aware of contamination from *point* sources such as factories and municipal sewage systems. Recently, we have become more aware of the threat of *nonpoint* source contamination from many relatively small, widespread sources. Each source by itself may seem insignificant; however, when added together, they can pose a serious threat.

Hundreds of thousands of homes in Kentucky have gardens. Each garden may contribute a relatively small amount of runoff containing soil, chemicals, and fertilizers. This runoff flows into surface water such as lakes, rivers, and bays. On the other hand, nitrate (from fertilizers and manure) and some pesticides can leach through the soil and contaminate groundwater (Figure 12.1).

Added up, these small amounts of contamination form a sizable problem. Only when individuals take responsibility and make wise choices can we control nonpoint source contamination.

Why Be Concerned?

Clean water is essential for human health, wildlife, recreation, and industry. Water contamination poses many threats. For example:

- Pesticides and nitrate can contaminate drinking water supplies. Nitrate levels as low as 10 parts per million (ppm) in drinking water can cause methemoglobinemia (blue-baby syndrome). While humans more than six months old are not seriously affected by nitrate in drinking water, cattle and sheep are. Sediments from erosion can destroy aquatic habitats for species that need clear, oxygen-rich water. Residues from lawn and garden fertilizers can overstimulate aquatic plant growth in shallow lakes and bays, making water unsuitable for fish and wildlife. Contamination of water by toxic chemicals can reduce fish and shellfish populations or make them unfit for human consumption. These problems concern not only those who fish for sport but also the commercial fishing industry and consumers.
- Contamination can make lakes, rivers, and beaches unsafe for swimming and other recreational activities.

Environmentally Sound Gardening

Gardens thrive with good water quality practices. The same simple, practical techniques that improve soil, beautify landscapes, reduce maintenance, and enhance plant health also can protect water quality.

For gardeners, the keys to protecting water quality include the following:

- Reducing the amount of potentially dangerous substances introduced to the environment
- Minimizing the amount of water that runs off the gardener's property

Landscape Design

An environmentally sound garden begins with proper planning and design. Properly selected plants and landscape features can reduce runoff and minimize pesticide and fertilizer use. Pavements allow much more runoff than a landscape of trees or grass (Table 12.1). On the other hand, maintaining a "perfect" lawn often involves more reliance on chemicals than do other types of landscapes.

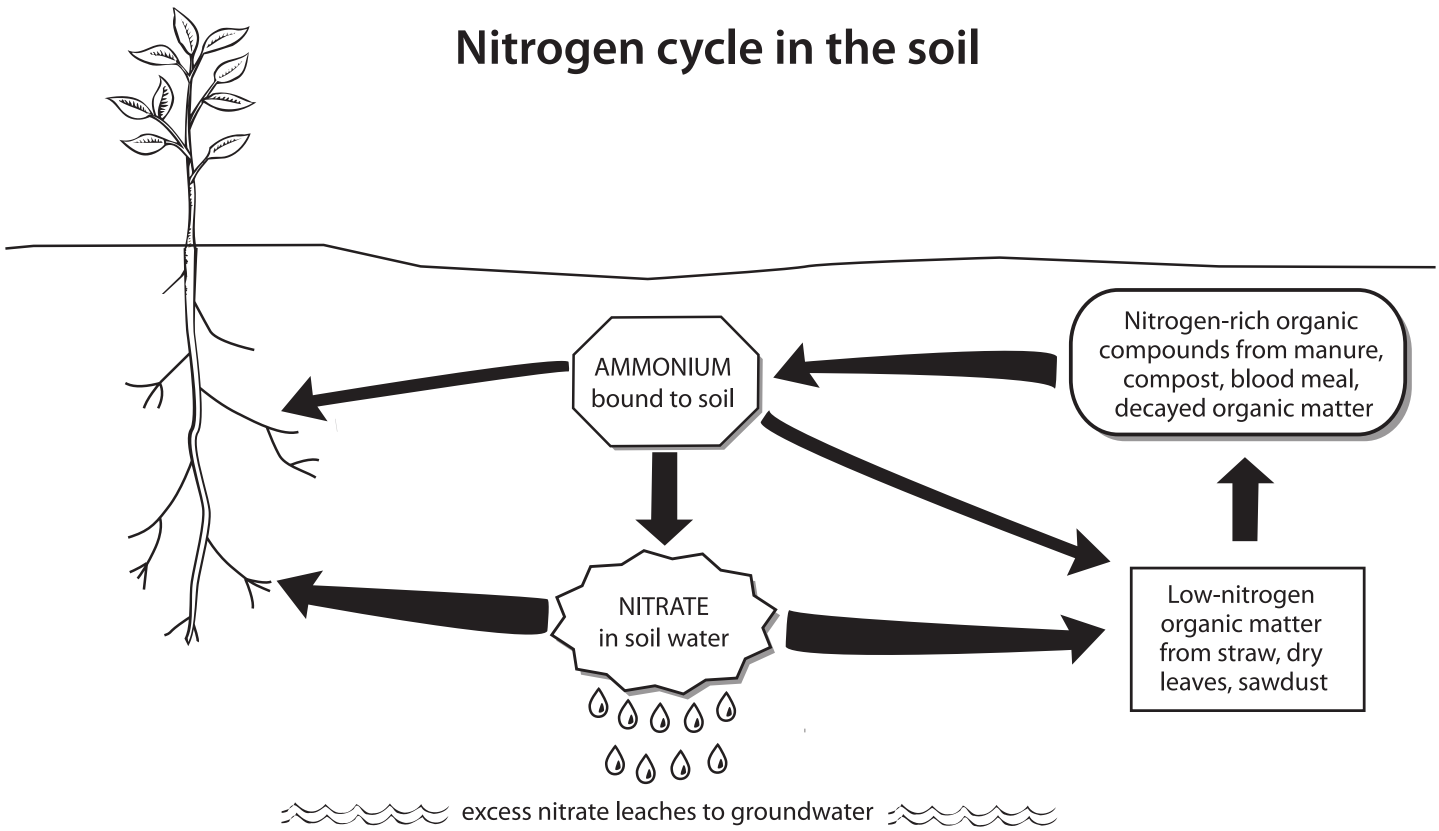


Figure 12.1. Nitrogen cycle in the soil. All of the arrows represent biological processes in the soil. These steps proceed more rapidly when the soil is warm and there is adequate moisture, but the soil is not saturated. Note that there are three possible fates of nitrate:
(a) Taken up by plants, if they are present
(b) Used by microbes to help break down coarse organic matter such as dry leaves
(c) Excess nitrate not used by plants or microbes can be carried to the groundwater by heavy rain or excess irrigation.
(Note: An alternate schematic of the nitrogen cycle is illustrated in Chapter 4, Soils and Fertility, AGR-204.)

What You Can Do

- Select plants adapted to the environmental conditions (sun, moisture, soil, and temperature) of your site to ensure healthy plants and reduced maintenance.
- Replace turf in inappropriate areas (e.g., dense shade; steep slopes; narrow, hard-to-irrigate areas; and heavy-traffic areas with compacted soil) with plants, mulches, or paving materials that require less irrigation, fertilizer, and pesticides.
- Use porous paving materials (e.g., wood decking, modular pavers, porous asphalt, gravel, or wood chips) instead of impermeable concrete or asphalt.
- Allow roof runoff to spread over well-drained soil, where infiltration can occur.
- Build gravel trenches along paved walkways and driveways to catch runoff.
- Where runoff is a special problem, create gravel seepage pits or a series of infiltration beds over a gravel or tile drainage system. Consult an agriculture engineer to ensure proper design.

Soil and Fertility Management

Soil is the essential foundation of a garden. Proper soil and fertility management produces a healthier landscape and reduces the potential for water contamination from erosion, fertilizers, and pesticides.

Drainage refers to the ability of soil to transmit water through the surface and subsoil. Most landscape plants, fruit trees, and berry bushes require good soil drainage to a depth of at least two feet.

Drainage also affects the potential for water contamination. A coarse mineral soil, such as sand, drains rapidly but

Table 12.1. Estimated runoff from different surfaces.

Land Cover	Runoff (%)
Dense forest	10
Light forest	15
Lawns	25
Gravel areas	80
Pavement and roofs	90

Source: King County, Washington, Surface Water Design Manual (January 1990).

also allows dissolved chemicals to leach into the groundwater. Clay particles bind these chemicals and slow their movement through the soil, reducing the likelihood of groundwater contamination. But a dense clay soil drains slowly, thus increasing surface runoff.

Fertility refers to the presence of minerals necessary for plant life. Unfortunately, the fertility of garden soils often is less than ideal for plant growth. Gardeners usually compensate by adding fertilizers, either from synthetic or natural sources. Overapplication of any synthetic or natural nutrient source can result in excess nutrients being carried into lakes and streams or leaching into groundwater. Overfertilization also wastes money, damages plants, and can encourage weeds.

Rainfall and moving water can carry away soil particles, organic matter, plant nutrients, and soil contaminants. This water-soil-chemical runoff can cloud natural waters, stimulate unnatural and ecologically disastrous algal blooms, and contaminate fish. Therefore, it is essential to minimize erosion and runoff.

What You Can Do

There are several things you can do to reduce the likelihood of fertilizers contaminating groundwater and surface water. They include the following:

- Have your soil tested; testing will detect pH problems that affect nutrient availability to plants. Tests also reveal deficiencies of nutrients such as phosphorus, potassium, and calcium. Kentucky county Extension offices will submit soil samples for testing for a minimal fee and provide a recommendation once results are known. See Chapter 4 regarding information on how to take a soil test. Your county Extension office also can provide names of soil testing labs.
- Use only the amount of fertilizer recommended; more is not better.
- Fertilize according to what your plants actually need. Established trees and shrubs do not need annual applications if they are putting on adequate growth and their leaf color is healthy.
- Use slow-release fertilizers (organic or synthetic) when possible to reduce the loss of excess nitrogen into groundwater or surface water.
- If you use quick-release synthetic fertilizers, make several small applications over a period of time instead of a large amount all at once. Split applications reduce the potential for nitrogen leaching.
- Time fertilizer applications correctly. Trees and shrubs make best use of fertilizer just before or as new growth begins in the spring. Fertilize herbaceous perennials at the beginning of the growing season. Fertilize annuals when they are actively growing.

Conditioning can greatly enhance soil productivity. Incorporating organic matter, such as compost, ground bark, or sawdust, increases the soil's ability to store moisture and nutrients. In addition, organic matter can buffer the effects of pesticides in the soil and prevent rapid leaching of many chemicals into groundwater.

Organic matter helps both sandy and clayey soils. In sandy soils, it improves moisture retention and reduces leaching of fertilizers and pesticides. In heavy clay soils, it improves water infiltration.

There are several approaches to reducing erosion. For example:

- Slow down runoff. Try terracing slopes; creating grassy swales; or building earth, wood, or masonry diversions.
- Mulch bare soil. Use straw, grass clippings, wood chips, ground bark, or geotextiles (landscape fabrics).
- Plant vegetation that lends itself to erosion control. Buttonbush, rough-leaf dogwood, silky dogwood, deciduous holly, and native grasses are a few examples.
- Protect existing vegetation where high water velocities are expected. E.g., use a concrete splash block at your rain gutter outlet, or place large, rough-edged stones at drainpipe outlets.
- Grow cover crops in your vegetable garden during winter to reduce erosion, trap nutrients, and add organic matter to the soil.

Using Garden Wastes

Like many things we do, gardening creates wastes: grass clippings, prunings, and leaves. Thrown into the garbage, yard wastes use up scarce landfill space. Landfills themselves can contaminate groundwater. Decaying vegetable matter thrown into a lake or stream can compete with marine animals for the limited oxygen supply. If processed in the garden, however, these wastes can be a valuable resource, contributing to healthy soil and plants.

What You Can Do

- Use leaves and grass clippings as a mulch. This practice reduces erosion, irrigation requirements, and weed problems.
- Run prunings and woody brush through a chipper and use the chips as mulch or to cover pathways.
- Compost leaves, needles, grass clippings, and annual weeds (before flowering) to create a valuable organic soil amendment.
- Cover compost piles with a tarp during the rainy season to help prevent leaching of nutrients.
- In case nutrients do leach from the compost piles, locate the piles away from bodies of water or places where runoff might occur.

- Compost herbicide-treated grass clippings for at least a year to eliminate potential herbicide problems. It's best to keep these clippings separate from other compost materials.
- Compost diseased plant materials, annual weeds that have flowered, or perennial weeds only if your compost pile is "hot."

Watering

The goals of environmentally sound irrigation are to maximize water infiltration and minimize runoff. Reduce the potential for runoff by reducing the need for supplemental irrigation. Use mulches to conserve moisture, and choose drought-resistant plants.

Overwatering can wash away soil, pesticides, and nutrients, which eventually find their way into surface water or groundwater. Overwatering occurs when water is applied faster than the ground can absorb it or when you let the water run too long. By watering efficiently, you will reduce your water bill while protecting water quality.

Hand watering, with either a hose or a watering can, generally is appropriate only for containers or small beds. Hand watering lawns and planting beds usually does no more than wet the soil surface, since most people are unwilling to invest the time needed for thoroughly watering large beds and lawns.

Sprinklers can generate considerable runoff if they apply water too fast or throw water onto paved surfaces. Soaker hoses reduce runoff and evaporation losses because they apply water slowly. Trickle or drip irrigation is more efficient, reducing water use by 50 to 80 percent compared with overhead irrigation.

Do not water according to the calendar, since a plant's water requirement varies depending on weather, soil, species, age, and size. Never allow seedlings to dry out. Newly established plants need frequent watering until their root systems become well established. Established trees and shrubs usually do well if you soak them once or twice a month during dry periods. Many drought-resistant plants require little or no watering once they are established.

Watch for signs that indicate your lawn needs watering: gray-green grass, turf that does not spring back when walked on, and blades of grass rolled lengthwise. Lawns generally need irrigation at least once a week in dry summers to stay green. Alternatively, you can let your lawn go dormant; it will turn green again when fall rains begin.

Apply no more than one-half inch of water per hour, but adjust this amount according to soil type. Use small cans to measure the amount of water your sprinklers apply. Turn off the water at the first sign of soil saturation or runoff.

What You Can Do

- Select plants that need minimal water. Many native plants and other species adapted to dry summers and falls require little, if any, irrigation.
- Decrease the amount of lawn. Turf generally requires more irrigation than a landscape of established trees, shrubs, and groundcovers.
- Increase your lawn's drought tolerance through good cultural practices (soil preparation, aeration, fertilization, and mowing at proper frequency and height).
- Store runoff from your roof in a rain barrel. Mount a hose tap at the bottom so you can use the water in your landscape and garden.
- Divide your landscape into irrigation zones, grouping plants that use a lot of water in one zone and those that use less in another. Built-in irrigation systems should have separate circuits for lawns and planting beds.
- Avoid frequent, low-intensity irrigations. They tend to encourage shallow rooting and make plants more susceptible to drought.
- Apply water slowly (generally not more than one-half inch per hour).
- Adjust sprinkler patterns and output to avoid runoff and application of water to paved surfaces.
- Where possible, use soaker hoses or drip irrigation rather than sprinklers.
- If you must water by hand, sink perforated cans into the soil by each plant to apply water directly to the roots.
- Water when plants need it, not according to the calendar.
- Apply mulches to conserve soil moisture.

Pest Management

A pest-free garden is expensive, impractical, and environmentally undesirable. Attempts to maintain a pest-free garden often result in heavy use of pesticides, which in turn increases the potential for water contamination.

Try to keep pest populations below the level at which they cause unacceptable damage. Allowing low levels of pests to survive helps maintain a population of their natural enemies.

The first step to effective pest management is to inspect your plants often so you can catch problems before they become serious. If you detect and deal with insect and disease problems early, you can reduce or eliminate the need for pesticides. The objective is to make your garden a healthy place for your plants and an inhospitable place for pests.

Nontoxic Pest Control Methods

Insects

- Keep your garden free of weeds and debris that provide a habitat for pests.
- Prune out insect-infested parts of plants and destroy the prunings.
- Cover susceptible crops with floating row covers or nylon screen to exclude certain pests.
- Use insect traps where appropriate. (Research indicates that light traps usually are ineffective.)
- Use a stream of water or a brush to dislodge insects.
- Handpick insects from plants.
- Encourage beneficial insects by planting flowers that provide nectar and pollen.

Diseases

- Plant disease-resistant cultivars.
- Rotate annual plants (both flowers and vegetables).
- Allow adequate space between plants and prune for good air circulation.
- Time waterings so that foliage dries by nightfall.
- Prune off and destroy diseased plant parts. Do not add them to your compost pile unless you are hot composting.
- Improve soil drainage and aeration.

Slugs

- Place beer in containers to attract and kill slugs.
- Overturn clay pots or place flat boards next to plants to lure slugs. Check frequently and kill collected slugs.

Weeds

- Hand-pull weeds or cultivate with a hoe where appropriate.
- Use mulches generously.
- Keep lawns healthy and dense to crowd out weeds.

What You Can Do

- Plant pest-resistant species and varieties of plants. Check with local nurseries, landscapers, Extension agents, or other Master Gardeners to see whether resistance information is available for the plants you are considering.
- Rotate vegetables and annual flowers so that the same plant or plant family does not occupy the same space every year. For example, tomatoes, potatoes, and petunias are all in the nightshade (Solonaceae) family. Rotation can reduce insect infestations and the buildup of soilborne diseases.
- Keep your garden clean. Rocks, wood, and debris provide great hiding places for slugs and insects.
- Weed your garden. Weeds can harbor insects and diseases that attack your plants.
- Time plantings to avoid peak insect infestations. Often the most destructive phase of an insect's life is brief and predictable. Check with your Extension office to see whether this information is available for specific insect pests.
- Preserve naturally occurring beneficial organisms by minimizing your use of pesticides.
- Properly identify plant problems. If your problem is caused by a pest, proper identification is important in selecting the safest and most effective control strategy. Remember that most problems are cultural or environmental and do not respond to pesticide applications.
- Determine whether a problem really justifies treatment. Many pests cause only cosmetic damage and are not life-threatening to plants.
- Try the least toxic control strategies first. Cultural methods often are a good place to start.
- Record your observations and the results of your treatments for future reference.
- If you use pesticides, choose those that pose the least threat to water quality. Examples include pyrethrins, insecticidal soaps, horticultural oils, and *Bacillus thuringiensis (Bt).*
- If you decide to use pesticides, apply them when the pest is most susceptible, not according to a predetermined calendar schedule.
- If using insecticides, spot treat only those plants or plant parts affected. Compared to cover sprays, spot treatments can drastically reduce insecticide use (by more than 90 percent in some cases) and still achieve good control.
- Apply preventive fungicides only to plants likely to develop disease problems. Better yet, plant disease-resistant species or cultivars.
- If you use pesticides, carefully read the label for directions, use restrictions, and health and environmental precautions.

For More Information

UK Cooperative Extension Publications

Living Along a Kentucky Stream (IP-73)
Principles of Home Landscape Fertilization (ID-73)

More information on this topic is available from the University of Kentucky Environmental and Natural Resource Issues web page at https://water.ca.uky.edu/

Chapter 13

Composting

By Craig G. Cogger, Extension soil scientist, Washington State University; Dan M. Sullivan, Extension soil scientist, Oregon State University; and James A. Kropf, Extension agent, Pierce and King counties, Washington State University. Adapted for Kentucky by Brad Lee, Extension specialist for water quality, and Richard Durham, consumer horticulture Extension specialist and state Master Gardener coordinator, University of Kentucky.

In this chapter:

Gardeners have long made and used compost to improve garden soil.

Today, we also compost plant and vegetable matter because it is an important way to reduce the waste burned or dumped in landfills. Yard wastes and vegetable scraps can make up as much as 20 percent of household garbage. Composting effectively recycles that waste into valuable organic matter that can be used as soil amendments.

Backyard composting is a simple, yet important, way to improve our communities and the environment.

The benefits are the same whether you compost in carefully tended hot piles or in passively managed slow piles.

Science of Composting

Composting carries out part of the earth's biological cycle of growth and decay.

Plants grow by capturing energy from the sun, carbon dioxide from the air, and nutrients and water from the soil. When plants (and the animals that eat them) die, they become raw material for the composting process. Microorganisms, fungi, insects, worms, mites, and other creatures convert the carbon from dead plants into energy for their own growth, releasing carbon dioxide into the air and generating heat in the process (Figure 13.1). They also recycle nutrients from decaying plants into their own bodies and eventually back into the soil through their waste or as decayed products as they die. Other plants and microorganisms use the carbon and nutrients released by the composting process, and the cycle begins again.

The material that remains from the decay process is similar to soil organic matter. It holds water and nutrients in the soil and makes the soil more porous and easier to dig.

The decay process can be manipulated to make it proceed quickly. The key is to balance food, water, and air in the compost pile to favor the growth of thermophilic (heat-loving) microorganisms.

One byproduct of microbial activity is heat. When conditions are favorable for high-temperature microorganisms, compost piles heat rapidly to 120°F to 150°F. The high temperature kills most weed seeds and pathogens (disease organisms) but does not kill mycorrhizae (beneficial fungi that help plant roots absorb nutrients). Once the hot phase is complete,

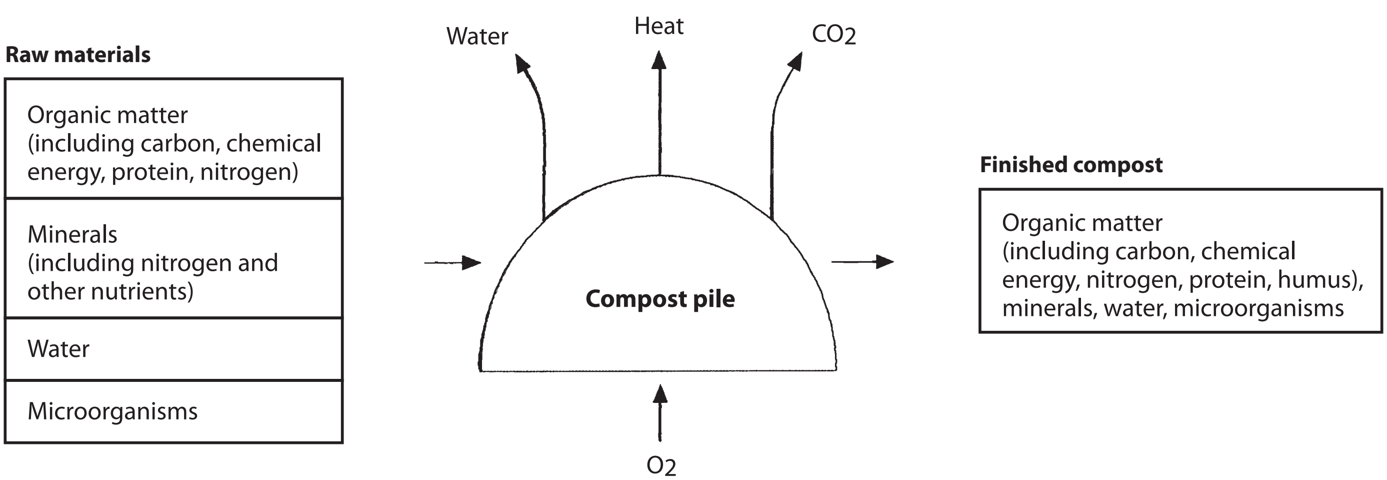


Figure 13.1. The composting process. The amounts of carbon, chemical energy, protein, and water in the finished compost are less than in the raw materials, and the finished compost has more humus. The volume of the finished compost is 50 percent or less of the volume of raw material.

lower-temperature microorganisms, worms, insects, and other invertebrates complete the decay process.

If ideal conditions for hot composting are not maintained, microorganisms still break down wastes, though decay is slower, cooler, and less effective at killing weed seeds and pathogens. Compost produced this way is still useful as a soil amendment, but it may contain weed seeds or pathogens if they were in the components used to make this "cold" compost.

Managing the Decay Process

The speed of the composting process and the quality of the finished compost are influenced by food, particle size, mixing, pile size, moisture, aeration, microorganisms, and nutrients.

Food (Raw Materials)

For fast composting, the initial mix must have the proper moisture and air content as well as organic materials that provide a rich food (energy) source for bacteria. Table 13.1 shows some materials commonly used in making compost. They are separated into energy materials, bulking agents, and balanced materials.

Energy materials provide the nitrogen and high-energy carbon compounds needed for fast microbial growth. If compost lacks bulking agents, these materials usually are too wet and dense to allow much air into the compost pile. When the pile is opened, it will have a foul, "rotten egg" smell.

Bulking agents are dry, porous materials that help aerate the compost pile. They are too low in moisture and nutrients to decay quickly on their own.

Balanced raw materials have both energy and bulking agent properties. These materials compost readily without being blended with other ingredients. Examples include horse manure mixed with bedding, spoiled alfalfa hay, and deciduous leaves. These materials are handy for ensuring the success of hot compost piles.

If balanced raw materials are not available, mixing bulking agents with energy sources provides the right balance of moisture, air, and nutrients for rapid composting. A mixture of one part energy source with two parts bulking agent (by volume) usually gives a reasonable mix for rapid composting. If energy materials are not available, a high-nitrogen fertilizer such as urea (44–0–0) or a high-nitrogen lawn-type fertilizer (without pesticides) may be added at a rate of about four ounces (one-half cup) per bushel, or about two to three pounds per cubic yard of starting compost material.

Table 13.1. Compost raw materials.

Energy materials *(High moisture, low porosity, high nitrogen)* • Grass clippings • Fresh dairy, chicken, or rabbit manure • Fruit and vegetable waste • Garden trimmings
Bulking agents *(Low moisture, high porosity, low nitrogen)* • Wood chips • Sawdust • Grass hay • Wheat straw • Corn stalks • Plain cardboard (not coated in slick paper or plastic)
Balanced raw materials *(Low to medium moisture, medium porosity, medium nitrogen)* • Ground-up tree and shrub trimmings • Horse manure and bedding • Deciduous leaves • Legume hay • Cow/dairy manure with bedding

Particle Size

Small particles have more surface area for microbial activity and are easier to mix. Grinding, cutting, smashing, or chopping raw materials reduces particle size. Hot composting requires a relatively uniform particle that is one-eighth to one-half inch in diameter.

Often, woody branches that have not been ground make it difficult to turn a pile. They also decompose very slowly. Grinding or chipping woody branches or piling them separately to allow them to slowly decay on their own may make the composting process work more efficiently.

Mixing

Contrary to popular opinion, layering is not the best way to build a pile. If all the materials are on hand when the pile is being built, mix them thoroughly throughout the pile. If materials accumulate over time, add new materials to the center of the pile. This practice helps aerate the center, where lack of oxygen is likely to occur.

Pile Size

If you are hot composting, the pile must be big enough to hold heat. A pile of about one cubic yard is big enough for year-round composting, even in cold-winter areas. A hot pile decays much faster than a cold pile. Small piles are usually colder because they have small cores that hold less heat. They also dry out faster.

Moisture

All materials in the pile must be moist but not soaking wet. Check moisture when the pile is turned. The mixed material should feel moist, but you should not be able to squeeze water out of it. At dry times of the year, you may need to add water.

Air

The microorganisms responsible for fast decomposition need oxygen, so the pile needs to be porous enough to pull in outside air to replenish oxygen as it is used. Including bulking agents in the mix creates a porous pile. As the pile decomposes, it will settle, reducing its exposure to air (aeration). Turning the pile or adding more bulking agents improves aeration.

Microorganisms

Raw materials used to form a compost pile usually contain all the microorganisms needed to make compost. If they're needed, the best source of microorganisms is finished compost. You don't need compost starters with special microorganisms. For a new compost pile, a few cups of garden soil may help start the process.

Nutrients

Just like people, microorganisms need nutrients (such as nitrogen, phosphorus, and sulfur) to grow and reproduce. These nutrients occur in the raw materials used in the compost mix. You usually don't need additional fertilizer from any source (organic or inorganic).

Nitrogen fertilizer may be beneficial for mixes consisting mainly of bulking agents. The best way to add fertilizer is to dissolve it in water and wet the pile with a dilute solution.

Additives such as blood meal and bone meal are simply organic fertilizers; they do not contribute anything magical to the compost pile.

How to Make Compost

You don't need a bin or other container to make compost. Piles work well. Some people prefer containers, however, because they look neater or because it is easier to shield them from pests. Containers can be simple or fancy. Make them from materials such as old pallets, lumber, mesh fencing, or cinder blocks (Figure 13.2).

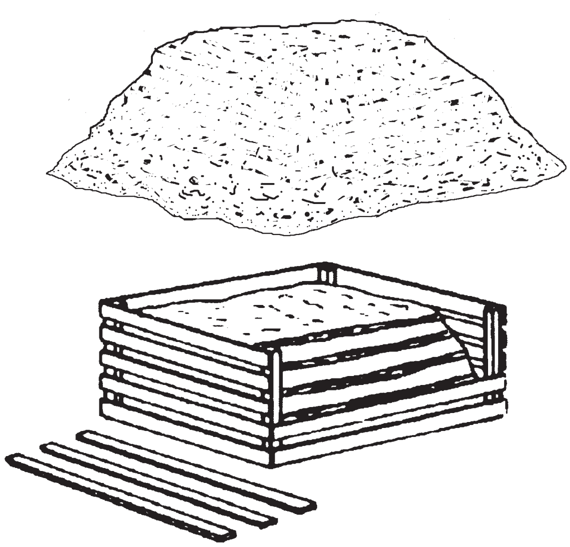


Figure 13.2. Some people compost in open piles; others prefer using bins.

Slow (Cold) Composting

You can turn yard wastes into a useful soil amendment conveniently and easily by slow composting. It often is the best method for people who do not have the time to tend a hot compost pile. Simply mix nonwoody yard wastes into a pile and let them sit for a year or so. Microorganisms, insects, earthworms, and other decomposers will slowly break down the wastes. A mixture of energy materials and bulking agents provides the best food source and environment for decomposition (see Table 13.1).

Add fresh wastes by opening the pile, placing the wastes in the center, and covering them. This method helps aerate the pile and also buries the fresh wastes so they do not attract pests such as flies, rats, and raccoons.

Fruit and vegetable wastes are particularly appealing to pests, so be sure to bury these wastes within the pile. If pests are still a problem, you may need to screen the pile or use another method of composting those wastes.

One option is to bury them directly in your garden. Dig a hole or trench about a foot deep, add a few inches of waste, mix it with the soil, and refill the trench with soil.

Another way to avoid pests is to compost fruit and vegetable wastes in a worm bin (described later in this chapter).

Slow composting does not produce the heat needed to kill many weed seeds. It is best to pull and compost weeds before they go to seed. If you put seeds in the compost pile, be prepared for more weeding.

Fast (Hot) Composting

If you create and maintain a balance of air, moisture, and energy for compost microorganisms, they produce a hot pile that breaks down quickly. The heat kills many weed seeds and disease organisms. Making hot compost takes extra effort, but it produces a high-quality product quickly.

One method for making hot compost is described below.

Steps for building the pile

1. Collect enough material to make a pile at least one cubic yard in volume. (An open pile five feet wide at the base by three feet high holds about a cubic yard.) Use roughly two parts bulking agent to one part energy material (see Table 13.1). Chop, shred, mow, or smash coarse materials so they will break down faster.
2. Start the pile by adding energy material and bulking agent, then mix with a pitchfork.
3. Squeeze a handful of the mixed material to check its moisture level. If you can barely squeeze out a drop of water, the moisture level is ideal. If the pile is too dry, add water and check the moisture again. If it is too wet, mix in some drier material.
4. Continue adding energy material and bulking agent, mixing, and checking moisture until the pile is built.

Turning

Use a pitchfork to turn the pile weekly, and add water when needed. Turning improves the porosity of the pile and speeds decay. It also mixes material from the outside of the pile into the hot center. Cover the pile during rainy periods so it will not get too wet.

Curing

After initial mixing, a regularly turned pile usually stays hot (120°F to 150°F) for several weeks to a month. It will shrink to about half its original volume by the end of this time.

The pile then needs to sit another four to eight weeks to cure. Curing affects the availability of nitrogen and the microbial activity of the compost. Uncured compost may harm some plants, especially when compost is used in potting soil or to start seeds. Curing is less critical when small amounts of compost are worked into soil. With two compost piles, one batch can cure while another batch is started in the second pile.

Temperatures during curing are 80°F to 110°F. The compost is ready to use when at least eight weeks have passed since initial mixing, the pile no longer heats when turned, and the material looks dark and crumbly.

What if Hot Compost Isn't Hot?

If the pile isn't hot, do the following:

- If the pile is dry, add more moisture.
- If the pile is mostly bulking agent, add energy materials or nitrogen fertilizer.
- If the pile is too wet, add more bulking agent. In the rainy season, cover the pile or build a larger one.
- If the pile has a foul smell, try turning it more often or adding more bulking agent to increase the amount of air.
- If the pile is too small, try building a larger pile to better hold heat.

Sometimes you may have several problems to overcome. If the pile will not heat, all is not lost, because the pile will eventually break down by the slow method.

Using Compost

Compost's biggest benefit is to the garden. Mix compost with soil to add organic matter or use it as mulch.

Amending Soil

Well-decomposed, earthy compost is a good soil amendment. It makes soil easier to work and creates a better medium for plant growth. Mix one to two inches of compost into your soil before you plant a vegetable garden, lawn, flower bed, or cover crop.

Mulching

Compost applied to the soil surface helps to control weeds, conserve water, and protect soil from erosion. The best time to apply compost mulches is in early summer, after plants are established and the soil has warmed. Later, the mulch can be dug or tilled into the soil. When you are mulching perennial plantings, choose compost made from woody bulking agents; it decomposes slowly, resists compaction, and slows the establishment of weeds.

Sometimes compost will form a mat, crusting on the soil surface and impeding water movement into the soil. If matting does occur, simply work the compost into the upper soil layers to prevent crusting.

Worm Bins: A Way to Compost Food Wastes to Avoid Pests

Kitchen scraps composted in an outdoor bin sometimes attract pests, so you might prefer to compost them using worm bins.

Starting a Worm Bin

Most worm bins are made of plywood, but large plastic tubs with covers also work, as long as it is possible to drain off excess moisture. One solution is to nest two plastic containers and make holes in the bottom and and the lower third of the sides of the upper container, allowing excess moisture to escape and collect in the lower container. Worms avoid light, so the container 's interior should be dark, and it should have a good lid. The lid should cover the top but does not need to be securely attached. The container should have air holes—either on the lid, sides, or, if the container is not sitting directly on the ground, on the bottom. If you use a plastic bin, be sure to add both drainage and air holes. Never use a container that has been used for storing toxic chemicals. Construction plans for worm bins are available from many Extension offices or county solid waste departments.

The size depends on how much food waste you add per week. A box measuring one foot by two feet by three feet can handle six pounds of kitchen waste per week, which is about average for a family of four to six.

Place worm bins where you can control temperature and moisture. An ideal temperature range for worms is from 55°F to 77°F. Worms also need a moist environment (more on this below), and air circulation is a must in and around a worm box. Choose a location that is convenient for maintaining the box.

Start by putting bedding in the worm box. Corrugated cardboard, newsprint, and newspaper shredded in one-inch-wide strips make excellent bedding. Worms need some grit for breaking down their food, so add a little topsoil for this purpose. Put the worms in the bedding with their first feeding of food waste.

Many food wastes can be composted in worm bins. These wastes include fruit and vegetable peels, grains, pasta, baked

Commonly Asked Questions About Worms

Can a worm see?

No, worms don't have eyes. However, they are very sensitive to light, and they try to hide as soon as they are exposed to light.

Where is the worm's mouth?

The worm's mouth is in the first anterior segment. There is a small protruding lip just over the mouth. When the worm is foraging, this lip stretches out to sense food.

Does a worm have teeth?

Worms have no teeth for chewing their food. They grind food in their gizzard by muscle action.

How does a worm grind his food?

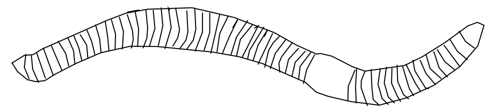
A worm can take only a small particle of soft, moistened food in its mouth. It ingests the food along with a grinding material such as sand, topsoil, or limestone. Contractions from muscles in the gizzard compress the particles against each other, thus mixing them with fluid and grinding them into smaller pieces.

Do worms need air?

Worms need a constant supply of oxygen from the air. The oxygen diffuses across the moist tissue of their skin, from the region of greater oxygen concentration (air) to that of lower concentration (inside the worm).

How do I use worm compost?

Use worm compost like any other compost. Sterilizing is not necessary.



goods, coffee grounds, and (in moderation) even coffee filters. Again, do not use animal products, including cheese, other dairy products, or meat.

Moisture

In order to survive, worms require 75 to 90 percent moisture in both their bodies and their bedding. To achieve this percentage, add three pounds of water for each pound of dry bedding (a ratio of 3:1). An easy way to check the moisture content of bedding is to squeeze it. If you release a few drops of moisture, the bedding is moist enough. If you can squeeze out five or more drops, the bedding is probably too wet.

Kinds of worms to use

Two varieties of red worms adapt to a box environment: *Lumbricus rubellus* and *Eisenia foetida*. These red worms feed on the surface of organic matter.

Nightcrawlers and other garden earthworms are very important for soil improvement but won't survive in a worm box. They live only in furrows in the soil.

Health and Safety Questions

Are there any plant materials to keep out of a compost pile?

When composting by the slow method, keep diseased plants and seed heads of weeds out of the compost pile. For any compost, avoid coarse, woody materials because they break down slowly and make the pile hard to turn.

Some plants contain compounds that slow microbial decay. Eastern redcedar *(Juniperus)*, often used for fence posts because of its resistance to decay, can break down slowly in compost piles. Also, avoid black walnut leaves and wood as these contain juglone, a compound that inhibits the growth of many plants. Some extremely dense, woody materials, such as avocado pits, do not compost.

Can a compost pile catch fire?

A compost pile will ignite only if it has a very hot zone next to a dry zone. Fires do not start in moist or small piles.

Can I use manure in my compost?

Fresh animal manures sometimes contain organisms that can make people sick (pathogens), such as the bacteria *Salmonella* sp. and *E. coli* O157:H7, or the parasite *Cryptosporidium parvum*. These pathogens are not taken up into plants, but they can be present in soil that adheres to roots or low-growing leaves and fruits. The risk is minimized if no fresh manure is used in the garden.

Careful peeling or washing fruits and vegetables with detergent removes most pathogens, but some risk remains. Thorough cooking effectively kills pathogens.

The greatest risk from manure-borne pathogens is for low-growing or underground crops such as carrots, lettuce, and strawberries. The edible part of these crops may become contaminated with soil, the crops are difficult to wash, and they often are eaten raw.

Pathogens in fresh manure typically die over time, especially when the manure dries out or is exposed to freezing and thawing. The rate of die-off depends on the type of pathogen and manure and on environmental conditions such as temperature, moisture, and sunlight. Thorough, high-temperature composting kills pathogens, but it is difficult to maintain these conditions in a backyard compost pile. **If any manure is used in the garden (even in compost), the gardener should wait at least 120 days between application to the garden and harvest.** You can limit your risk by excluding fresh manure from compost that will be used on fresh garden crops.

Keep dog, cat, and pig manure out of your compost pile and garden. Some of the parasites found in these manures may survive a long time in compost or in the soil and remain infectious to people.

Are herbicides a problem in compost?

On rare occasions, herbicides from compost have harmed plants grown in soils amended with the compost.

Herbicides break down in the environment over time. The rate of breakdown depends on the type of herbicide and environmental conditions. The high temperatures and biological activity in a compost pile accelerate herbicide breakdown. Herbicides also are inactivated by binding with organic matter in compost. Breakdown and binding reduce the risk of herbicide damage.

Lawn clippings can be a source of herbicides in compost. The best way to eliminate this source is to leave treated clippings on the lawn rather than composting them. Other options are to reduce herbicide use in areas where you compost the residues, or to use herbicides that break down quickly.

If you suspect there are herbicides in your compost pile, let the pile sit for a year or more, allowing more time for breakdown and binding.

Troubleshooting Tips

In General:

- Control odors by removing excess or inappropriate waste.
- Make sure you haven't added cheese or other animal products of any type to the compost system.

For Worm Boxes:

- Provide adequate fresh bedding.
- Do not fill the bin with a lot of food waste until the worm population is established.
- Minimize fruit flies by covering fresh food waste completely with several inches of bedding and covering the bedding with a sheet of newspaper, cardboard, or plastic tucked in around the edges.
- If you see signs of rodents or other animals around the worm bin, place a sheet of wire mesh over the bottom of the bin or raise the bin 12 to 18 inches off the ground.
- Keep the lid latched or well secured if possums or raccoons are a problem.

Number of Worms

Measure worms by weight rather than number. The number of worms you'll need depends on the weight of the food waste you plan to add each day, on average. Start by adding one pound of waste each day for each pound of worms.

After that, let the worms tell you how much food to add. If all the food is gone between feedings, add a little more. If the bin starts to smell because food is not being eaten, add less.

Adding Waste

It is a good practice to vary where you bury wastes in the worm box. You can bury kitchen wastes in about nine places in a worm box that is two feet by two feet, and that's nine feedings before you have to bury again at the first location.

Kitchen wastes break down very quickly, so you don't need to grind them. Do pulverize egg shells.

Leaving the Box Untended

When you're away from home for a few days, just feed the worms a little extra and leave them undisturbed. They can go three to four weeks without feeding. Make arrangements with someone else to feed the worms when you'll be away longer.

Changing the Bedding

After some time, the bedding's color will darken. Eventually, it will disappear as worms and microorganisms decompose it. Both processes create a less favorable environment for the worms. Also, as castings accumulate in large amounts, it harms the worms—castings of one worm are toxic to other worms. Decide when to change the bedding based on its condition and the number of worms in the box.

Population Control

Worms multiply fast, so you'll need to take care that they don't overpopulate. Use extra worms to start a new worm box, or give them to someone else who is starting to worm compost.

Odor and Pest Control

Control odors by not overloading the box with waste, using only appropriate waste, and providing adequate fresh bedding. Do not fill the bin with a lot of food waste until the worm population is established. Fruit flies are more of a nuisance than a serious problem, but the troubleshooting tips in this chapter can help you deal with them.

Worms can be obtained in many ways:

- Ask a friend who already maintains a worm bin.
- Search the internet for worm sources.
- Check with your county Extension office for any upcoming workshops involving composting with worms.

For More Information

For more information, contact your county Extension agent.

University of Kentucky Cooperative Extension Service Publications

Home Composting (HO-75)
Constructing a Wire-Mesh Compost Bin (ENRI-307)
Constructing a Wooden-Pallet Compost Bin (ENRI-308)
Constructing a Snow-Fence Compost Bin (ENRI-309)
Constructing a Wood-and-Wire Compost Bin (ENRI-310)
Constructing a Garbage Can Compost Bin (ENRI-311)
Constructing a Worm Composting Bin (ENRI-312)
Vermicomposting: Building a Worm Bin, University of Kentucky Extension Service

Chapter 14

Landscape Design

By Jan McNeilan, retired Extension consumer horticulturist, and Ann Marie VanDerZanden, former Extension Master Gardener state coordinator, both of Oregon State University. Adapted for use in Kentucky by Richard Durham, consumer horticulture Extension specialist and state Master Gardener coordinator, University of Kentucky.

In this chapter:

Landscape designs differ depending on how the landscape will be used. Although the principles are the same, a homeowner who wants an aesthetically pleasing, low-maintenance landscape will create a design very different than that of an avid gardener whose main purpose in life is to spend time in the garden.

This chapter is not meant to define the art of landscape design but rather to help you take a realistic approach to landscape planning. Your end design should meet your needs and incorporate principles of sustainability into an evolving landscape.

Kentucky gardeners are fortunate to be able to use a wide variety of plant materials to create landscapes that meet their needs. This available diverse plant material can be used to create outdoor rooms with canopies of trees; walls of shrubs and vines; and carpets of groundcovers, perennials, and annuals to provide color and interest.

Before beginning, consider what type of landscape will suit your needs. Landscapes reflect many approaches. Examples of landscape types are low maintenance, water-wise, formal, informal, native, wildlife-attracting, small space/container, shade, and specialty/collection.

Avid gardeners often are collectors who consider plant arrangement and placement as their gardens develop. While adhering to basic design principles, landscape design for these gardeners is an ongoing process. Just as seasons change, their landscapes take on new looks to include new structures and plants gathered from nurseries, garden centers, friends, and neighbors.

Merely planting trees and shrubs is not landscaping. Designing a landscape gives you an opportunity to create habitats for people, plants, and wildlife.

As you try to preserve clean air, clean water, and landfill space, your challenge is to create a landscape that is both aesthetically pleasing and environmentally sound. A sustainable landscape requires minimal inputs of labor, water, fertilizer, and pesticides to thrive. Creating a sustainable landscape means working toward a thoughtful balance between resources used and results gained. By factoring in environmental considerations, you can create a pleasant place that is part of an environmental solution rather than an environmental problem.

Planning

The smaller your house, grounds, or budget, the greater the need for correct and complete planning. Every square foot of space and every dollar must produce maximum results. Plan for the best use of the site, the least environmental impact, and minimum upkeep.

A master plan is essential to ensure that all work done on the property will blend into the desired final outcome. Keep in mind that landscape development can be a long-term process within the framework of your plan. There is no need to develop your entire lot at once. Completing the landscape over a five-year period is a feasible approach. This time frame allows you to evaluate plants as they grow and mature and generally is more manageable financially than doing everything at once.

Grading may be needed for a new home site. If you must have grading work done, consider ways to save topsoil and protect existing trees and vegetation from construction damage and soil compaction.

Site Analysis

For a new landscape, a thorough site analysis can help you develop a plan to enhance and maintain your property's sustainability. It's also a useful first step in renovating and changing an existing landscape. See the landscape design planning questionnaire at the end of this chapter for ideas.

A site analysis will tell you what you have to work with. A thorough understanding of your conditions is important, because in a sustainable landscape, native and introduced plants must be well suited to existing light, moisture, and soil conditions.

Your site analysis also will help you make the best use of available space in the most attractive way possible, while at the same time enabling you to consider the environmental impact of your landscape plan. Make the most of the site's natural features and advantages. Be sure to include structures such as fences, walls, patios, or decks to enhance the human environment and make the landscape more enjoyable.

Finally, the site analysis will help you select plants that best fit your landscape's design and purpose.

Factors Influencing Landscape Design

Factors influencing landscape design include property characteristics; neighborhood sights and sounds; climate; and family activities, growth, and change.

Property Characteristics

In laying out a design, preserve all of your site's best natural features, such as mature trees, brooks, ponds, rock outcroppings, good soil, turf, and interesting variations in terrain. These natural elements affect the ease of construction and enhance landscape possibilities.

Carefully survey the area to determine whether site conditions are a problem or they can be incorporated into your design. Examples of problems are thin, overcrowded trees or unstable slopes that may interfere with landscape construction. You also may have to contend with *microclimates* such as windy areas, low places with cold air pockets, or areas with poor soil and inadequate water drainage.

Changes in elevation can add interest and variety to home landscapes. The character of the land—its hills, slopes, and trees—should determine the basic landscape pattern. A hilly, wooded lot lends itself to an informal or natural design, with large areas left in their natural state. In such a setting, large trees can be retained. Protect native plantings whenever possible.

Although natural slope variations are an asset, avoid creating too many artificial slopes. Avoid excessive use of terraces or retaining walls. If these features are necessary to facilitate construction or control water drainage, design them to blend into the natural terrain.

Neighborhood Sights and Sounds

Keep good views open and screen out those that are undesirable. Often a well-placed shrub or two provides necessary screening. Additionally, well-placed plantings can act as noise barriers.

Climate

Climate includes sunlight, all forms of precipitation, wind, and temperature. In the case of a new home, these factors affect how the house is placed on the lot, how the land is used, and what is planted. Don't fight the climate; capitalize on its advantages. In warm regions, enlarge the outdoor living area. In cold regions, plant so that the winter scene is enjoyed from the inside. For example, evergreens and hedges are picturesque when covered with snow, ice, or rain droplets.

It is important to study the amount and location of both sun and shade because individual people respond to them differently. Patterns of sun and shade change, depending on the time of day and season (Figure 14.1). The sun is higher and shadows are shorter in summer than in winter. Northern exposures receive the least light and therefore are coolest. East and west exposures receive more light; western exposures are warmer than eastern ones because they receive afternoon light. Southern exposures receive the most light and tend to be warmest.

The main rooms of a house should benefit from winter sun and summer breezes. You can control the amount of sunlight and shade by the location of buildings, fences, and plants. You also can take advantage of shade created by structures or plants on your neighbors' property.

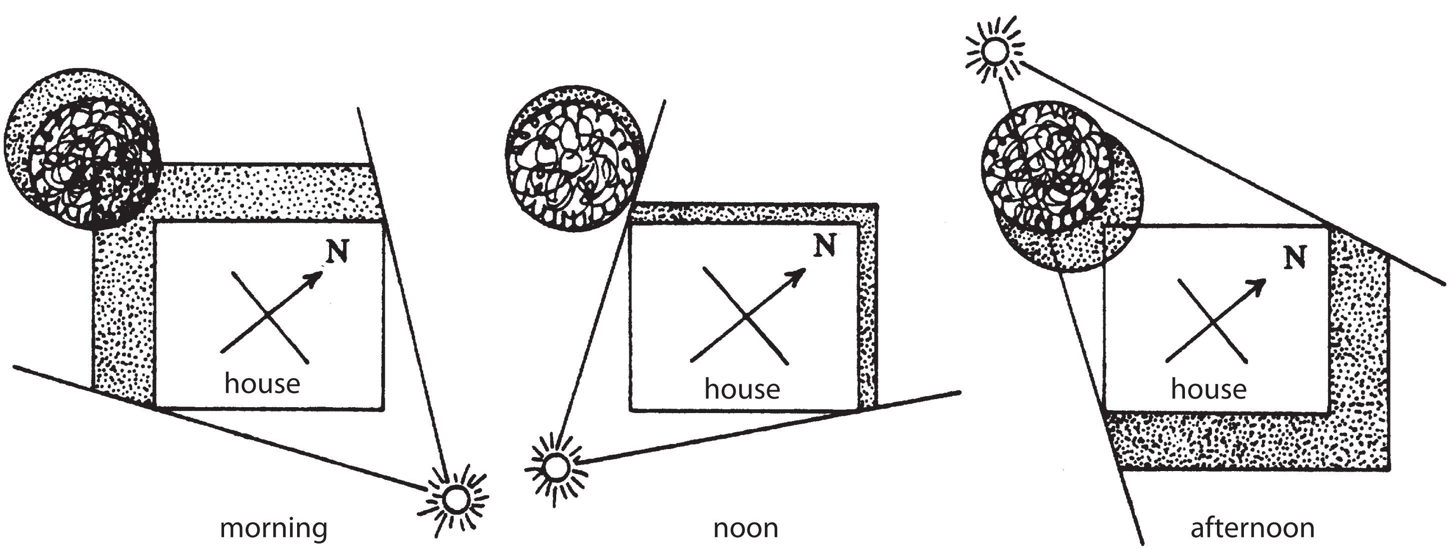


Figure 14.1. Daily light pattern. Speckled areas indicate shade.

Figure 14.2. Tree planted at a 45° angle from the corner of a house.

Trees have an especially strong effect on sunlight. When locating trees in your landscape design, consider keeping a sunny area for a vegetable garden while maximizing shady areas for the house and patio or deck. Deciduous trees (those that shed their leaves) shade the house in summer and admit sun in winter.

Plant trees at a 45° angle away from the corners of the house (Figure 14.2); when mature they will accent the building. Trees should not block views from windows. Remember that having too many trees shuts out sunlight and reduces air circulation. When renovating an old landscape, consider how light will change when plants or trees are removed.

Maintenance Requirements

During the early design phase, decide how much time and energy you want to spend on maintenance. Some people enjoy puttering about the yard and may desire a high-maintenance design. Others, however, want a landscape that requires minimal maintenance. Generally, the simpler the landscape, the less there is to maintain.

A low-maintenance landscape is the goal of most homeowners. The following strategies will help you reduce maintenance requirements:

- Limit the size of the lawn.
- Use groundcovers, bark chips, and other mulches for weed control.
- Use paving or gravel in heavily traveled areas. Provide edging strips of brick, concrete, or bender board for flower beds and shrub borders to ease mowing.
- Use fences, walls, or informal plantings (instead of clipped formal hedges) for screening.
- Design raised flower beds for easy access and to help control weeds.
- Use native plant materials.
- Install an underground irrigation system if you get little summer rain.
- Use small flower beds. Use flowering trees and shrubs for additional color.
- Be selective when choosing plant materials. Compact varieties require less pruning; insect- and disease-resistant varieties require less spraying; drought-tolerant plants require less watering.
- Keep the design simple.

Remember that low-maintenance practices are often also sustainable landscape practices.

Family Activities, Growth, and Change

How your landscape will be used should be a determining factor in its design. Analyze your family activities and design a landscape that will mature with the family. Don't plan a static landscape; it would not work as your family's needs change.

Parts of a Landscape

A landscape is made up of several parts. Some of these—private-use areas, children's play areas, front yards, public areas, and service and work areas—are discussed in this section.

Private-Use Areas

The private-use area or outdoor living room is an important part of the American home. No yard is too small to have a private sitting area where family and guests can gather. Where possible, access from the house to the outdoor area should be easy (Figure 14.3).

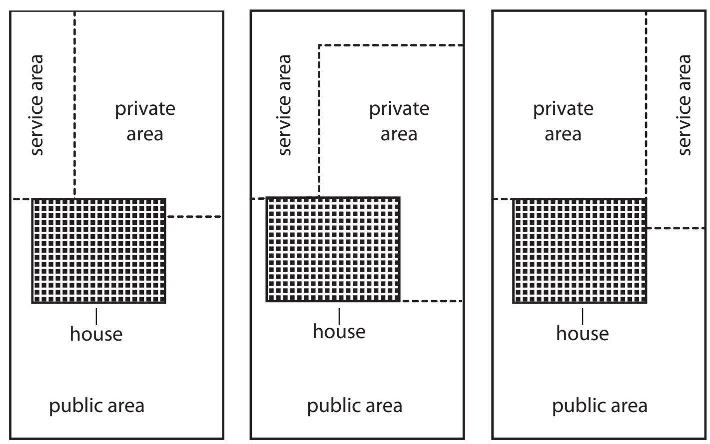


Figure 14.3. Use areas in a landscape.

When designing private areas, consider home security. Motion sensor lights can protect these areas at night, and pruning shrubs for openness and visibility can prevent them from being used for concealment during the day. For vulnerable entry points to your property or home, choose defensive plants that are thorny or difficult to walk through.

Consider the following guidelines when planning outdoor private living areas:

Privacy—Enclose the area from public view and nearby neighbors. Properly grouped shrubs and trees work well. For a small area, use a trellis, containers with vines, or a fence. Screen the area from work areas such as clotheslines, woodpiles, and garden sheds.

Year-round interest—Plants in the outdoor living area should be varied and provide interest throughout the year, especially if the area is visible from the house. For winter interest, select shrubs and trees with colorful bark, evergreen foliage, or colorful fruit. The rest of the year, use annuals, perennials, shrubs, and trees to create interest. Take a seasonal inventory of your proposed plant list to make sure it includes year-round interest. Pools, stone steps, paving, walls, bird feeders and baths, and other architectural features do not change with the seasons. They provide interest throughout the year.

Climate control—Weather control extends the outdoor living area's usefulness. Evergreen trees provide year-round screening and shade, while deciduous trees screen the area from hot summer sun but allow maximum winter sun for solar heat. Windbreaks reduce wind. An awning or trellis-type roof can protect against inclement weather. If space allows, a garden pool or fountain can convey the effect of coolness during summer with the added benefit of attracting wildlife.

Deck or patio—The center of activity for an outdoor living area often is a space with garden or patio furniture and sometimes a grill or outdoor cooking area. It may be a porch, deck, or terrace next to the house, or it may be a shady area nearby. It may be decked, paved, or in turf. Flagstone, brick, concrete blocks, and stamped concrete are common surfaces.

The size of this area depends on its expected use and the type and amount of furniture desired. A 10-foot-by-10-foot area holds four chairs and is about the minimum size for comfortably accommodating four people. Increase the size if you want space for more chairs or a picnic table.

Children's Play Area

The play area can be part of the outdoor living area or separate from it. Consider your children's ages and activities to determine the size and surface of the play area. For very young children, a small area enclosed by a fence near the kitchen or living area is desirable. As children grow up, you'll need to adjust the design to meet changing recreational needs.

Front Yard

The area in front of homes traditionally has been left more or less open so passersby can view the home. On small lots, it has become increasingly popular to screen the front yard with fencing, shrubs, or vertical plantings. Privacy may be desirable when a picture window faces the street or when the front yard is used for outdoor sitting. Where space is limited, a tall, attractive fence can provide privacy and a background for shrubs and smaller plants.

Again, consider home security when designing your landscape. It may be appropriate to use fencing that provides a sense of privacy but can be seen through. Plants that can be pruned for visibility are another option.

Be sure to consult local agencies when constructing a fence.

Public Area

This is the area seen from the street. The landscape in this area should create a sense of spaciousness. If you want the front yard to be part of the public area, keep the lawn or groundcover open and place shrubs to the sides of the house and in foundation plantings. When selecting shrubs to frame the front door, consider their texture, color, size, and shape, so they enhance the total effect but do not block doors or windows. Placing tall trees in the backyard and medium-size ones on the sides and in front is effective. The house should be the focal point of the view.

Service and Work Areas

An area screened from major views is good for service and work areas, such as space for garbage cans, access to utility meters, tool storage, wood storage, compost piles, propagating structures, small greenhouses, kennels, and clotheslines.

Elements and Principles of Design

Landscape design has no hard and fast rules because each landscape is a unique creation. However, the following design principles will help you create an aesthetically pleasing and useful landscape:

Simplicity—Simplicity is achieved when different parts of the design are grouped or arranged to appear as a single unit. For example, you can group plants of similar colors or textures, or mass three or more plants of the same species together (Figure 14.4).

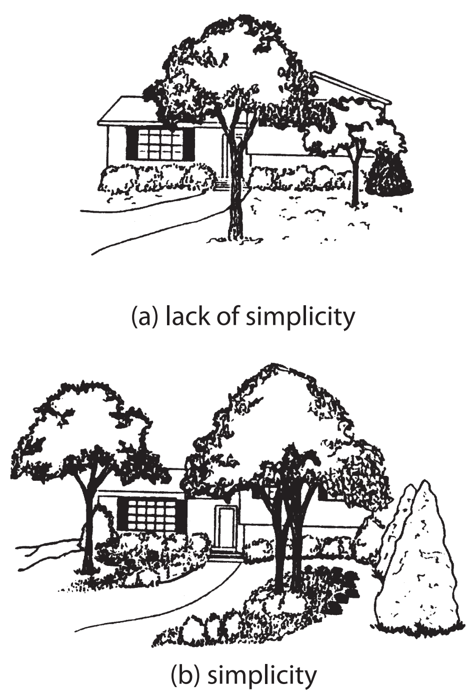


Figure 14.4. Lack of simplicity (a) and simplicity (b). Although 4b contains more elements than 4a, they are grouped to create a more simple design.

Rhythm and line—Continuity within the landscape and integration of different elements into the design affect rhythm and line. Effective use of repetition can direct the eye or a person through the landscape and create a sense of unity among different landscape spaces (Figure 14.5).

Balance—The two common types of balance in landscapes are symmetrical and asymmetrical. *Symmetrical* balance is most common in formal landscapes. It has an axis, and everything on one side is duplicated or mirrored on the other side (Figure 14.6a). *Asymmetrical* balance uses different objects on each side of the axis, but the end result still is a similar visual mass on either side (Figure 14.6b).

Proportion—This principle refers to the relationship between different elements within the landscape. The relationships to consider are plants to buildings, plants to other plants, and plants to people. To achieve correct proportion, always create designs based on the mature height of plants.

Focal point—Focal points give the eye a place to rest when viewing the landscape as a whole. A focal point may be a plant specimen, garden accessory, or water feature. The front door often is the focal point of the public use area; if so, design the landscape to enhance it.

Figure 14.5. Rhythm and line. The plantings direct the eye toward the house.

Plant Selection

This section discusses some of the factors involved in choosing the right plants for your landscape. For specifics on plant selection and care, see Chapter 18, Annual and Perennial Flowers (HO-102), and Chapter 15, Lawn Management (AGR-206). Well-chosen plantings are necessary to achieve your desired landscape effect. Thousands of varieties of trees, shrubs, vines, and perennials are available, but remember: plants are not merely ornamental accessories. Their masses define space in the yard and, consequently, the silhouettes that produce garden design. Therefore, when selecting plants, consider both their cultivation requirements and their aesthetic value.

The best advice in plant selection is to find the right plant for the right place. The U.S. Department of Agriculture (USDA) plant hardiness zones are a starting point, since they are based on winter temperatures. In determining where a plant will survive, however, you need to consider other factors as well, including frost occurrence, seasonal rainfall distribution, humidity, soil characteristics, water availability, and duration and intensity of light. These factors may be more important to a plant's survival than winter temperatures. Every plant tolerates a range of conditions for each of these factors. Their combined effect determines true plant adaptability.

Before selecting plants, consider your site and determine what, if any, environmental conditions exist that might cause problems. Carefully completing a site analysis will help. To what elements will plants be exposed (full sun, shade, wind, reflected heat)? What are the soil conditions (fertile or poor, high or low pH, depth, drainage)? Based on this evaluation, choose plants that are adapted to your specific growing environment.

For example, some plants, such as rhododendrons and azaleas, prefer acid soils (low pH). Most other woody plants grow well across a wide range of soil pH, from acid to alkaline. If your soil is extremely acidic or alkaline, you many need to amend it to adjust the pH, depending on what plants you want to grow.

(a) symmetrical balance

(b) asymmetrical balance

Figure 14.6. Symmetrical balance (a) and asymmetrical balance (b).

Insect and Disease Resistance

When selecting plants, look for varieties that are resistant to insect damage and disease in order to eliminate unnecessary applications of insecticides and fungicides. You can obtain resistance information from plant catalogs, garden centers, nurseries, and Extension offices.

Understanding Plant Survival: Hardiness Zones

A plant species that flourishes in one part of a given USDA plant hardiness zone is likely to be adaptable in other parts of the same zone or in a warmer zone. Some gardeners question a zone rating when a plant fails to survive its first winter. A single test, however, is rarely reliable. A small, young plant may be tender but may become quite hardy as it grows older. Other conditions also affect the degree of hardiness. No single winter is quite average; each differs in suddenness and severity of freezing.

Just because a plant may survive in a given zone does not necessarily mean it is recommended for planting in that zone. For example, using the USDA hardiness zone system, crape myrtle, *Lagerstroemia indica*, usually survives as a low-growing, semi-hardy specimen in the colder areas of zone 6. It develops and flowers normally, however, in zone 7. This species, therefore, is properly recommended only for zones 7 and above, although it is often used as a semi-hardy plant in zone 6.

Many ways exist to develop microclimates to allow a tender plant to grow in an otherwise inhospitable zone. For example, you can control soil fertility and water availability to some extent to delay plant growth in spring or to hasten hardiness in fall. Windbreaks can provide protection from cold winter winds. Raised beds allow soil to warm earlier in the spring.

Factors Affecting Plant Adaptability

Factors such as temperature are largely beyond your control but do have predictable yearly averages. Of the major factors that govern plant adaptability, frost dates, length of growing season, and minimum winter temperatures are among the hardest to control.

Frost

Average first and last frost dates have been calculated for each plant hardiness zone. These dates give an indication of when to expect the first frost of fall as well as the last frost of winter or spring.

However, air temperature and movement are important factors in frost occurrence and may create microclimates within your garden. Because warm air rises and cold air sinks, cool air tends to accumulate in low spots and in areas with minimal air movement, thereby creating frost pockets. Species that are marginally hardy in a given zone should not be planted in frost pockets.

Rainfall

Total average rainfall has a significant effect on plant growth and development, and rainfall distribution is equally important. Some areas receive substantial rainfall, but it may not occur during the growing season. Where summers are dry, plants may need supplemental water in order to survive. Using species that need little water is one way to reduce the amount of irrigation needed.

Soil and Moisture Conditions

Good soil and proper moisture conditions are crucial to plants' survival. Many plants respond unfavorably when their soil environment changes. For example, some can tolerate extremely dry or wet conditions while others cannot; some do well in poor soil while others do not. Nursery-grown plants are not inexpensive, so provide the best growing conditions possible for each species. Group plants of similar growing requirements together to conserve water.

Soil characteristics are a major factor in determining which plants will thrive in your garden. The ideal garden soil is *loam*—a light, crumbly mixture with approximately equal parts sand, silt, and clay. Good garden soil includes at least four percent organic matter. Organic matter is important because it promotes better water and nutrient retention in the soil, air exchange (porosity), and friability or looseness to allow good root penetration. Garden soils can be altered, but it is important to complete a soil test first to determine what improvements your soil needs.

Degree of Sun or Shade

The angle of the sun in relation to the earth varies from summer to winter. The sun's angle not only affects day length but also the shadows in a garden. These shadows determine the amount of sun that plants receive and thus may have a significant effect on their growth.

Slopes that face south or southwest get more heat during the day than those that face north or northeast. Slopes with southern exposure dry out more quickly and often require supplemental water. Taking advantage of different exposures in the landscape may extend your growing season.

Aesthetic Considerations

Texture, seasonal foliage color, flowers, fruit, and bark can provide touches of beauty. You even can select plants to relate to exterior house colors.

Try to have some color in the yard year-round. Flowering trees provide pastels in spring; beds of perennials and annuals furnish vivid hues in summer; trees and shrubs whose leaves turn yellow, orange, and crimson brighten gray autumn days; the bark and fruit of some species is attractive in winter. Interesting year-round effects can also be created by strongly contrasting features.

Select plants with more than one feature during the seasons. For example, choose a tree with blossoms in April, beautiful fall or midsummer color, and exfoliating (shedding) bark for winter interest.

Plant Size

Consider the mature size of plants you select for your landscape. A common mistake is to select plants that soon become too large for their locations. The drastic pruning that then becomes necessary adds to the cost of maintenance and may reduce the grace and beauty of the specimen. Overgrown plants that are left unpruned alter the balance and accent of a design. In addition, they may partially hide the house instead of complementing it.

Plant Form

Shrubs are woody plants that grow to a height of three to 12 feet. They may have one or several stems with foliage extending nearly to the ground. Common forms include the following:

- Low or spreading (e.g., juniper species)
- Round or upright (e.g., euonymous, photinia, and forsythia)
- Vase (e.g., Vanhoutte spirea)
- Pyramidal (e.g., hybrid tea roses)
- Columnar (e.g., arborvitae species)

Trees are woody plants that typically grow more than 12 feet tall and have only one main stem or trunk. The *head* or leafy portion of the tree develops a typical form such as one of the following:

- Round or oval (e.g., maple, oak, and pine)
- Vase (e.g., elm)
- Pendulous (e.g., weeping willow, cherry, and birch)
- Pyramidal (e.g., spruce, fir, and hemlock)
- Columnar (e.g., hop hornbeam)

Mature shrubs and trees are usually more open and spreading than young plants. For example, an oak tree's head may be a pyramid shape when it is young, an irregular oval in middle age, and a spreading vase form in old age.

Trees are long-lived and relatively inexpensive in terms of initial cost and maintenance when compared to lawns, flower beds, hedges, and many other landscape features. In the past, many builders committed costly errors by destroying trees when establishing new residential subdivisions. Most real estate developers now appreciate the value of trees and attempt to save them when land is graded before house construction. However, trees that are old and diseased or improperly located should be removed and replaced with more suitable specimens.

Some common forms of shrubs and trees are shown in Figure 14.7.

Groundcovers such as turf, low-spreading shrubs, creeping plants, and prostrate vines are essential landscaping materials. Many designs no longer include turf but instead use hardy groundcovers. Groundcovers also are grown on banks that are too rough or steep to mow and under trees where grass does not grow satisfactorily.

Plant Texture

A plant's texture depends on the size and arrangement of its foliage. Plants with large, widely spaced leaves have coarse texture. Plants with small, closely spaced leaves have fine texture. Texture can vary by season, depending on whether a plant is deciduous or evergreen.

Some variation in texture is needed to make a landscape interesting. Avoid extremes in texture, however.

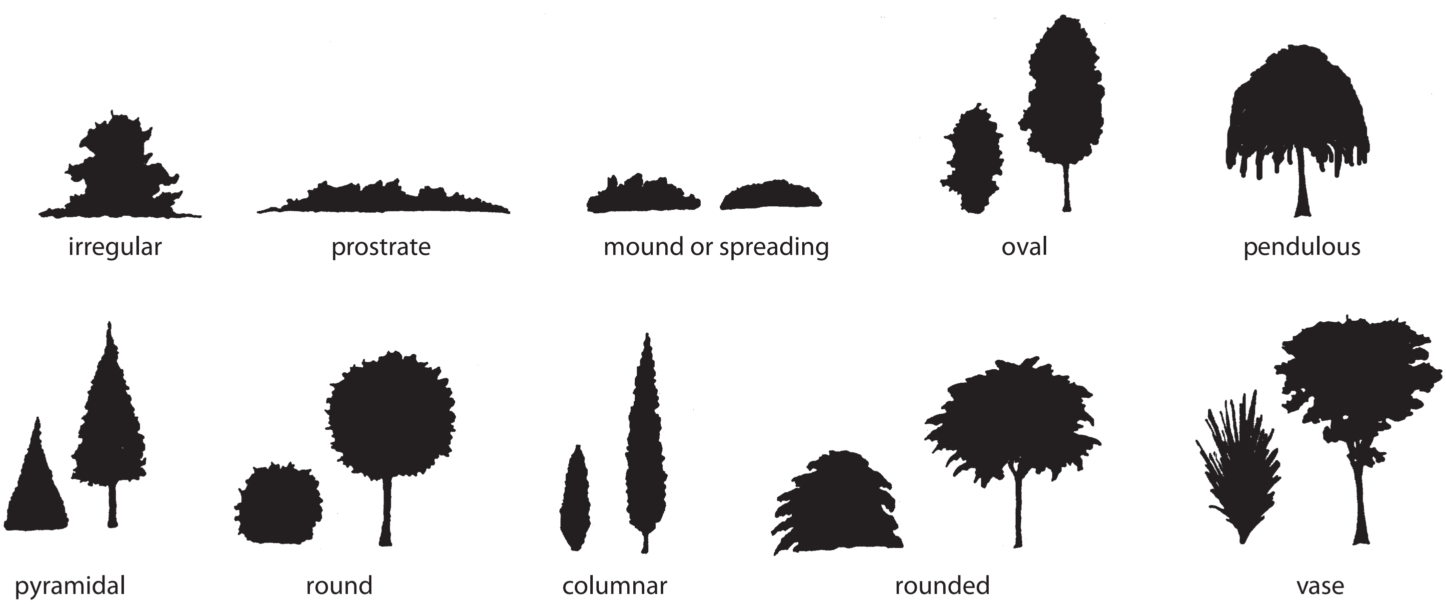


Figure 14.7. Common tree and shrub forms.

Drawing a Landscape Plan

If you want the fun and satisfaction of preparing your own landscape plan, this section will help you draw a plan that embodies the elements of good design. These steps will enable you to develop a final plan that can be implemented over several years as time and money permit. The landscape design planning questionnaire at the end of this chapter is a good place to start. It will help you assess your site and your needs.

Prepare a Map

Prepare a scale map of your property (Figure 14.8). Use graph paper, with one square equaling a certain number of feet, or draw to scale using a ruler or engineer's scale as follows:

Measuring Device	Small Lot	Large Lot
Engineer's scale	1 inch = 10 ft	1 inch = 20 ft
Ruler	1 inch = 8 ft	1 inch = 16 ft

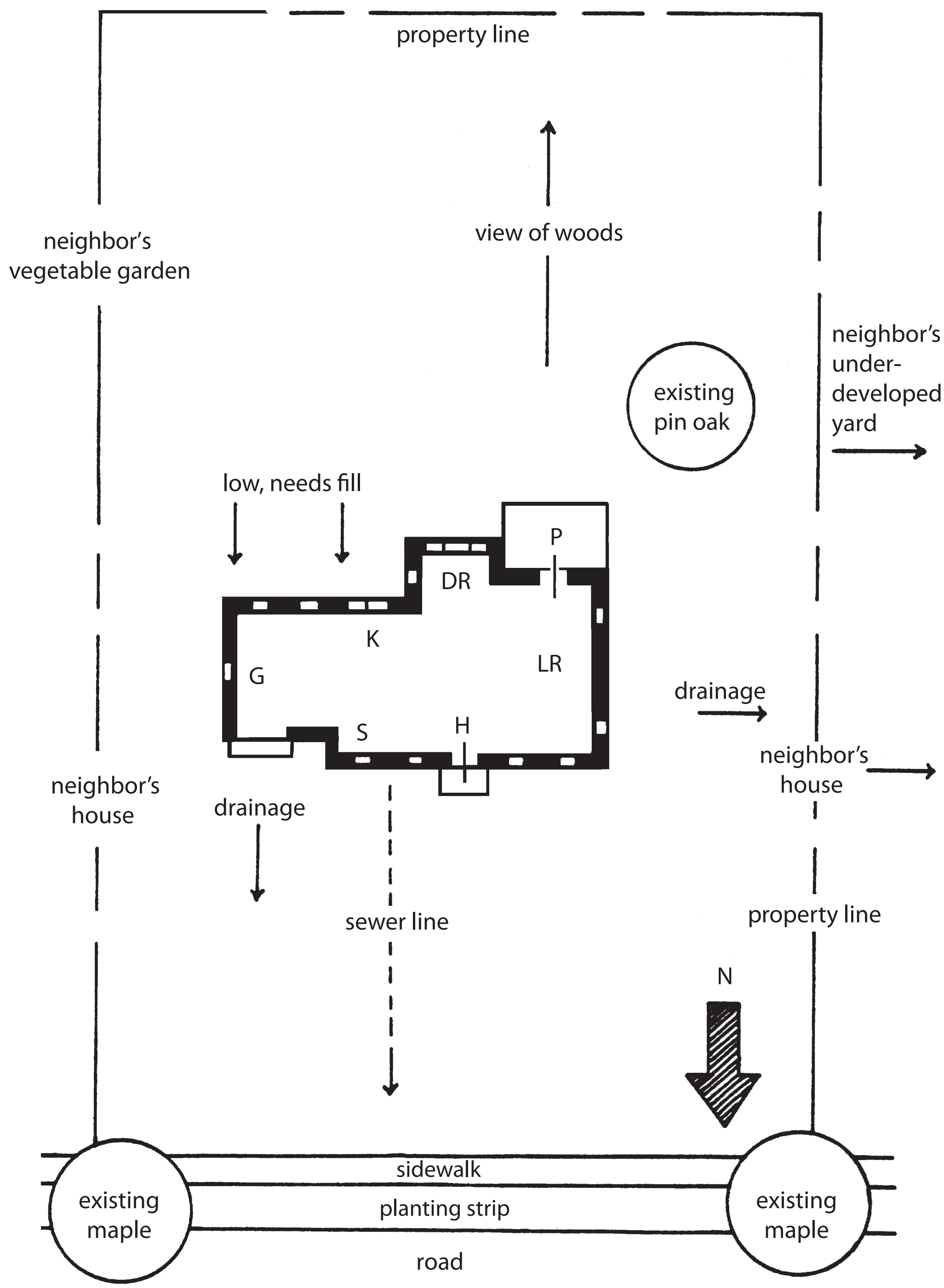


Figure 14.8. Property map.

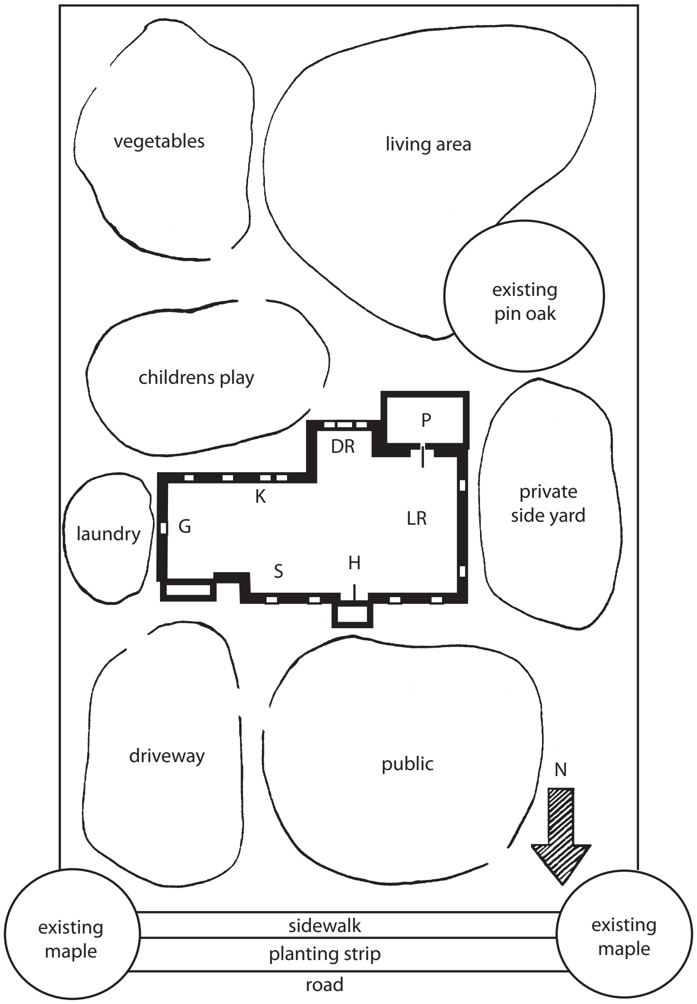


Figure 14.9. Placing use areas on a map.

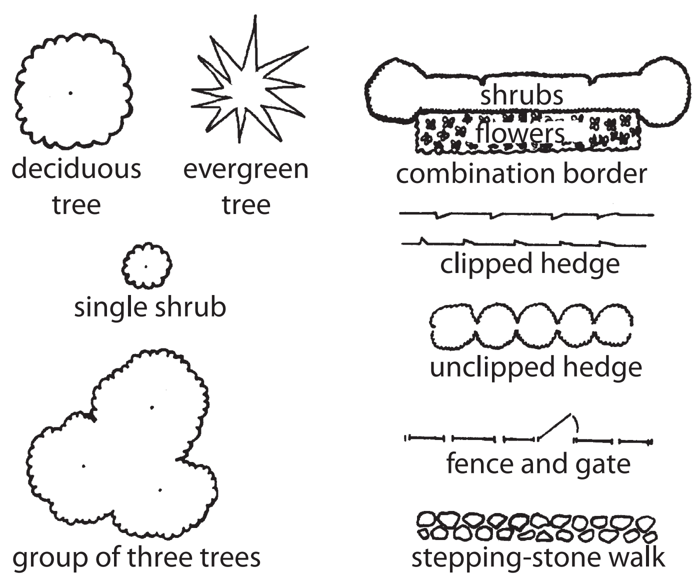


Figure 14.10. Landscape symbols.

The map should include the following:

- Property lines
- North arrow
- Scale used
- Contour of the land (Use an arrow to show direction of surface water flow.)
- Existing landscape features—house, garage, other buildings, trees, walks, and driveways
- Septic tank, sewer lines, or underground power lines
- Views (Point arrows in the direction of each good view.)
- Doors, windows, porches, and rooms (G = garage, K = kitchen, etc.)
- Undesirable features of your own or adjoining property

Identify use areas and place them on the map.

The following use areas are common in residential landscapes:

- Private-use area (may include cooking and eating area)
- Children's play area
- Front yard
- Public area
- Service and work area (e.g., laundry)
- Fruit and vegetable garden
- Flower beds
- Walks and driveways
- Garden pool

Choose those use areas that are appropriate for your design and add others if needed. Refer to the landscape design planning questionnaire for additional use items to consider.

Fit them together considering traffic flow and how the space will be used (Figure 14.9). How will people move from one area to another or from the house to outside areas? Will outdoor areas be functional in relation to the house? Will you make use of existing features such as views or changes in the terrain? Try different combinations in relation to rooms of the house, surrounding areas, and potential views.

Develop the Landscape Plan

In this step, your landscape plan begins to take shape. Select the most appropriate landscape based on the uses identified in the previous step. Use landscape symbols to indicate trees and shrubs (Figure 14.10). Draw the symbols to scale so they represent the actual amount of space involved (Figure 14.11). For example, a mature white pine has a spread of approximately 20 feet, so make the symbol represent 20 feet.

On your map, indicate driveways, walks, other structures, and plants. Indicate where plant masses are needed to separate areas; screen undesirable views; and provide shade, windbreaks, and beauty. At this point, do not attempt to name trees and shrubs. Rather, think in terms of plant masses that will serve a particular purpose and tie areas together into a unified design. Keep in mind the design elements discussed in this chapter.

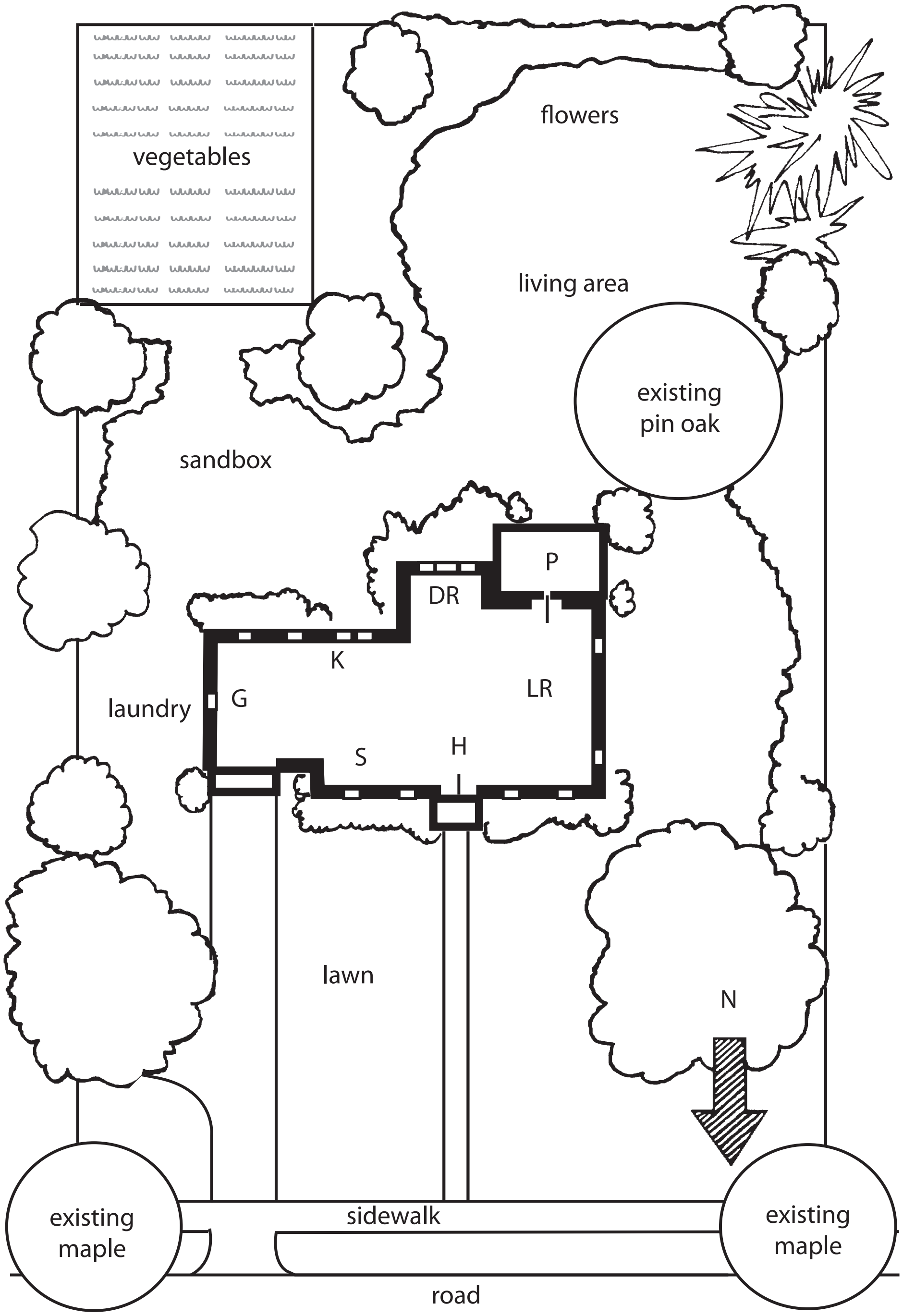
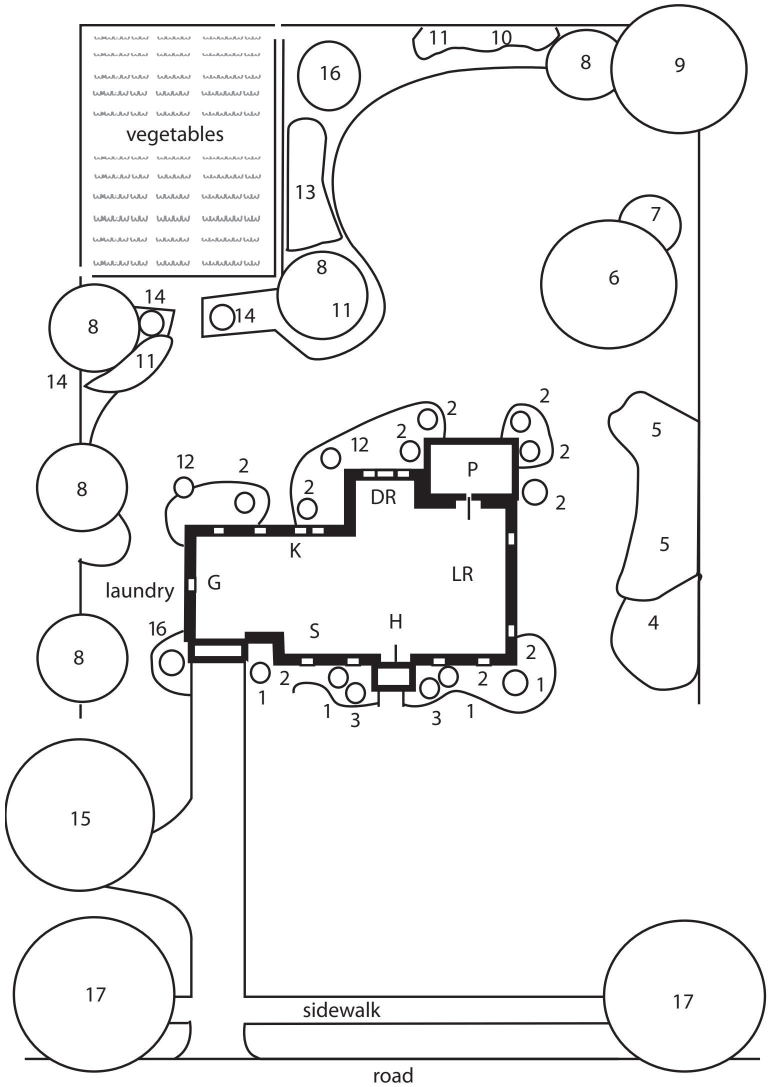


Figure 14.11. Sample landscape plan.

To confirm that your proposed scheme is practical, make sure you can answer the following questions satisfactorily:

- Is the driveway design pleasing, useful, and safe? Is the entrance easily accessible? Is there a turnaround? Is there guest parking?
- Are walkways convenient? Are guests directed to the front door?
- Will the landscape be attractive from the living room, picture window, porch, and dining room? Will it be attractive all year?
- Is there a private living area? Is it screened from neighbors, the service area, and other buildings?
- Is the clothesline near the laundry?
- Is the gas meter, power meter, or oil tank easily accessible and, if necessary, screened from public view?
- Has home security been considered?
- Will the septic tank, sewer lines, or drainage fields interfere with planting shade trees?
- Do all parts of the landscape fit together into a unified plan?



Planting key
1. Japanese yew
2. Japanese holly
3. Boxwood
4. Barberry
5. Azaleas
6. Pin oak
7. Pink dogwood
8. White dogwood
9. White pine
10. Chinese holly
11. Perennial border
12. Abelia
13. Flowering quince
14. Nandina
15. Flowering crabapple
16. Lilac
17. Existing maple

Figure 14.12. Landscape plan with planting key.

Create a Final Plan and Planting Key

Specific plants for your landscape design can be selected in many ways. For example, you may choose to initially concentrate on the desired cultural needs of the plants or desired height, but you will eventually need to address several other purposes when selecting plants (Table 14.1).

Next, select a plant or group of plants to meet your specifications. Consult garden books and nursery catalogs or visit a local nursery. Become familiar with plant materials and discuss the plan with nursery growers. Try not to get too bogged down in this process! Review the section on "Evaluating Landscape Sustainability" before making final plant selections.

Finally, on your map, designate specific plantings and develop the planting key (Figure 14.12). By following the guidelines in this chapter, you will create a pleasing landscape. Remember, however, that plans are made to be changed, and a landscape is a work in progress.

Table 14.1. Sample specifications for a tree or shrub mass.

Purpose	**Shade, Background, Hedge, Screen, or Accent**
Height	Low, medium, or tall
Form	Spreading, upright, arching, or globe
Seasonal interest	Fruit, flowers, and foliage
Type	Needleleaf evergreen, broadleaf evergreen, or deciduous
Cultural needs	Shade, sunlight, and moisture requirements
Maintenance	Pruning and insect- or disease-control requirements

Renovating an Established Landscape

Making major changes or renovating a mature landscape can be a challenge. If you move to a home with a mature landscape, it's a good idea to live with the design for a full year before deciding which shrubs and trees to keep and which ones to remove or transplant. When making these judgments, keep the previously described design principles in mind.

The following questions may help you decide how to renovate an overgrown, mature landscape:

- Has a site analysis been done?
- What is important in the landscape and what is expendable?
- If the landscape has ample shade, could more shade-loving plants be incorporated?
- Does the landscape have seasonal color and interest?
- Have trees and shrubs become so overgrown they block light from desirable plants that need sun?
- Are your houseplants getting as much light as they used to, or are mature outdoor trees or shrubs blocking their light?
- Do shrubs crowd each other? Do they block views from windows? Should they be pruned or removed? What are some innovative ways to prune overgrown shrubs?
- Have use areas changed? Could old play areas be incorporated into the landscape differently?
- Could raised beds be incorporated to make gardening easier?
- Has a security check been made? Are mature plants concealing doors and windows? Have plants been thinned to create visibility?
- Is there enough time and help to accomplish a major renovation?
- How long will the renovation take? What should be done first?

Evaluating Landscape Sustainability

In order to create a truly sustainable garden, you may need to change your expectation of what a landscape ought to look like. Perfect lawns, plants, and fruits are all desirable. However, by adjusting your expectations slightly, you can reduce the labor and chemical inputs needed in your landscape. The following checklist gives guidelines for determining your landscape's sustainability:

- What are the environmental benefits of the landscape?
- Are mulches used to maintain soil fertility and earthworm activity?
- Were plants selected properly to reduce pruning, spraying, and fertilizing?
- Are plants placed in ideal growing conditions (e.g., correct light and drainage)?
- Were plants properly sited so that, when mature, they complement rather than stress each other?
- Have drainage problems been corrected to provide adequate water penetration?
- Was the landscape planned to help prevent erosion?
- Has water runoff been handled properly?
- Has the landscape been developed to reduce the need for high-nitrogen fertilizers?
- Does plant selection take into consideration the effect of sunlight on summer cooling and winter heat?
- Has the landscape created a better environment for people?
- Does the landscape attract beneficial wildlife?

Creating landscapes that are both environmentally sound and aesthetically pleasing can be difficult. However, there are many steps you can take to achieve both beauty and environmental enhancement. The following design strategies all lead to a sustainable landscape:

- Take advantage of existing terrain.
- Capitalize on microclimates.
- Select plants that are appropriate for your growing environment.
- Select plants with disease and insect resistance.
- Incorporate mulches to suppress weed growth and reduce runoff and water evaporation from soil.

For More Information

- *Ground Covers for KY Landscapes* (HO-78)
- *Perennials for Shady Locations* (HO-77)
- *Perennials for Sunny Locations* (HO-76)
- *Annual Flowers* (HO-65)
- *Landscape Design with Plants: Creating Outdoor Rooms* (HO-62)

Landscape Design Planning Questionnaire

This questionnaire will help you organize your thoughts when designing or renovating your landscape. It may bring to mind topics you have not considered and will give you a better idea of how to design a landscape to meet your needs.

Site information

First, gather information about your existing yard to see how it will affect your plan.

Color of house: ____________________ Architectural style:____________________

Desirable views: ____________________

Undesirable views: ____________________

Overhead utilities: ____________________

Unique features: ____________________

1. Soil:
☐ Clay
☐ Sandy
☐ Rocky
☐ Compacted
☐ Surface Rocks

2. Direction of winds:
Summer _________
Winter _________

3. Are wind screens needed?
☐ No
☐ Yes: Where?

____
____
____
____
____
____

4. Are sound buffers needed?
☐ No
☐ Yes: Where?

____
____
____
____
____
____

5. Are there elevation differences?
☐ Minimal
☐ Moderate
☐ Severe slopes

6. Are retaining walls needed?
☐ No
☐ Yes: Where?

____
____
____
____
____
____

7. Are there soggy areas (high water table)?
☐ No
☐ Yes: Where?

____
____
____
____
____
____

8. Where will water drain?

____
____
____
____
____
____

9. Is a French drain required?
☐ No
☐ Yes

10. Sun exposure:

11. Where is your yard too hot in the summer?

12. Existing trees, shrubs, and surface roots:

13. Existing site features and structures:

14. Existing walks:
☐ Brick
☐ Cement
☐ Gravel
☐ Stone
☐ Bark

15. Is there a parking strip?
☐ No
☐ Yes: Where?

16. Preferred level of maintenance:
☐ High
☐ Medium
☐ Low

Landscape Design Planning Questionnaire, continued

Design considerations

Now, consider how the landscape will be used.

17. Who will use your yard?
☐ Adults
☐ Children
☐ Elderly
☐ Pets

18. Preferred style:
☐ Formal
☐ Semiformal
☐ Informal
☐ Theme (e.g., English, Japanese, or natural)

19. Preferred shapes (for lawns, walks, decks):
☐ Rectangular
☐ 45° angles
☐ Circles
☐ Straight lines
☐ Curving/free-form
☐ Combination

20. Type of front entryway:
☐ Straight to the door
☐ Meandering
☐ Private courtyard

21. Outdoor structures/features:
☐ Patio roof
☐ Raised planters
☐ Children's play area
☐ Satellite dish
☐ Dog pen/run
☐ Storage shed
☐ BBQ area
☐ Gazebo
☐ Deck
☐ Fence
☐ Swimming pool
☐ Spa/hot tub
☐ Sculpture
☐ Boulders
☐ Dry creek
☐ Mounds/berms
☐ Pond
☐ Bench
☐ Fountain
☐ Waterfall and stream
☐ Greenhouse
☐ Other:

____
____
____
____
____
____

22. What size patio/deck do you need?
☐ 2–4 people
☐ 4–8 people
☐ 8–12 people
☐ 12+ people

23. Do you want walkways connecting parts of your yard?
☐ Yes
☐ No

24. Do you want outdoor lighting?
☐ Landscape
☐ Security

25. What items need storage space?
☐ Garden equipment
☐ Garbage cans
☐ Other:

____
____
____
____
____
____

26. Do you need off-street parking for guests?
☐ Cars
☐ RVs
☐ Other:

____
____
____
____
____
____

27. How will you water?
☐ Garden hose
☐ Sprinkler system
☐ Drip irrigation

28. Photos can help you visualize what you want. Do you have photographs of your yard?
☐ Yes
☐ No

29. Finally, think about the types of plants that will meet your needs. What type of plants do you like?

____
____
____
____
____
____

30. Broadleaf evergreen trees and shrubs:
☐ Flowering
☐ Nonflowering

31. Deciduous trees and shrubs:
☐ Flowering
☐ Nonflowering
☐ Conifer trees
☐ Fruit trees
☐ Shade trees
☐ Junipers
☐ Vines
☐ Roses
☐ Annual flowers
☐ Perennial flowers
☐ Vegetables
☐ Herbs
☐ Other:

____
____
____
____
____
____

32. Do you like fragrant plants?
☐ Yes
☐ No

33. Favorite colors:

____
____
____
____
____
____

34. Least favorite colors:

____
____
____
____
____
____

35. How much lawn do you want?
☐ None
☐ Small
☐ Average
☐ Large
Where will the lawn be?

____
____
____
____
____
____

36. Is anyone in your family allergic to specific plants?
☐ Yes
☐ No

37. Is anyone in your family allergic to bees?
☐ Yes
☐ No

38. Are deer a problem?
☐ Yes
☐ No

39. What special garden areas do you want?
☐ Vegetables
☐ Annuals
☐ Roses
☐ Perennials
☐ Herbs
☐ Wildlife/native
☐ Orchard
☐ Shade
☐ Rock garden
☐ Cut flowers
☐ Fragrance
☐ Wheelchair-accessible
☐ Other:

____
____
____
____
____
____

40. Other comments:

____
____
____
____
____
____

Chapter 15

Lawn Management

By Gregg Munshaw and A.J. Powell Jr., Plant and Soil Sciences. Revised by Kenneth Clayton, Plant and Soil Sciences.

In this chapter:

Turfgrass is the foundation of a quality landscape. It improves the beauty of other ornamentals and provides a safe recreational surface. Quality lawns greatly increase the economic and sociological value of urban homes. They beautify and reduce the often harsh urban environment by decreasing noise, glare, heat, dust, and mud. Lawns and other recreational turfgrass areas are an integral part of our daily activities.

As trees and ornamentals within a landscape mature, turfgrass becomes less obvious and somewhat less important. In immature landscapes, however, the importance of a uniform turfgrass cannot be overstated. Millions of individual grass plants (Figure 15.1) form the turfgrass, but collectively the grass plants become one landscape plant. Just as an individual tree or shrub should have uniform shape, the turfgrass should be uniform in texture, color, height, and density. Whether the turfgrass is cut high or low, has coarse or fine texture, is fast or slow growing, or is dark or light green is of little importance in landscaping for non-recreational turfgrass. Uniformity is the key to quality. A list of common turfgrass terminology and sources for further information may be found in this chapter.

Lawn Establishment

To establish turfgrass with the greatest potential for uniformity, quality, and management ease, select the best grass for your needs and establish it properly. Use the right mowing practices, fertilization, irrigation, and pest controls to maintain that uniformity.

If your lawn isn't established properly, you may never achieve a quality lawn, and your maintenance costs may be prohibitive.

Choosing the Best Grass

The right grass for Kentucky lawns may not be the one you like best but rather the one that is best adapted and easiest to grow. Kentucky is in the transitional climate zone, where we have hot summers and cool winters. Because of this, there is no single turfgrass that is perfectly adapted to our climate. Due to its name, many believe that Kentucky bluegrass is the best grass choice for Kentucky. However, because Kentucky bluegrass generally lacks heat tolerance, it can struggle and become diseased during warm summers. Depending on budget and level of maintenance desired, many grasses can be grown throughout Kentucky. However, to minimize the impact on the environment, a turfgrass that will not require frequent inputs to look good should be selected. Generally, Kentucky bluegrass is somewhat adapted to Central and Eastern Kentucky, bermudagrass and zoysiagrass to Western Kentucky, and tall fescue throughout the state. Also, red fescues or ryegrasses may be desirable in some situations. For most lawns throughout the state, tall fescue is the best choice due to heat and drought tolerance. All of the grasses, however, differ in their performance and qualities. Table 15.1 gives certain characteristics that will help identify many lawn and weed grasses.

Sod is grown in Kentucky for all species except perennial ryegrass and fine fescue.

Kentucky Bluegrass (*Poa pratensis*)

Many cultivars of Kentucky bluegrass are sold in Kentucky. The common types, such as the cultivar Kenblue, are persistent when maintained at high mowing heights, at low nitrogen fertility, and with minimum traffic. Many improved cultivars have better summer quality and improved heat tolerance and disease resistance. However, to determine how a cultivar sold at your local store/sod farm will perform in Kentucky, visit www.ntep.org to check current and previous data.

Adaptation—Grows best on well-drained soils in full sunlight; very poor performance in Western Kentucky.

Major qualities—Fine texture, good resiliency, good spreading habit, relatively slow growth.

Major problems—Very poor traffic tolerance; not adapted to shade; severe white grub susceptibility; diseases such as leaf spot and melting out often cause thinning in May and June; irrigation required when maintained with high-nitrogen fertilization; becomes semidormant (brown) when not irrigated during the summer; slow seed germination (10-21 days); very poor seedling vigor, causing slow establishment; not adapted to clay soil; will creep into landscape beds.

Seeding rate—two pounds pure live seed per 1,000 square feet.

Mixtures—Can be mixed with perennial ryegrass or fine fescue as indicated in this chapter.

Table 15.1. Characteristics of some turfgrasses and perennial grass weeds.

Grass	Stolons (aboveground stems)	Rhizomes (belowground stems)	Texture[1]	Ligule[2]	Bud Leaf[3]	Other Characteristics
Red fescue	No	Few	F	S	F	Narrow, needlelike blades, usually folded.
Creeping bentgrass	Yes	No	F	L	R	Often grows in moist areas; grows in patches; stolons usually white; veins prominent.
Rough bluegrass	Few	No	F	L	F	Boat-shaped tip; dual veins in midrib; grows in patches.
Kentucky bluegrass	No	Yes	M	S	F	Boat-shaped tip; dual veins in midrib; smooth leaf.
Perennial ryegrass	No	No	M	S	F	Underleaf shiny; red stem base; veins prominent.
Nimblewill	Yes	No	M	Sh	R	Aerial tillers; short leaves; compressed sheaths; grows in patches; stolons usually green; rooting at lower nodes.
Quackgrass	No	Yes	M	M	R	Claw-like clasping auricles; blue-green color.
Bermudagrass	Yes	Yes	C-F	Mh	F	Upright tillers grow at 30°-60° angle from lateral stems; some hairs on leaf surface; sheaths round; long stolons.
Zoysiagrass	Yes	Yes	C-F	Mh	R	Tillers grow at 90° angle; sheaths compressed; tuft of hairs at collar; hairy on leaf surface; very knotty nodes.
Tall Fescue	No	No	C	S	R	Leaf margin serrated; red stem base; veins prominent.
Timothy	No	No	C	L	R	Bulbous base.
Orchardgrass	No	No	C	L	F	Stem very flat; blue-green color.
Dallisgrass	No	No	C	L	R	Hairs grow on leaf margin.

1 Texture: F = fine, M = medium, C = coarse
2 Ligule: S = short, M = medium, L = long, h = hairy
3 Bud leaf: F = folded, R = rolled

Tall Fescue *(Festuca arundinacea)*

Tall fescue is used for lawns, hay, and pasture throughout Kentucky. When properly seeded and managed as a lawn, however, it has little resemblance to the tall fescue in pastures. Although it is normally a bunchgrass, when a dense cover of tall fescue is established in a lawn, leaf coarseness and clumping are not problems.

To determine how a cultivar sold at your local store/sod farm will perform in Kentucky, visit www.ntep.org to check current and previous data.

New, turf-type cultivars are more finely textured and denser cultivars than Kentucky 31 (KY 31), and they may have more brown patch disease problems. They are best for highly maintained, more formal lawns. KY 31 is best for large acreage, minimum-maintenance turfgrass areas, and slopes that need to be stabilized. Turf-type tall fescues more closely resemble a good Kentucky bluegrass lawn than pastures.

Adaptation—Most widely adapted turfgrass for use in Kentucky.

Major qualities—Adapted to full sun or medium shade; performs well on heavy clay to sandy soils; good traffic tolerance; no serious insect problems; very competitive with weeds; little if any irrigation required (except in severe drought); faster to establish than Kentucky bluegrass.

Major problems—Requires more frequent mowing than Kentucky bluegrass; some brown patch disease problems during hot summers; turf has little resiliency; lateral spread is very slow.

Seeding rate—Six pounds pure live seed per 1,000 square feet.

Mixtures—Mixtures with other species such as Kentucky bluegrass are not recommended except where sod is grown specifically for transplanting purposes.

Fine Fescues *(Festuca rubra, Festuca ovina, Festuca trachyphylla, etc.)*

These fine-leaf grasses are often designated as creeping red, chewings, hard, or sheep fescue. Fine fescue is a niche grass that will tolerate some shade, drought, and low fertility.

Very little fine fescue is grown in Kentucky, thus cultivar recommendations are not specifically available. See www.ntep.org for top-performing cultivars from other states.

Adaptation—Poorly adapted except where some shade is present; not adapted to heavy shade or heavy traffic.

Major qualities—Tolerant to low fertility; tolerant to droughty and acid soils; fine texture.

Major problems—Poor traffic tolerance and often clumps when heavy traffic imposed; becomes semi-dormant (brown) in summer when located in full sun; susceptible to severe grub damage; lateral spread is very slow; will not survive continuous heavy-nitrogen fertilization.

Seeding rate—Two pounds pure live seed per 1,000 square feet.

Mixtures—When a turfgrass area includes both full sun and shade, a mixture of approximately 50 percent to 80 percent Kentucky bluegrass and 20 percent to 30 percent (by weight) fine fescue may be seeded.

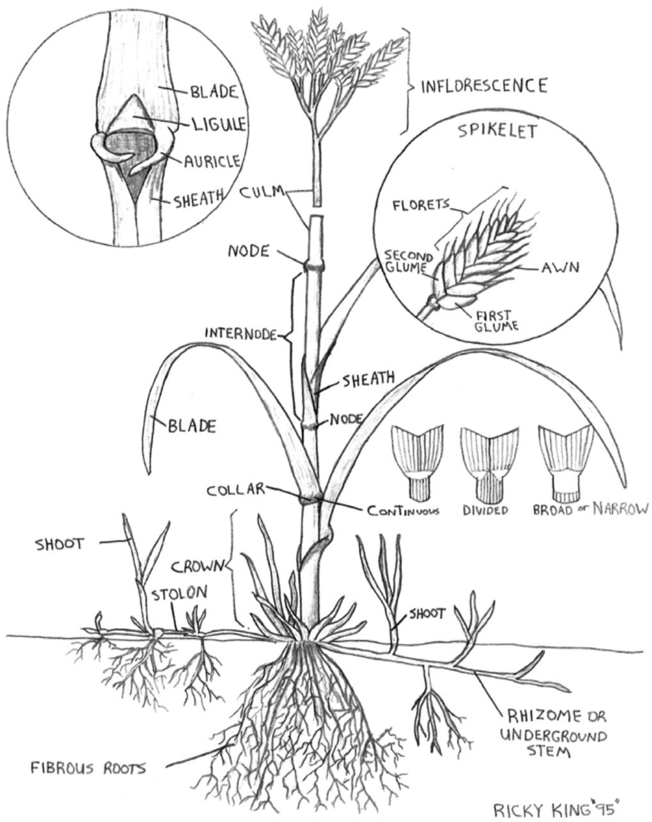


Figure 15.1. Physical structure of a grass.

Perennial Ryegrass *(Lolium perenne)*

Most perennial ryegrass cultivars are not reliable and form a clumpy, open turfgrass that has little appeal and poor persistence. Several new, improved, fine-leaf perennial ryegrasses are available. These blend well with Kentucky bluegrass when it is necessary to obtain quick cover, protect the soil from erosion, or seed out of season.

To determine how a cultivar sold at your local store will perform in Kentucky, visit www.ntep.org to check current and previous data.

Adaptation—When seeded alone, ryegrasses may not survive the summer unless irrigation and disease control are provided. Although not adapted to heavy shade, they can survive it some years and are easily established among the surface roots of trees.

Major qualities—Fine texture similar to Kentucky bluegrass; more tolerant than other grasses to heavy clay and compacted soils; germinates quickly (five to seven days); excellent seedling vigor; great traffic tolerance; can be mowed short (approximately one inch); will often dominate nimblewill and other weed species; can be seeded with minimum soil preparation.

Major problems—Somewhat difficult to mow (requires sharp mower); susceptible to summer brown patch disease; has little heat tolerance; needs summer irrigation if thick stand is established; sod has little resiliency.

Seeding rate—Four pounds pure live seed per 1,000 square feet when broadcast seeded.

Mixtures—For quick establishment and increased erosion control, seed no more than 10 percent to 15 percent by weight (approximately one-quarter pound per 1,000 square feet) with Kentucky bluegrass (1¾ pounds per 1,000 square feet); do not seed with tall fescue or fine fescue.

Bermudagrass *(Cynodon dactylon)*

Bermudagrass occurs naturally in many Kentucky lawns and is most often considered a weed. Native bermudagrass, often called "wiregrass," is usually found or planted in hot, dry locations where it is difficult to grow cool-season grasses.

Cultivars should be selected that are adapted to Kentucky winters. To determine how a cultivar sold at your local store/sod farm will perform in Kentucky, visit www.ntep.org to check current and previous data.

All bermudagrass cultivars must be planted in late May or early June.

Adaptation—Mainly adapted to full sun and well-drained soils.

Major qualities—After establishment, bermudagrass is tolerant to low fertility and drought and makes a resilient, traffic-tolerant turfgrass.

Major problems—Difficult to mow (requires sharp mower); not shade tolerant; is dormant (brown) from approximately early October to early May; winterkill can be a concern during especially cold winters; because of its creeping habit of growth, bermudagrass often becomes a serious pest in gardens and flower beds and will rapidly creep into a neighbor's lawn.

Planting rate—Plug on one-foot centers, sprig in six-inch rows one foot apart, or (for large areas) broadcast two to seven bushels of shredded sprigs over 1,000 square feet and cover by light disking or soil topdressing.

Seeding rate—(Seeded varieties), one pound per 1,000 square feet for non-coated seed, or two pounds per 1,000 square feet for coated seed.

Zoysiagrass *(Zoysia japonica)*

This is an excellent summer grass for areas with full sunshine or moderate shade and heavy summer traffic.

Zoysiagrasses in general are known for having better cold tolerance than bermudagrasses. Several cultivars are available that are adapted to the transition zone climate. To determine how a cultivar sold at your local store/sod farm will perform in Kentucky, visit www.ntep.org to check current and previous data.

Adaptation—Zoysiagrass has moderate shade tolerance so may be used in sun and shade situations. It has excellent winter hardiness and will grow throughout Kentucky.

Major qualities—After establishment, extremely tolerant to low fertility and drought and makes a very resilient, traffic-tolerant turfgrass; very competitive against weeds and has few pest problems; will grow very slowly and thus will not require frequent mowing; spreads slowly, so not as invasive as other creeping grasses.

Major problems—Dormant (brown) from October to early May; can become thatchy, especially if overfertilized.

Turfgrass Terminology

Annual, summer—A plant that completes its life cycle, from seed, in one growing season.

Annual, winter—A plant that initiates growth in the fall, lives over winter, and dies after producing seed the following spring or summer.

Blend—A combination of two or more cultivars of a single turfgrass species.

Bunch-type growth—Plant development by tillering at or near the soil surface; no lateral stems produced.

Clippings—Leaves cut off turfgrass by mowing.

Cool-season turfgrass—Turfgrass species best adapted for growth during cool portions (60°F-75°F) of the growing season. Examples: Kentucky bluegrass, tall fescue, fine fescue, perennial ryegrass.

Coring—A method of turfgrass cultivation by which soil cores are removed using hollow tines or spoons.

Cultivation—Disturbance of the soil without destruction of the turfgrass. Examples: coring, spiking, aerification.

Cutting height—On a mower, the distance between the soil surface and the plane of cut.

Dethatch—To remove an excessive thatch accumulation, usually by a mechanical practice such as vertical mowing.

Foliar burn—Injury to leaf tissue caused by dehydration due to contact with high concentrations of certain fertilizer salts or chemicals.

Herbicide—A pesticide used for controlling weeds.

Irrigation—Application of water to turfgrass by either hand-set sprinklers or by automatic means using electronic controllers.

Localized dry spot—A dry spot of sod that resists rewetting by normal rainfall or irrigation. Usually associated with an accumulation of thatch, a high spot, shallow soil over buried debris or rock, or major fungal activity that renders the soil hydrophobic.

Mixture—A combination of two or more species.

Mowing frequency—The number of times the lawn is mowed per week or month.

Mowing height—The distance above the ground surface at which the turfgrass is cut during mowing.

pH (soil)—A numerical measure of the acidity of the soil. A pH of 7 is neutral, above 7 is alkaline (basic), and below 7 is acidic.

Reel mower—A mower that cuts turfgrass by means of a rotating reel of blades that passes across a bed knife fixed to the mower frame, thus giving a shearing type of cut.

Renovation—Turfgrass improvement involving replanting into existing live and/or dead vegetation.

Resiliency—The capacity of the turfgrass to spring back when balls, shoes, or other objects strike the surface, thus providing a cushioning effect.

Rhizome—An underground elongated stem with new plants springing from nodes along the stem.

Rotary mower—A mower that cuts turfgrass by high-speed impact of a sharp blade rotating in a cutting plane that is parallel to the turfgrass surface.

Scalp—To remove an excessive quantity of functioning green leaves at any one mowing, resulting in a brown appearance with exposed crowns, lateral stems, and dead leaves.

Scum—A layer of algae on the soil surface of thinned turfgrass.

Slowly available fertilizer— A fertilizer that designates a rate of dissolution of nitrogen that is less than that obtained from completely water-soluble (readily available) fertilizers.

Sod—Plugs, squares, or strips of turfgrass with adhering soil; can be used in vegetative planting.

Sprig—A stolon, rhizome, or tiller used to establish new turfgrass or plants in furrows or small holes.

Stolon—An elongated stem that grows along the surface of the ground and from which leaves and roots develop at the nodes.

Thatch—A layer of undecomposed or partially decomposed turfgrass roots and stems situated above the soil surface and constituting the upper stratum of the medium that supports turfgrass growth.

Tiller—A lateral shoot, usually erect, that develops intravaginally from axillary buds.

Turf—A covering of mowed vegetation, usually a turfgrass, growing intimately with an upper-soil stratum of intermingled roots and stems.

Turfgrass—A species or cultivar of grass that is maintained as a mowed turf.

Verdure—The layer of aboveground, green, living plant tissue remaining after mowing.

Warm-season turfgrass—Turfgrass species adapted to favorable growth during warm portions (80°F–95°F) of the growing season. Examples: zoysiagrass, bermudagrass.

Soil Preparation

Proper soil preparation is critical to the establishment and long-term quality of a lawn. Soil conditions are very poor on many lawn sites, because the lawn was the last consideration instead of the first. The following factors should be strongly considered when starting a new lawn.

Grading

Ideally before a new lawn is established, the topsoil should be stockpiled to the corner of the lot prior to house construction. After the house is finished, all building debris should be removed from the lawn area. This is a step that most contractors skip, and they simply push the topsoil over the construction debris. If you are building a house, insist that the site is thoroughly cleaned prior to moving topsoil. The subgrade should be sloped away from the house in order to reduce the possibility of water entering the basement. After the subgrade has been completed, the stockpiled topsoil can be respread. With four to six inches of good topsoil, establishment and maintenance of your lawn can be a pleasure rather than a nightmare. Often contractors will remove some of the topsoil from the yard and leave you with one-half to one inch of topsoil, which results in many challenges in growing lawns and landscape plants.

Soil Amendments

It is hard to purchase good topsoil. Frequently, the homeowner ends up getting soil much poorer than what is already there, and often it is seriously infested with weed seed.

Adding large quantities of organic matter is the best way to improve a poor soil. Peat moss, well-decomposed sawdust, well-rotted and weed-free manure, sewage sludge, or compost will improve soil that is either too sandy or contains too much clay. Use two to three cubic yards of organic matter for each 1,000 square feet of lawn area. The organic matter should be spread evenly over the surface and thoroughly mixed into the upper four to six inches of soil before seeding.

Lime and Fertilizer

The soil should be tested to determine exact lime and fertilizer needs. Your local office of the Cooperative Extension Service can provide soil cartons and the information you will need for performing soil tests. The soil should be taken from the completed grade, rather than the subgrade. Soil tests are very inexpensive and can be conducted at any time of the year. Many soils throughout Kentucky do not require additional phosphorus or potassium. Because applying fertilizers to soils that do not require them can be serious pollutants, no fertilizers or lime other than nitrogen should be applied without taking a soil test. Refrain from applying nitrogen until seeds have germinated and roots are able to remove nutrients from the soil. Nitrogen applied at seeding will have a higher tendency to leach through the soil or runoff with rain with no plants to remove nutrients or slow water movement on the soil surface.

Planting

Before Planting

A newly graded lawn area should be allowed to settle before planting. Two or three good rains or irrigations will aid in the settling. Puddles of water that form during a rain or irrigation indicate low spots that need to be leveled or have drainage installed. Excessive water on the lawn is as bad or worse as not enough water. Good surface drainage is a must!

The final seedbed should be firm and free of large clods, rocks, and discarded building materials.

When to Establish

There are only certain periods each year when temperature, moisture, and weed competition favor successful seeding of lawns.

The best time to seed cool-season grasses such as Kentucky bluegrass or tall fescue is from mid-August through early October. The second-best time is from mid-February to mid-March, and not later than mid-April. Due to weed competition and moisture stress, late spring to midsummer seedings are seldom successful.

Sod of Kentucky bluegrass and tall fescue can be installed almost anytime except midwinter, when soil is frozen. During extremely hot and dry summers, however, sodding should be delayed, or the soil should be watered to cool it just prior to installation.

Vegetative strains of bermudagrass and zoysiagrass are normally sprigged or plugged and should be established during May or June after the soil is warm. Seeded bermudagrass should be planted at the same time, so the turfgrass can be well established before a potentially bad winter.

Seed, Sod, or Vegetative Planting

Kentucky bluegrass and tall fescue lawns can be seeded or sodded, while improved strains of bermudagrass or zoysiagrass are most usually planted from existing vegetative material. Soil preparation is the same, regardless of the planting method used.

Seeding is usually accomplished with a rotary seeder or the commonly used seed and fertilizer spreader. For uniform distribution, the seed should be divided into two equal lots, which should be seeded at right angles to each other. It is imperative that the seed is lightly covered by soil (referred to as seed-soil contact) for good germination. Cover the seed by raking lightly or rolling, and avoid a smooth surface. It is best to mulch the area with clean straw or other suitable material. Mulch will help keep moisture at the soil surface and minimize soil movement (erosion) before the grass can hold it in place. The mulch covering should be thin enough to expose approximately 50 percent of the soil surface, which usually requires approximately one bale of straw per 1,000 square feet of area. It is important to water frequently in order to keep the soil surface moist until seedlings become established, especially if a mulch is not used.

Before ordering or obtaining sod, be sure you are prepared for its installation. It is generally best to establish a straight line lengthwise through the lawn area. The sod can then be laid on either side of the line with the ends staggered, as when laying bricks.

The better the sod quality, the easier it is to transport and install it. Quality sod is light, does not easily tear apart, and generates a root system quickly. Sod is perishable and should not remain on the pallet or stack longer than 36 hours. The presence of mildew and distinct yellowing of the leaves is usually good evidence of reduced vigor.

Installing sod is an art. A sharpened concrete trowel is very handy for cutting pieces, forcing the sod pieces tightly together, and leveling small depressions. Just as seed-soil contact was important above, sod-soil contact is also important. Immediately after the sod is laid, it should be rolled and kept moist until the sod is well-rooted into the underlying soil. Any air spaces between the sod and soil will cause those areas to dry out, and rooting will be impaired.

Vegetative planting, using either sprigs or plugs, is the common method used in establishing high-quality bermudagrass and zoysiagrass. Once again, plant material-soil contact is critical for success. Sprigs can be either broadcast over an area and covered lightly with soil or can be individually planted on 6- to 12-inch centers. In either case, the individual sprig should have one end about two inches below the soil surface and the other end above the soil surface, so that a node or joint with some leaves extends aboveground. Sprigs can be purchased by the bushel or can be purchased as sod and then shredded. One bushel of sprigs is approximately equivalent to one square yard of sod. Plugs of zoysiagrass are commonly available and are one to two inches in diameter and one to two inches deep. The plugs should be fit tightly into prepared holes and tamped firmly into place. Sprigs and plugs should be kept moist until they are well established. Vegetatively planted bermudagrass can be fully grown in one to two months, while zoysiagrass may take a year or longer, depending on planting density, environmental conditions, and cultivar.

Caring for New Lawns

Moisture is probably the most important consideration immediately after planting. Regardless of the method used for planting, the soil must be kept moist for two to three weeks.

Mowing should not be delayed just because the lawn is new. After the turfgrass begins to grow, mow to recommended heights.

Lawn Renovation

Preparing a Seedbed

Little success can be expected if you just broadcast seed on the soil surface. In order for seed to germinate and survive, it must have good soil contact. Sometimes a heavy raking will loosen the soil surface sufficiently, but most often the surface is hard, and weeds or dead grass make raking difficult.

A vertical mower or dethatching machine can often be rented from a local lawn supplier or equipment-rental agency. Not only will vertical mowing or dethatching loosen the dead grass and weeds, it will leave shallow grooves or slits in the soil surface. Seeds falling into these slits are much more likely to germinate and live. For best results, it may be necessary to traverse the area several times in different directions in order to disturb the soil sufficiently.

Most commercial lawn companies and some rental agencies have power seeders. These machines vertical mow/dethatch and distribute the seed in a single pass; however, it is still desirable to seed in multiple directions to avoid missing any areas.

Selecting the Right Grass

Assuming that the lawn is established to an adapted grass, it is usually more desirable to seed the same species as the existing grass in order to maintain uniform appearance. Do not seed coarsely textured grasses like KY 31 tall fescue into a Kentucky bluegrass lawn. Turf-type tall fescue is the preferred renovation grass, as it has a similar texture to Kentucky bluegrass. Kentucky bluegrass is very difficult to establish within an existing lawn—the seeds are very small and seedling vigor is low.

Success is best achieved when:

- Existing grass and/or weeds are almost entirely killed by insects, disease, drought, or non-selective herbicides.
- The majority of existing grass and weeds can be completely removed with a dethatching machine.
- Renovation can be accomplished in early fall or early spring.
- The surface can be kept moist for about two weeks with irrigation.

Sowing the Seed

The seed should be evenly spread over the area at the rate of two pounds per 1,000 square feet for Kentucky bluegrass, six pounds per 1,000 square feet for tall fescue, or two to four pounds per 1,000 square feet for perennial ryegrass or red fescue. Rake the seed lightly into the seedbed or traverse the area again with the dethatching machine for good seed-soil contact.

If using a power seeder, seed only about one pound per 1,000 square feet per pass and make multiple passes, if possible. If only making one or two passes, you can broadcast three to four pounds per 1,000 square feet before making the last pass.

Remember, chances of success are good if you seed during late August and September, fair during late February or early March, and very poor from mid-spring to August.

Proper Care

Newly seeded areas should be watered immediately after seeding. Watering should continue as long as necessary to obtain satisfactory germination and growth. The surface should be kept consistently moist without forming puddles. Begin mowing as soon as some of the grass grows higher than the desired mowing height. Keep the mower blade sharp as a dull blade can rip young plants out of the soil.

If the area is seeded in spring and crabgrass is a potential problem, apply a preemergent crabgrass herbicide immediately after seeding. Siduron (Tupersan) or mesotrione (Tenacity) are the only preemergent herbicides that can be used. A second application should be applied in late spring or early summer. Follow the specific label directions.

Caution: Germination of desirable grasses may be decreased if broadleaf weed killers such as 2,4-D have been applied one to two weeks before seeding. These herbicides should not be applied to young seedlings. Before applying these herbicides, wait until the new grass has grown enough to be mowed at least twice.

Lawn Maintenance

The intensity of turfgrass maintenance varies with the homeowner's inclination, expertise, available working hours, and budget. It also varies greatly depending upon your soil and the grass species in place. There are certain maintenance practices, however, which are necessary for quality turfgrass.

Table 15.2. Optimum mowing height for some grass species.

Species	Height (in)
Kentucky bluegrass	2 - 3
Tall fescue	2.5 - 4
Creeping red fescue	2 - 3
Perennial ryegrass	1 - 2
Bermudagrass	1 - 1.5
Zoysiagrass	.75 - 1

Mowing

Some of the most serious mistakes are mowing lawns too closely, too infrequently, or using a dull mower blade.

Below-optimum mowing heights restrict root development, and the grasses become susceptible to disease, heat and drought damage, traffic injury, and weed infestation. Check the blade height and follow the guide in Table 15.2.

Mowing is somewhat injurious to grass because it removes a portion of the youngest, most active leaves. Unless the tiller is beginning to flower, which usually occurs in late spring, the growing point of each stem is located near the soil surface and protected from the mower blade. Therefore the grass plant is just a series of leaves that we often call a pseudostem. The true upright growing stem does not develop until the flowering process begins (Figure 15.2).

The general rule is to mow often enough so that no more than one-third to one-half of the leaf is removed at any one mowing. If the grass grows too tall between mowings, increase the mowing height—do not cut it all off at one time. Removing half or more of the leaf blade in any one mowing results in a negative impact on the root system. Remember, the lower you mow, the more frequently you need to mow.

A sharp mower blade makes mowing easier and results in a better looking and healthier turfgrass. Dull blades result in a longer healing time for the leaf, which can result in increased disease pressure. Further, dull blades require more power to cut through the leaf, resulting in increased fuel usage. You may need to sharpen the mower two to three times a year.

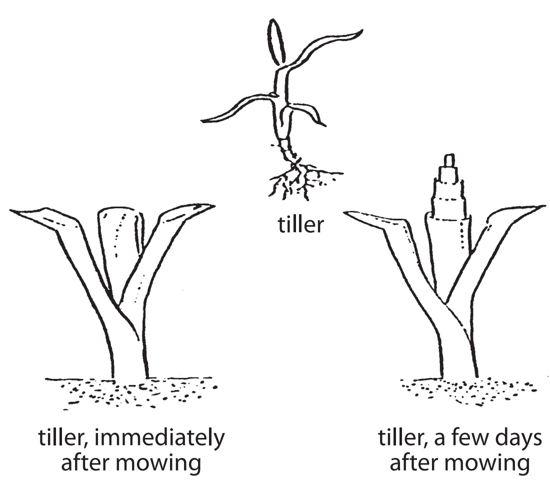


Figure 15.2. Grass tiller and pseudostem after mowing.

Removal of Clippings and Thatch

Unfortunately, most people still believe clippings increase thatch, which is the tightly intermingled layer of organic matter that sometimes accumulates between the soil surface and the green leaves. Research has shown, however, that thatch is caused by species (grasses that produce rhizomes and stolons have greater thatch), too much nitrogen fertilization, acidic surface soil, frequent irrigation, and a low population of earthworms.

Clippings have no effect upon thatch accumulation. They contain 75 percent to 85 percent water and are easily decomposed into humus. Research has shown that thatch is made up of about 60 percent dead and living roots and rhizomes, with the remaining 40 percent composed of dead stems, leaf sheaths, and crown tissue—all highly ligneous (woody) and slow to decompose.

When clippings are not removed, they occur only in the upper surface layers as "pseudo" thatch. This pseudo thatch can be raked out of the turfgrass, but raking it out won't reduce a problem with real thatch, which cannot be removed with a rake because it is tightly interwoven by a mass of roots. Real thatch can be removed only partially with mechanical dethatchers.

Thatch is currently not a problem in most cool-season grass lawns. It never accumulates in tall fescue, moderately fertilized lawns, or in lawns with a healthy earthworm population.

Many people also remove clippings to reduce disease problems. Removing any biomass does help slow down a fungus, but Kentucky lawns seldom have a serious disease problem. When they do, the disease almost always occurs during the hot summer when the turfgrass is growing slowly and producing few clippings.

Some people remove clippings to prevent windrowing or globs of wet clippings left on the lawn's surface. Mow more frequently to avert this problem. As mentioned previously, mowing should be repeated when the leaves have grown about 30 percent to 50 percent above the previous mowing height. If you are mowing at a two-inch height, mow again when the turfgrass reaches a height of about three inches. If it rains for a week and the height reaches five inches, raise the mower to three inches for the next mowing. After a couple days, lower the height back to the original two inches and mow again. Don't take off all the leaves at once because it increases the amount of clippings that shade the remaining grass, often causes the mower to pile up or windrow the clippings, weakens the grass by removing its photosynthetically active leaves, and looks unsightly.

You need to mow frequently during April and May, when almost 50 percent of the total annual growth occurs.

Some cheaper mowers do a poor job of distributing clippings even when conditions are great. However, all mowers work best when the grass leaves are dry, the grass has grown no more than 50 percent higher than the previous mowing height, and mower blades are sharp. A common complaint against returning clippings is that the homeowner does not like the look of the clippings on the lawn. However, if the lawn is mowed properly and leaf clippings are short, they don't look unsightly because they filter down between the remaining grass leaves and quickly decompose.

Some mowers are advertised as mulching mowers that cut or shred the leaves into smaller fragments. These mowers work as advertised; however, to prevent clogging of the mower, the turfgrass must be dry and mowed often.

Another reason for removing clippings is to remove the mess—clippings tracked into the home and scattered onto the sidewalk or driveway—and create a slightly neater appearance on the surface of dense turfgrass. But is removing clippings worth the problems it creates? No!

Finally, not removing clippings helps the environment. It's not necessary to use landfills to dispose of vegetative material that will decompose into something as useful and safe as humus.

So what can we do with grass clippings? That's easy! Don't collect them in the first place. Clippings add fertilizer back to the lawn, maybe as much as 25 percent of the lawn's annual needs. One thousand square feet of a well-fertilized lawn can produce as much as 400 pounds (dry weight) of clippings per year. These clippings average about 4.8 percent nitrogen, 0.7 percent phosphorous, and 2.6 percent potassium, and they also have minute quantities of many minor nutrients—good stuff.

If you must collect clippings, use them yourself. First, consider spreading them lightly over a low-maintenance turfgrass area, vacant lot, etc. Scatter them; don't dump them into a pile.

Second, consider using them as a mulch around ornamentals or between rows in the garden to reduce weed competition, conserve soil moisture, and supply nutrients as the clippings break down. Apply them at least an inch thick and turn them under in the fall to improve soil tilth and supply additional nutrients.

Third, consider composting the clippings and using the compost to modify soil in the garden or in plant pots. Grass clippings alone are sometimes difficult to compost since they become very dense and anaerobic, often causing an odor problem. It is best to compost a mixture of clippings, tree leaves, wood chips, garden weeds, etc. You can often hasten composting by keeping the pile moist and by occasionally adding some soil, nitrogen fertilizer, and lime.

When using clippings as a mulch or compost, be aware that such compost may contain weed seed such as crabgrass. Also, make sure that the lawn has not been sprayed with a herbicide within a few days of mowing, because residues from certain broadleaf weed herbicides may cause damage to the mulched plants.

Finally, because clippings are full of nutrients, it is important to sweep or blow them off sidewalks and back onto the lawn. Clippings that are washed into the stormwater system act just like fertilizer and can cause algal blooms in ponds and lakes.

Fertilization

In order to sustain a quality lawn, nitrogen fertilizer must be applied annually to help maintain turfgrass uniformity and a good, green color, while also reducing weed problems. However, if fertilizer is applied improperly or at the wrong time, you can lose these benefits.

Soil Test

Randomly collect one to two pints of soil from the top few inches of the lawn and take it to the local Extension office. The University of Kentucky Soils Testing Lab can determine if phosphorus (P), potassium (K), or lime are needed. The recommended rates of nutrients can be applied with a fertilizer containing only P (for example, triple superphosphate 0–46–0) or K (for example, muriate of potash 0–0–60), or by using a complete fertilizer, such as 10–10–10, 17–17–17, 10–20–10, etc. Once you get a high level of P and K in the soil, little additional P or K may be needed for several years. As was mentioned previously, many soils throughout Kentucky do not require P or K due to parent material or many years of fertilizing with these products. Additional applications of these nutrients to soils with adequate levels is a waste of your money and can have a negative impact on the environment.

Timing

Fall is the best time of year to apply nitrogen to cool-season grasses, such as Kentucky bluegrass and tall fescue (Table 15.3). In response to fall nitrogen, the turfgrass develops a better root system, becomes very dense, and has much better color in late fall and early spring. By eliminating or minimizing spring fertilization, you prevent the heavy flush of growth that occurs with it, develop a better root system, and develop a more heat-tolerant, weed-free turfgrass.

If for some reason nitrogen was not applied the previous fall, an application during early spring will improve green-up. Even if fall nitrogen was applied, it is helpful in some years with heavy spring rainfall to apply a half-rate of nitrogen in late May or early June, but only if necessary to improve color. Crabgrass and other summer annual weeds respond to the nitrogen much more than bluegrass or fescue. The more you fertilize cool-season grasses with nitrogen in spring and summer, the more you need to irrigate, control thatch, and use chemicals to control weeds, insects, and diseases. A lush, green lawn may not be worth these problems.

Late spring to early summer is the best time to fertilize bermudagrass and zoysiagrass, since they are warm-season grasses and perform best during hot summer months.

How Much Nitrogen to Apply

A good rule is to apply about one pound of actual nitrogen per 1,000 square feet per application. Most home lawns will perform well with only two pounds of actual nitrogen per year. Additional nitrogen may be warranted for lawns that have a lot of traffic from kids or pets or are heavily irrigated. Lawns

Table 15.3. Schedule for nitrogen application to lawns.

Maintenance Level	Applications per Year	Cool-Season Grasses[1] (Kentucky Bluegrass and Fescue)	Warm-Season Grasses (Bermudagrass Zoysiagrass[2])
Low	1	Oct-Nov	Jun
Medium	2	Sept-Oct, Nov-Dec	May, Jul
High	3	Sept-Oct, Oct-Nov, Nov-Dec	Apr, Jun, Aug
Very High	4	Sept-Oct, Oct-Nov, Nov-Dec, late May-early June (1/2 rate)	Apr, May, Jun, Aug

1 Red fescue and all cool-season grasses grown in shady lawns should be fertilized only once per year.
2 Zoysiagrass needs only minimal nitrogen after lawn is fully established.

Table 15.4. Examples of fertilizers and rates needed for 1 lb of actual nitrogen per 1,000 sq ft.

Fertilizers	Rate (lb)
Farm	
Ammonium Nitrate (34-0-0)	3
Urea (46-0-0)	2.2
10-10-10	10
5-10-10	20
Specialty	
24-4-4	4.5
16-6-8	6
27-4-9	3.5
20-5-10	5
32-4-8	3

Note: Rates apply 1 lb N per 1,000 sq ft of lawn.

receiving more than two pounds of actual nitrogen per year will often require additional mowing and pest control. The fertilizer analysis tag indicates actual nutrients and the first number (as in 10–6–4) indicates the percent of nitrogen, so you can easily calculate the pounds of actual nutrient in a bag. For example, a 50-pound bag of 10–6–4 contains five pounds (50 x 0.10 = 5) of actual nitrogen. It also contains three pounds (50 x 0.06 = 3) of P2O5 and two pounds (50 x 0.04 = 2) of K20. The remainder of material in the bag (50-(5+3+2) = 40), i.e., 40 pounds, is called the filler or carrier. To apply one pound of nitrogen per 1,000 square feet, you would need to apply 10 pounds (10 x 0.10 = 1) of the 10–6–4 fertilizer.

Table 15.4 shows both farm fertilizers and hypothetical fertilizers representative of many specialty fertilizers with high nitrogen and low phosphate levels.

Farm Versus Specialty Fertilizers

Lawns can be fertilized either with the specialty fertilizers, which are often sold in garden centers, or with farm fertilizers. The main advantages to the specialty fertilizers are their normally good nutrient ratios, uniformity in particle size, low burn potential, and the printing of calibration and application rate information on the bag.

Farm fertilizers are usually three to five times less expensive, but they have some disadvantages. Farm fertilizers such as ammonium nitrate and 10–10–10 must be used with caution because of their burn potential. You should not apply them during extremely hot weather or when moisture is on the grass leaves. However, if they are applied in the fall and early winter as suggested and at the proper rate, they will seldom, if ever, burn a turfgrass. The biggest problem with these fertilizers is the lack of calibration and application information on the bag. You have to calculate the correct amount to apply and calibrate the spreader to get the appropriate coverage.

Depending on the type of spreader used, it is sometimes difficult to get only 2.2 or 3 pounds of fertilizer evenly spread in a 1,000-square-foot area. Without experience, it often appears that too little fertilizer is being applied, and the temptation is to apply more. Be careful! Applying more than 1½ to two times the recommended rates will greatly increase the burn potential and cause an excessive flush of growth. An application of 10 pounds per 1,000 square feet, such as with 10–10–10, is easier to detect in the grass. However, the burn that results when applying more than 15 pounds per 1,000 square feet is even more serious with these mixed fertilizers because of the potassium salts that are included.

Most of the specialty fertilizers also contain a certain amount of slow-release nitrogen, which is indicated on the bag under the heading "water-insoluble nitrogen" or "coated nitrogen." Usually the amount of this slow-release nitrogen is less than one-third of the total amount of nitrogen in the bag. Slow-release nitrogen adds safety in application, but the small amount of it that's included doesn't really provide good long-term nitrogen availability.

Most of the specialty fertilizers can be programmed exactly the same as you would program a farm fertilizer.

If you do not remove clippings, most specialty fertilizers contain sufficient P and K to maintain the soil level. Therefore, once you correct any soil deficiency, continual use of specialty fertilizers will be sufficient for P and K for many years.

Spreader Calibration

Spreader calibration becomes necessary if you use a fertilizer brand that does not have calibration information or if the bag information does not include your spreader model. Since the density and granule size of fertilizers are quite variable, it sometimes becomes necessary to recalibrate the spreader for almost every application.

When using a drop-type push spreader, begin by guessing at a spreader setting, then apply a known amount (such as five pounds) to a test area and determine the square footage covered (length multiplied by width) or apply the fertilizer over a plastic sheet or sidewalk area of known square footage and collect and weigh the fertilizer deposited.

After calculating the rate applied per 1,000 square feet, if the first guess was right, treat the lawn at that setting. If not, readjust the spreader and follow the same procedure until the correct calibration is achieved.

Calibrating to a half-rate setting and going over the yard twice will ensure a more uniform coverage and color.

It is somewhat easier to calibrate a rotary-type push spreader or a hand-crank (shoulder strap) rotary spreader than a drop-type spreader, since the width of coverage with those spreaders is much greater (10 to 25 feet). Measure a test area of lawn (for example, a side yard that equals 2,000 square feet). Put the correct amount of fertilizer (for the 2,000 square feet) into the spreader with the opening adjusted to be just slightly larger than the size of the individual granule. If more than two or three passes are required to dispense the fertilizer, then select another known area (for example, the backyard). Increase the size of the opening and continue to refine the calibration until the total amount needed is spread in a couple of passes through the yard.

Calibration is not easy and usually requires more time than the application itself. Because of wear and rust, spreader openings often change in relative size. Whether the calibration information from the bag or your actual calibration is used, always recheck to see if the approximate amount of fertilizer is actually used.

After completing the fertilizer application, immediately clean the spreader. Because of its high salt content and ability to absorb moisture, fertilizer left in a spreader will cause immediate rusting. Also, do not let the wash water from the spreader run onto the lawn. It may cause uneven growth or excessive burning.

Liming

A soil pH test is required to determine the extent of soil acidity. The pH test should be run every two or three years, especially if the lawn is under high maintenance. Natural weathering of soils and the addition of acid-forming fertilizer can lower the pH sufficiently to reduce the growth and quality of most grasses, especially Kentucky bluegrass. However, due to limestone parent material in many Kentucky soils, our soils are naturally high in pH and may improve with some acidification. Liming without the need to lime can tie up nutrients in the soil and weaken the overall health of the lawn.

The limestone normally purchased at rock quarries is cheap but very coarse, and it is difficult to apply in lawn spreaders. It is probably most easily applied by shovel from the back of a pickup truck. Often as much as 100 to 300 pounds will be required per 1,000 square feet.

Agricultural limestone is recommended if the soil is acid. Finely ground agricultural limestone is often sold through garden centers in 50-pound bags as agricultural lime or dolomitic limestone. Like rock quarry limestone, it is also difficult to get through lawn spreaders in sufficient quantities and is very dusty. The dolomitic limestone is also usually slightly more expensive because it contains some magnesium carbonate as well as calcium carbonate (ag lime). Since our Kentucky soils contain sufficient quantities of magnesium, the dolomitic limestone is not needed.

A bagged, pelleted-lime product is available in many lawn and garden stores. This product flows freely through lawn spreaders and is not extremely dusty. It is, however, more expensive than agricultural lime and must be used at equivalent rates.

Hydrated and burned lime can often be purchased. Although somewhat lesser quantities than other limestone types are needed to reduce the acidity, some burn problems may occur. Gypsum (calcium sulfate) is often sold as a substitute for lime or as a soil conditioner to loosen a heavy clay soil. It is not effective in changing pH or improving the structure of Kentucky soils.

Core Aerification

Core aerification is a mechanical cultivation process in which cores of soil, about three-quarters of an inch by three inches, are removed from the soil surface with an aerifier and then scattered back on the soil surface. On heavily trafficked golf greens and athletic fields, core aerification is extremely beneficial in reducing compaction and organic accumulation on the surface, as well as smoothing the surface. Core aerification may be somewhat beneficial for home lawns to penetrate surface organic matter that sometimes becomes hydrophobic and to provide some leveling as the soil cores are distributed back into surface depressions. On the other hand, core aerification is not as beneficial for lawns as it is for sport turf surfaces because of the following:

- Surface compaction, which is caused by heavy traffic, is not usually a problem on lawns.
- Clay, the dominant soil texture on most urban lawns, is difficult to penetrate with the aerifier, and clay soil cores are hard to extract from the coring tines.
- It is difficult to influence the surface significantly. To achieve best results, cores need to be made on two-inch-square or three-inch-square centers, which is hard to achieve with aerifiers available on the consumer market.
- Coring just before broadcasting seed is often suggested as a method for renovating lawns. This is not effective, however, unless the grass/weed cover is very thin and the extracted soil can be considered as topdressing for the seed. If the aerifier only extracts cores on six-inch-square or eight-inch-square centers, then effectiveness will be nil.

Watering

Water a lawn only during excessively dry periods once it is established. Frequent, shallow watering should always be avoided. It causes shallow rooting and encourages crabgrass invasion and diseases.

Water thoroughly when you do water. The soil should be wet to about four inches deep, which usually requires one-half to one inch of rainfall or irrigation. You can check with a probe or knife to see the depth of moisture.

Early morning is the best time of the day to water, but unless a serious disease problem exists, evening watering causes few, if any, problems. Lawns can also be watered at midday, but you can expect increased evaporation loss.

Remember that localized dry spots, which frequently appear during the summer months, are often misdiagnosed as insect or disease problems.

To differentiate localized dry spots from disease or insect patches of dying grass, always probe the soil first, using a screwdriver, soil probe, shovel, etc. If the top one to two inches is bone dry—powder dry—the problem is likely localized dry spot. Correcting it with a pesticide is impossible.

Pest Control

Pests can include weeds, insects, disease, and animals such as moles.

We misdiagnose disease and insect problems all too frequently. When you see dying patches of grass during the summer, always check the soil before treating with a pesticide.

Weeds

An adapted turfgrass species that is properly established, mowed, and fertilized will have few weed problems, but all weeds won't be eliminated.

Keep in mind that a plant becomes a weed when it grows where it is not wanted. That means plants that are considered desirable in some crops or waste areas can become serious lawn weeds. For example, many people believe that clover is desirable in turfgrass because it fixes nitrogen so that the turfgrass seldom needs fertilization. Others strongly object to its white flowers because they disrupt a lawn's uniformity and attract bees that may sting bare feet. Also clover often leaves a stain on clothing that is difficult to remove. Another example of this paradox is tall fescue. Although tall fescue is the best adapted lawn grass in Kentucky, many consider it objectionable in Kentucky bluegrass lawns because of its coarseness and clumping growth habit. Kentucky bluegrass can also creep into landscape beds and become a weed.

Broadleaf weeds—Chemical herbicides are used to control weeds. Some can be applied to control a specific weed but not damage the desirable grass. With other herbicides, all green vegetation to which the herbicide is applied will die. Sometimes these herbicides are persistent in the soil, and further reseeding of desirable grasses cannot be accomplished for months or even years after the herbicide application. Some herbicides must be applied before weeds germinate (preemergence), and others must be applied after weed emergence (postemergence). Knowing the nature of the herbicide is a must. The herbicide label describes the weeds controlled, the desirable grasses on which it is safe to apply it, and certain safety precautions. Always read the label.

Broadleaf weeds are generally characterized by netted veins in their leaves. Examples are dandelion, plantain, chickweed, ground ivy, henbit, white clover, spurge, and knotweed. Such weeds are most often controlled selectively after they germinate. These postemergence herbicides are absorbed into the leaf. They then move through the plant and kill the roots, underground stems, and the aboveground plant. Such systemic herbicides include 2,4-D; MCPP; and dicamba. Many products contain a mixture of two or three of these chemicals in order to get a broad range of control. For example, 2,4-D is an excellent dandelion killer, and dicamba is best for white clover. A mixture of the two will give maximum control of both species and many others.

Combination products containing 2,4-D, MCPP, and dicamba will kill almost all broadleaf weeds that grow in lawns. An exception is wild violet, which must be sprayed at least two times with triclopyr, a common brush killer, or mesotrione.

These chemicals are most safely applied in spring or fall, when the weeds are actively growing. Hot summer applications may injure desirable grasses, and if the soil is dry, the weeds probably won't be controlled. For the most effective control of broadleaf weeds, make applications in the fall when winter annuals are present. This will allow you to control perennial and annual broadleaves with one application. These products can be purchased as a spray or granular material. Generally products applied as a liquid are most effective. If a granular chemical is used, the foliage should be moist with dew before application to ensure that the granules stick to the leaf.

If these materials contact the leaf or are applied above the root zone, they may injure ornamentals. *Read all cautions on the label.*

Grassy weeds—Grassy weeds are characterized by parallel leaf veins. They are not often affected by the broadleaf herbicides described previously.

Annual grassy weeds, such as crabgrass and foxtail, are best controlled with preemergence herbicides that are applied before the weeds germinate. These herbicides should be applied before April 1 in Western Kentucky and before mid-April in Central and Eastern Kentucky. Examples are Pendimethalin (Pre-M), benefin + trifluralin (Team), prodiamine (Barricade), and dithiopyr (Dimension). Mesotrione (Tenacity) and siduron (Tupersan) are the only commercially available preemergence crabgrass herbicides that can be applied in the spring at the same time that desirable grasses are seeded. Other preemergent herbicides, if used, would prevent germination of the desirable grasses as well.

Postemergence crabgrass herbicides include fenoxaprop (Acclaim Extra), quinclorac (Drive XLR8), mesotrione (Tenacity), and topramezone (Pylex). These products should be applied while crabgrass is small and easier to control. Mature weeds typically require several applications to control.

Perennial grassy weeds such as tall fescue clumps, nimblewill, and bermudagrass are more difficult to control without also killing desirable turfgrass. A herbicide such as glyphosate (Roundup) will kill almost all grasses and weeds that are green when sprayed. Treated areas must be reseeded or sodded with desirable grasses. Nimblewill is best controlled with mesotrione (Tenacity), and bermudagrass with topramezone (Pylex). *Always read the label* for proper herbicide selection and use. Almost all grassy weeds require multiple applications for complete control.

Insects

Only a few of the insects that are present in a lawn actually cause damage. By far the most common damaging insect in Kentucky lawns is the white grub. Other insects such as the sod webworm, bluegrass billbug, and chinch bug are potentially damaging to Kentucky lawns, but their population is seldom sufficient to cause serious problems.

Successful control of turfgrass insects depends upon detecting their presence before they cause serious damage. This requires frequent inspections, looking for signs such as blades chewed off at ground surface; roots chewed off and sod easily dislodged; old insect casings or shells on the lawn surface; birds feeding heavily in the lawn; presence of moles or skunks causing damage; and moths or beetles flying over the surface in the late evening or early night.

Injury from heat and drought are often mistaken for insect injury. Applying insecticides will certainly not control damage caused by the localized dry spots that frequently appear in late spring or summer. Before assuming insect damage, always check to see if the underlying surface inch of soil is dry. Even though potentially damaging insects may be present, they may not cause turfgrass damage if the turfgrass is properly watered.

Insecticides can kill desirable as well undesirable insects, and if they are used improperly or overused, additional serious insect problems or thatch buildup can occur.

White grubs—White grubs are the most serious pest problem in Kentucky bluegrass lawns but seldom cause problems in tall fescue lawns. They devastate Kentucky bluegrass by feeding on the root system, which deprives the individual plants of moisture. In addition, moles, skunks, and even birds may further damage the lawn while feeding on white grubs.

Grubs are the larvae of any hard-shelled beetles. The most common of these beetles in Kentucky is the masked chafer, which is light tan and about one-half inch long. The Japanese beetle, which is increasing in Kentucky, is about one-half inch long, metallic green, and has coppery-brown wing covers. White grubs (larvae of the masked chafer and Japanese beetles) have stout, white bodies and brown heads, are one-half to three-quarters of an inch long, and are curled into a C-shape. The beetles lay eggs a few inches below soil level, mainly in June and July. The grubs hatch in three to four weeks and begin feeding on grass roots, so almost all turfgrass damage is done from late August through early November. When the soil temperature drops, the grubs quit feeding and move deeply into the soil for the winter. They resurface during spring and begin feeding again. Almost no turfgrass damage occurs in spring because the turfgrass has an extensive root system that is easily regenerated during the good spring weather. In May and June, white grubs pupate (resting stage) and emerge as adults after one year's development.

Large dead patches on your lawn, up to 20 feet in diameter, may develop in grub-infested areas. During late August through early November, homeowners should carefully look for any discolored grass. The drying sod can be rolled back like a carpet to expose the grubs. If the sod can be easily pulled back and numerous grubs are found, an insecticide such as trichorfon can be applied immediately and watered into the turfgrass (enough water to wet the soil to one-half inch depth) to prevent further damage.

For lawns with a history of white grub problems, insecticides containing chlorantraniliprole, imidacloprid, clothianidin, or thiamethoxam are available for preventive applications. Those products should be applied before egg hatch, ideally between late May and mid-July, and watered into the turfgrass.

Although moles may feed on grubs, an insecticide application won't starve or kill them, because they feed primarily on soil- inhabiting insects, mainly earthworms. Insecticides used to kill grubs should not kill earthworms, either.

Milky disease or milky spore disease, often sold to biologically control grubs, has not proven effective in Kentucky. It targets only Japanese beetle grubs and may not be effective on the targeted species.

Sod webworms—Although sod webworms are present in almost all turfgrass, they seldom cause damage to lawns. Sod webworm adults are beige to grayish-white in color, with a wingspread of about three-quarters of an inch. These moths are frequently seen during the growing season flying over lawns at dusk. The eggs laid by the female moths hatch in about two weeks. The caterpillars are grayish to beige in color, have small dark spots on their bodies, and may reach a size of three-quarters of an inch long. As they mature, they build silk-lined, grass-covered tubes near the soil surface. These larvae feed by chewing off grass blades near the plant crown.

Turfgrass damaged by sod webworms will show isolated yellow-to-brown patches of grass a few inches in diameter. The infected areas will appear to be closely grazed, and small green-to-tan pellets of excrement may be located within the damaged areas. Birds feeding on these caterpillars will often leave obvious probe holes in the turfgrass thatch.

Chinch bugs—Chinch bugs will occasionally infest a Kentucky bluegrass lawn, especially if the lawn is heavily contaminated with creeping bentgrass. Scattered patches of grass will turn yellow or brown due to the sucking of plant fluids by the young nymphs. Even when full grown, the black and white chinch bugs are only about one-quarter inch long and are difficult to find. The immature nymphs are only about one-twentieth of an inch long and may be reddish in color.

Bluegrass billbugs—In May or June, Kentucky bluegrass lawns are sometimes infested with bluegrass billbugs, a dark gray- to-black insect. Damage will occur as spotty patches of yellowing grass. The one-third-inch-long adult lays eggs within the stems of grass plants, and the hatched larvae feed in the stems. As they develop, the white, legless grubs leave the stems to feed externally on the plant crown, near which masses of fine, sawdust-like frass can be found.

Turfgrass Disease

Numerous diseases occur in Kentucky lawns, but the use of fungicides to control these diseases is generally not recommended. Diseases often require multiple fungicide applications, which not only are expensive but difficult for the homeowner to apply evenly. Most diseases do not completely kill the turfgrass, and considerable recovery can be expected during the following cool season of spring or fall. Also, the extent of these unsightly diseases can generally be minimized by proper mowing, moderate nitrogen fertilization, and infrequent irrigation. The most common disease problems are described below.

Leaf spot and melting out—Leaf spot and melting out (helminthosporium) is a very common disease on Kentucky bluegrass. When infected, the lawn will appear chlorotic; areas the size of a golf ball or coffee cup may be very brown in color. Upon close inspection, individual leaves will be shown to have tan spots with dark margins. Most damage occurs in spring and early summer, and complete turfgrass recovery is usually evident by late fall.

Dollar spot—Dollar spot mainly affects Kentucky bluegrass lawns. It can be active throughout the growing season but causes most damage when soil moisture is low and dew or fog is excessive. The disease appears as small, tan spots that are from the size of a silver dollar to a coffee cup. Light brown or reddish margins on the spots will be obvious if the individual leaves are inspected closely. If disease pressure becomes extreme, the spots can coalesce to form large brown areas. The damage is not often serious, but it can be very unsightly until growing conditions improve. A light fertilization with nitrogen and deep, infrequent irrigation is often needed to improve growing conditions enough to mask the damage.

Brown patch—Brown patch is most prevalent on perennial ryegrass and tall fescue lawns. It is mainly a hot-weather disease (85°F–95°F) but sometimes can occur in late winter to early spring when grass top growth has been allowed to accumulate and lodge. This disease is characterized by circular dead or brown turfgrass areas that may be a few inches to several feet in diameter. The outer edges of the infected area may have a gray, smoky color, particularly in early morning. While dew or surface moisture is present, you can often detect a mass of cobwebby-looking mycelium that tends to make the leaves slimy. This disease can cause unsightliness and can thin tall fescue turfgrass enough to increase its coarseness. Brown patch is difficult to control with fungicides, since damage can occur almost overnight. Heavy nitrogen fertilization, especially when applied in spring or early summer, encourages brown patch. Development of this pathogen can be discouraged by proper mowing (not allowing the grass to get more than one-third taller than normal mowing height before it is removed) and heavy but infrequent summer irrigation. Extremely tall mowing heights may also promote brown patch.

Summer patch—Summer patch mainly occurs on heavily fertilized, dense Kentucky bluegrass lawns. During the hot (85°F–95°F) summer, scattered light-green patches varying in size from two to six inches in diameter develop first along sidewalks, drive-ways, and especially on south-facing (hot) slopes. With continued hot weather, these patches fade to a dull tan and then to a light straw color. Some apparently healthy plants may be surrounded by the discolored turfgrass, giving a frog-eye effect. This disease can be controlled by timely fungicide applications, which are extremely expensive. The best control is obtained by following a fall nitrogen fertilization program and proper summer irrigation.

Red thread—Red thread (pink patch) is very common on Kentucky bluegrass and perennial ryegrass lawns and can be found from February through November. The symptoms are similar to that described for dollar spot, but red thread disease also causes small pink-to-reddish threadlike growths to emerge from tip ends of blighted leaves. During moist periods, a pink slime may cover the leaves and mat many leaves together. The damage is not extremely destructive, and the turfgrass will completely recover by late fall. A light application of nitrogen and heavy, infrequent irrigation is usually as effective in masking the disease as a fungicide treatment.

Localized dry spot—Localized dry spot is the most serious summer problem encountered on Kentucky bluegrass lawns. It first appears as patches of brown or dying grass, two to four inches in diameter. Localized dry spot continues to grow in a circular pattern, and it mimics any number of diseases and insect problems such as grubs, sod webworms, dollar spot, red thread, and summer patch.

As is the case with most serious lawn pest problems, dry spot most often occurs on lawns with south-southwest facing slopes, a severe thatch problem, heavy traffic, open sun areas, and heavy clay with shallow soil. These traits most often describe "front" lawns. After a good summer rain, a turfgrass with localized dry spot will usually improve for only two to three days. The improvement doesn't last long, because little moisture penetrates the soil. If the soil will only take one-tenth inch of water per hour, then a rain falling at one inch per hour is of little value. In addition, when a thatchy lawn becomes dry, the thatch becomes water repellent. Hours of light rainfall would be needed to penetrate the thatch.

You have to irrigate to correct dry spot. Most sprinklers apply water very slowly, at rates of one-quarter to one-half inch of water per hour. If the water begins to run off before you have thoroughly wet two to three inches of surface soil, wait an hour or so before continuing irrigation. The only way to know how deeply you have wet the soil is to probe the soil with a knife, screwdriver, soil probe, bulb planter, etc. After you've thoroughly irrigated two to three inches of surface soil, do not repeat irrigation until the surface begins to dry again. If the weather is extremely hot and dry and the soil is very bad, it may only be four to five days before the surface dries. If the weather is fairly cool at night, repeat irrigation is usually not needed for one to two weeks. With luck, you will also get some helpful rainfall during that period. Remember, when diagnosing lawn problems, always check the soil first.

Moles

Moles are typically a serious problem in lawns with good soil that are located near woody areas or pastures. The only serious species we have in Kentucky is the eastern mole. This mole dislodges and uproots the grass as it makes runs, and it smothers the grass in circles as it extracts soil into surface mounds. Moles are insectivores. They mainly eat earthworms, but they will also eat grubs, spiders, etc. They are active every month of the year and have to eat every day. They spend most of their time disrupting areas where insects and earthworms are most abundant.

If mounds appear in lawns, it is imperative that the fresh surface mound be spread out immediately by foot or rake, preferably before it rains and settles down. If you spread the soil out, the remaining hole will not be more than an inch in diameter. Never run over the mound with the wheel of a riding lawn mower. You will kill/smother out an area of grass bigger than a basketball.

Mole control is work, and no easy solutions exist. Consider the following:

- Cats will stalk moles and remove them gently from lawns; however, training of cats to stalk moles has not been productive.
- Dogs will actively remove moles, but they often tear up more lawn than the mole.
- The harpoon trap has historically proven the best method for mole control. If you have a lot of mole problems, it is best to purchase several traps, set them over active runs, and move the traps every day or two to make sure you are engaging those runs. If you do not see new runs, the mole has likely left the lawn and may not be back for several weeks or months.
- A pitchfork is a very effective method of mole control. Tamp down an active run and observe it often for soil movement. Quietly approach the run and forcefully insert the fork into the soil when the soil moves. Although this method sounds somewhat gruesome, it is likely one of the most humane methods of mole control, as there is no suffering for the animal.
- Molexit is a castor oil-based product that can cause moles to leave a lawn area for a few weeks, but the mole often returns with a vengeance.
- Talpirid or Tomcat Mole Killer are new products that use fake worms with an injected rodenticide called bromethalin. These gummy-type worms can be placed into active runs or mounds and appear to be the best solution for ridding lawns of moles. These can be placed into active runs or mounds to give immediate mole kill.

Here's the best method when using these fake worms:

- When you see an active run or mound that is a day or two old, place a fake worm within the run's empty space or within the empty space below the mound. The run (void) is only an inch or two below the grass and is easy to locate. The mounds are usually six to 18 inches above the underground run, and you'll need to use a dowel or stick to push the fake worm through the one-inch-diameter hole that the mole has made in order to connect to the belowground run.
- When you see a network of runs or see runs that could be several days or weeks old, it is best to walk the runs down and then check the area daily. If any portion of the run is again raised by the mole, place a worm in it. Moles have a habit of working an area and then leaving that area for better hunting ground. It is not practical to place these fake worms in older runs because the organic worms may decay before the mole returns.

These fake worms look similar to earthworms or rubber fishing worms and will cost $2 to $4 each. Because you are placing them underground and because each worm has only sufficient bromethalin to kill a single mole, it is unlikely that you would poison a pet with this product. But as always, follow the safety precautions carefully.

Regardless of which method is used and how many you have killed, moles will often return within several weeks or months. The surface runs that are so obvious and annoying to the homeowner are not nearly as extensive as the underground runs that occur from 6 to 18 inches underground. It is easy for moles to reinfest a lawn via these deeper runs and likewise easy for the mole to escape your vengeance.

Shady Lawns

A comment often heard from people living in homes with older landscapes is "This lawn used to have good grass under the trees, but now it has almost nothing." It is a legitimate complaint. This situation occurs for at least two reasons:

- The shade becomes more intense as the trees grow older.
- As the turfgrass thins, the homeowner initiates a salvage program of reseeding, fertilizing, and killing weeds.

The problems with this approach are competition and disease.

Competition

Trees do get bigger and more competitive each year. The most serious competition is for sunlight. A group of large shade trees may reduce the incident sunlight to 5 percent to 10 percent of normal. If the trees are tall, it is sometimes possible to remove lower branches and reduce the competition for light.

Trees can also compete for nutrients and water, but this does not seem to be very important when trees are large. Small trees might show moisture stress during a summer drought, but that does not usually thin the turfgrass. Light is the limiting factor.

Algae and moss problems under shade trees are always a big concern. Since moss and algae become noticeable as the grass population decreases, it usually looks as if these lower forms of plant life are crowding out the turfgrass. Not so! They are just the first forms of plant life that occur in shady, wet areas in which the grass population is declining or nonexistent.

Chemicals such as copper sulfate (two ounces per 1,000 square feet) have been used to kill moss and algae. However, unless the shade or other problems are corrected, the moss will return. Along with shade, poor soil, and poor surface drainage, additional factors such as acid soil, soil compaction, and a close mowing height also encourage moss and algae.

Diseases such as powdery mildew are encouraged by the environment of wet and "still" air usually found under shade. Fungicides can be used for control, but the organisms will continue to reappear as long as the favorable environment exists.

To correct problems caused by shade, it is necessary to reduce the shade and increase the air movement under the trees. Removing lower branches and thinning of border plantings can be of some benefit.

The relative shade tolerance of perennial grasses that can be used in Kentucky lawns are listed below from the most shade tolerant to least shade tolerant:

- fine fescue
- tall fescue
- zoysiagrass
- perennial ryegrass
- Kentucky bluegrass
- bermudagrass

Choosing the Right Grass

It is not uncommon to see seed mixtures sold as "shade-loving" that contain a high proportion of annual ryegrass and very little fescue. The ryegrass comes up quickly but dies out the first year. Because of the initial competitive advantage of the ryegrass, the fescue never has a chance, and the hard-working homeowner concludes that grasses cannot be grown in that location. He or she may be right, but for the wrong reason. If shade is very dense, such as under large maple and oak trees, no grasses will persist.

Sun and shade mixes are popular choices for partially shaded lawns. These mixes usually contain Kentucky bluegrass, fine fescue, and sometimes perennial ryegrass. The Kentucky bluegrass persists and dominates in the full-sun areas, and the perennial ryegrass and fine fescue will grow in shaded areas. Perennial ryegrass will tolerate a little shade, while fine fescue tolerates much more. Kentucky bluegrass and perennial ryegrass look similar; however, fine fescue is much more fine-bladed than either of the other grasses, so uniformity in the lawn may not be ideal.

Recently, because of the frustrations of getting perennial grasses established under shade, many homeowners have chosen to seed one of the turf-type perennial ryegrasses. These grasses may not persist more than one to three years, but they are relatively easy and quick to get established. If used under shade, they should be seeded during late August or September at two to five pounds per 1,000 square feet. Seeding of such cool-season grasses is best accomplished during the fall, since the leaves from deciduous trees will be falling and thereby allowing more light to penetrate. Obviously, fallen leaves should be removed.

Soil Preparation

The soil surface can be scarified with a dethatching machine or rototiller or by briskly raking the soil surface. The seed should come in contact with some loose soil for best germination. Since ryegrasses are not well adapted to shade, they will lose their dark-green color the following summer and often thin out considerably. Reseeding the following fall may be necessary. Broadcasting a few pounds of perennial ryegrass over the shaded surface every fall and spring may be the best solution.

Fertilization

Since the understory grasses are competing with the trees for nutrients, should the grass be fertilized more often? No! A turfgrass that is "just existing" under subdued light does not need the same amount of nutrients that it would need if growing in full sun. For maximum survival, it is best to fertilize shaded turfgrass with nitrogen no more than once a year and perhaps not at all. The more nitrogen you apply, the more you force the turfgrass to grow, and the more you force the turfgrass to grow, the more light it needs. In reality, the turfgrass is getting less light because the trees are continuing to grow, and the more dense grass canopy tends to shade itself. The grass is actually growing itself to death because its only source of energy (sunlight) is insufficient.

With shaded grass, it is always appropriate to get a soil test to determine the needs for lime, phosphate, and potash. A deficiency of any of these will weaken a turfgrass, whether it's in the shade or sun. Lime, phosphate, and potash can be applied anytime during the year, but nitrogen is best applied in the fall when the grasses are best able to initiate and develop tillers and when deciduous trees are losing leaves, thus reducing shading. To allow the grasses to develop, be sure to keep the leaves raked— do not let them shade the grass.

Mowing

Always consider mowing shaded grass higher than non-shaded grass, never closer than about three inches. The taller height may allow the leaf blade to capture additional light.

Weeds

Many homeowners are concerned about a predominance of weeds growing under heavy shade. Often the weeds, such as ground ivy, wild violets, wild strawberry, and nimblewill, are more competitive under shade than the grasses are. So let them be! Why kill the weeds when it is virtually impossible to get desirable grasses to grow? In most cases, the green weeds look a lot better than bare ground. Most of these weeds will give good cover from April to October.

Ground Covers

Even the most avid "grass person" recognizes that the presence of trees is more important than grass and that a cultivated ground cover is more aesthetic than a patch of weeds intermingled over bare ground and surface tree roots. When this is the case, ground covers such as periwinkle, English ivy, pachysandra, and sweet woodruff can be planted. They thrive in heavy shade and give wonderful relief from the monotony of all turfgrass.

For More Information

University of Kentucky Cooperative Extension Service publications

Preemergence Herbicides for Kentucky Lawns (AGR-272)
Low-Maintenance Lawn Care, Stressing Pest Avoidance and Organic Inputs (ID- 154)
Considering the Environment in the Maintenance of Your Kentucky Lawn: A Season by Season Approach (ID-222)
Lime and Nutrient Recommendations/Soil Test Recommendations (Excerpt from AGR-1, page 20)
Liming Kentucky Lawns (AGR-214)
Lawn Establishment in Kentucky (AGR-50)
Renovating Your Lawn (AGR-51)
Selecting the Right Grass for your Kentucky Lawn (AGR-52)
Turfgrasses of Kentucky (AGR-216)
Fertilizing Your Lawn (AGR-212)
Mowing Your Kentucky Lawn (AGR-209)
Aerifying and Dethatching Lawns (AGR-54)
Turf Care Calendar (AGR-55)
Weed Control for Kentucky Home Lawns (AGR-208)
Principles of Home Landscape Fertilizing (ID-72)
Irrigation Tips to Conserve Water and Grow a Healthy Lawn (AGR-115)
Managing Mole Problems in Kentucky (FOR-42)
A No-math Method of Calibrating Backpack Sprayers and Lawn Care Spray Guns (AGR-220)
Disease Management in the Home Lawn (PPFS-OR-T-11)
Trees, Turf, and People (ID-203)
Controlling White Grubs in Turfgrass (ENT-10)
Velvet Ants (ENT0-442)
Insecticides for Control of White Grubs in Kentucky Turfgrass (ENT-441)
Yard Wasps (ENT-411)
Earthworms: Thatch-Busters (ENT-402)
Japanese Beetles in the Urban Landscape (ENT-451)

Videos

Mole Control in Lawn:
https://youtu.be/XKs-fWZhZ-8
Turf Master Gardener Training:
https://www.youtube.com/watch?v=UC1P47oEtvg
Daily Mower Maintenance and Cutting Heights:
https://www.youtube.com/watch?v=5_nhpchMyfs
Soil Testing and Fertilizers for Home Lawns:
https://www.youtube.com/watch?v=eTlVnAyR_rw
Seasonal Lawn Mower Maintenance:
https://www.youtube.com/watch?v=oxgbMDdT6bQ
Lawn Mower Blade Sharpening:
https://www.youtube.com/watch?v=JMy1j9NR89o
Organic Lawn Fertilizers:
https://www.youtube.com/watch?v=qLg12Chm_Ao

Chapter 16

Selecting and Planting Woody Plants

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In this chapter:

Woody ornamental plants are key components of a well-designed landscape. Landscape plantings divide and define areas, add aesthetic and psychological benefits, and increase a property's environmental and economic value.

There are many woody plants available for use in landscaping, so select carefully. Choose plants based on their ability to fulfill your purposes and grow well in your property's environment.

Install landscape plantings according to a plan, keeping two factors in mind:

- Use the right plants in each area to create your desired design effect.
- Place plants in the right environment with proper sun exposure, temperatures, soil pH, drainage, and water.

Landscape plants last for many years. Making wise decisions for types of plants and giving plants proper growing conditions and care will help ensure that they remain a healthy and aesthetically pleasing part of your landscape.

Planting Trees and Shrubs

You can purchase trees and shrubs in a variety of ways (Figure 16.1):

- Bare-root (BR) plants have little or no soil around the roots. This method is common for deciduous plants and small evergreens shipped by mail during the cooler months.
- Balled and burlapped (B&B) plants are dug with soil around the roots, with the root ball enclosed in burlap or a synthetic material, and are often available year-round.
- Container plants are grown and sold in containers and are also available year-round.
- Field-potted plants are grown in a field, dug with or without soil, and potted into containers filled with organic media (substrate), field soil, or a combination of the two.

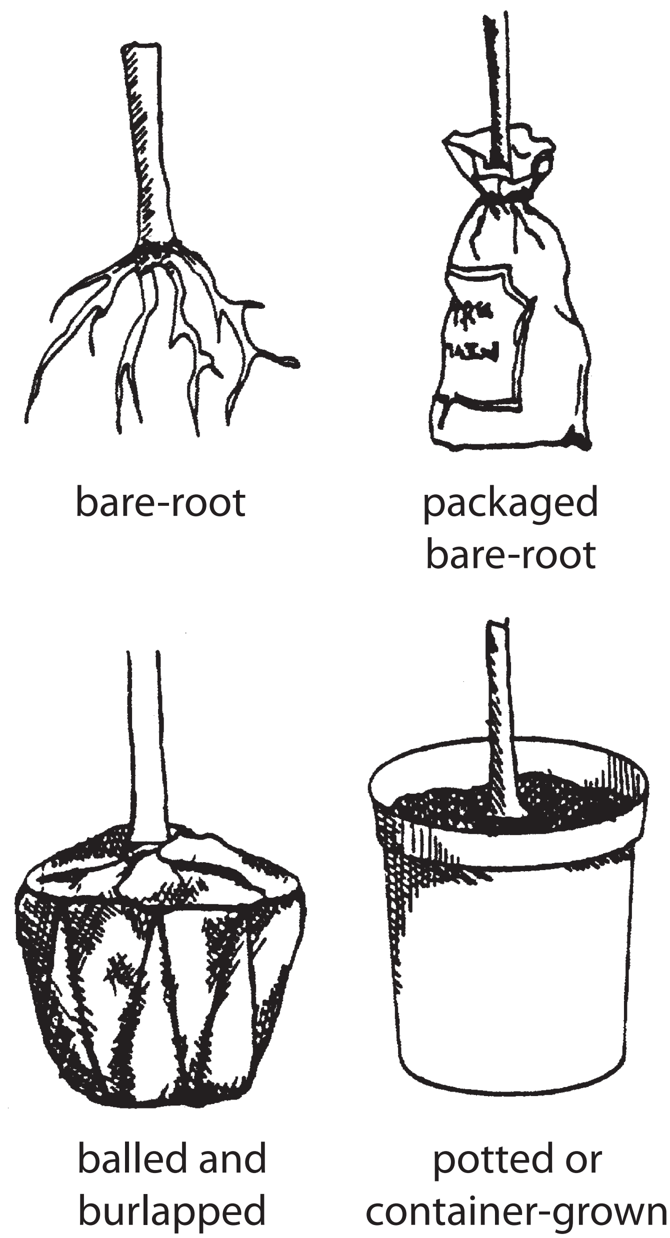

Figure 16.1. Types of nursery plants.

Planting

Proper planting procedures are crucial to establishing a healthy plant. Planting procedures depend on which type of plant you choose (e.g., bare-root, balled and burlapped). Instructions for the common types are given below.

Bare-root

- Cut back damaged roots with a clean cut. Then soak the roots in water for one to two hours.
- Dig a hole wider but not deeper than the root system. The root flair (where roots meet the trunk) should be no deeper than about one inch below grade.
- Put the plant in the hole to the level where it was growing in the nursery (Figure 16.2). You can put a cone of soil under the plant for support and spread the roots on top of the cone.
- Backfill with native soil that is not amended. Tamp down the soil to remove air pockets.
- Water thoroughly.

Balled and burlapped

- Dig a hole wider but not deeper than the root ball (Figure 16.3).
- Remove the burlap or synthetic material from around the ball along with all rope, string, or twine tying materials.
- Place the ball in the planting hole with the top of the ball even with the soil surface or slightly higher.
- "Excavate, if necessary, to find the topmost root and ensure that it will be no deeper than one inch below grade. Sometimes the digging process results in balled and burlapped plants with excess soil at the top of the ball. If needed, remove some of the soil at the top of the ball.
- Backfill with native soil that is not amended. Tamp down the soil to remove air pockets.
- Water thoroughly.

Container plants

- Dig a hole larger than the spread-out root system.
- Always remove the container, even papier-mâché and peat pots.
- Understand the differences between container plants and those grown in native soils. Roots of container-grown plants frequently circle the inside of the container. If this action is not stopped, the plant will fail to become established in the landscape. Roots of container-grown plants are also growing in a substrate (artificial soil containing pine bark, compost or other materials), which has a different texture than soil.
- Remove enough of the artificial mix to expose several inches of roots. You can do this by working your fingers into the mix, resulting in the loose mix falling away from the roots. You do not need to remove all of the mix, but you should remove as much as can be easily removed.
- If the roots have begun to circle the inside of the container, try to unwind them so that they will radiate out away from the trunk.
- If the root mass is so dense that it is impossible to separate the roots, you will have to resort to cutting the roots. Make several vertical slices into the root ball to stop the circling action. This is the least desirable corrective action but is often the only solution for plants that have become extremely pot-bound.
- Place the prepared root ball in the planting hole with the surface of the container media level with the soil surface or slightly higher.
- Backfill with native soil that is not amended. Tamp down the soil to remove air pockets.
- Water thoroughly.

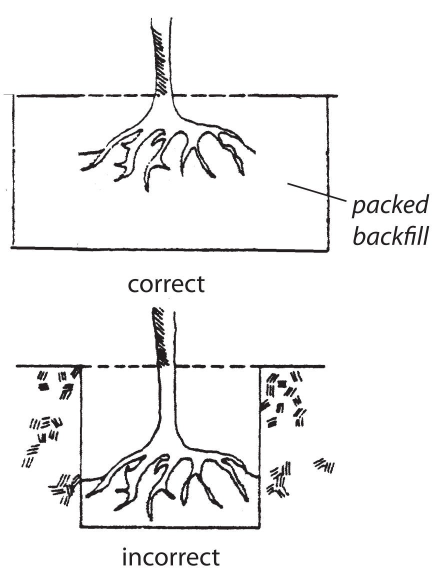

Figure 16.2. Planting depth for a bare-root tree or shrub.

Figure 15.3. For B&B and container plants, the hole should be a minimum of two or three times as wide as the soil ball.

Pruning

Contrary to popular opinion, it is not a good idea to prune one-fourth to one-third of a tree or shrub's branches to compensate for root loss when you plant it. However, light pruning may be helpful in correcting problems. Follow these steps:

- Remove dead or injured branches.
- Remove interfering, rubbing, or crossed branches.
- Remove branches forming narrow "V" crotches (multiple or codominant leaders). Leave the other branch to become the leader.

Staking

A plant that is supported by a stake from the time it is small grows differently than an unstaked plant. It will be taller and thinner and have deformed xylem and less root growth. It may not be able to stand by itself.

Bare-root trees generally need to be staked because they are tall and do not have the weight of firm soil around their roots to help stabilize them. If staking is not needed, don't do it. If you do need to stake a plant in a windy area, follow these steps (Figure 16.4):

- Drive two or three stakes into firm ground outside the planting hole. The line formed by the two stakes and the tree trunk should be parallel to the prevailing wind.
- Tie the two stakes to the trunk about two-thirds of the way up the trunk. Use a material that will not chafe or damage the bark.
- Allow some play in the line to allow slight swinging of the trunk. Gentle swaying of the trunk stimulates root growth on newly transplanted trees.
- Remove stakes as soon as possible after the roots are established and the plant is stabilized, typically after one growing season.

Fertilizing

Do not put fertilizer into planting holes and do not apply any fertilizer to the newly transplanted woody plant during the first growing season. Roots that come into contact with fertilizer particles may be damaged (burned). Root-stimulating products are also not needed, as their effectiveness is questionable.

Watering

A recently transplanted plant needs special attention through its first growing season. The nursery soil around a potted or B&B plant may be radically different from the soil where it is planted, and water may not move readily between the two. Therefore, it is important to apply water to both the nursery soil and the surrounding soil during the establishment period. Roots grow only where there is moisture; unless both media are moist, roots may never grow out of the original nursery soil.

Container soils have a bad habit of drying out much faster than the surrounding soil or backfill soil. Moisten both media adequately to prevent new plants from being injured or dying of drought. However, be careful not to overwater. Average rainfall in Kentucky is often adequate for woody plant growth once the plant has been established. However, newly transplanted trees and shrubs are not able to tolerate even brief periods with inadequate rainfall. When the top five inches of soil/medium become dry, water the plant thoroughly, making sure to wet the container and surrounding media to at least six to nine inches, and repeat as often as the soil becomes dry.

Mulching newly established shrubs and trees helps prevent moisture loss. Apply no more than two to three inches of mulch, and ensure that mulch is pulled away about four inches from the base of the trunk.

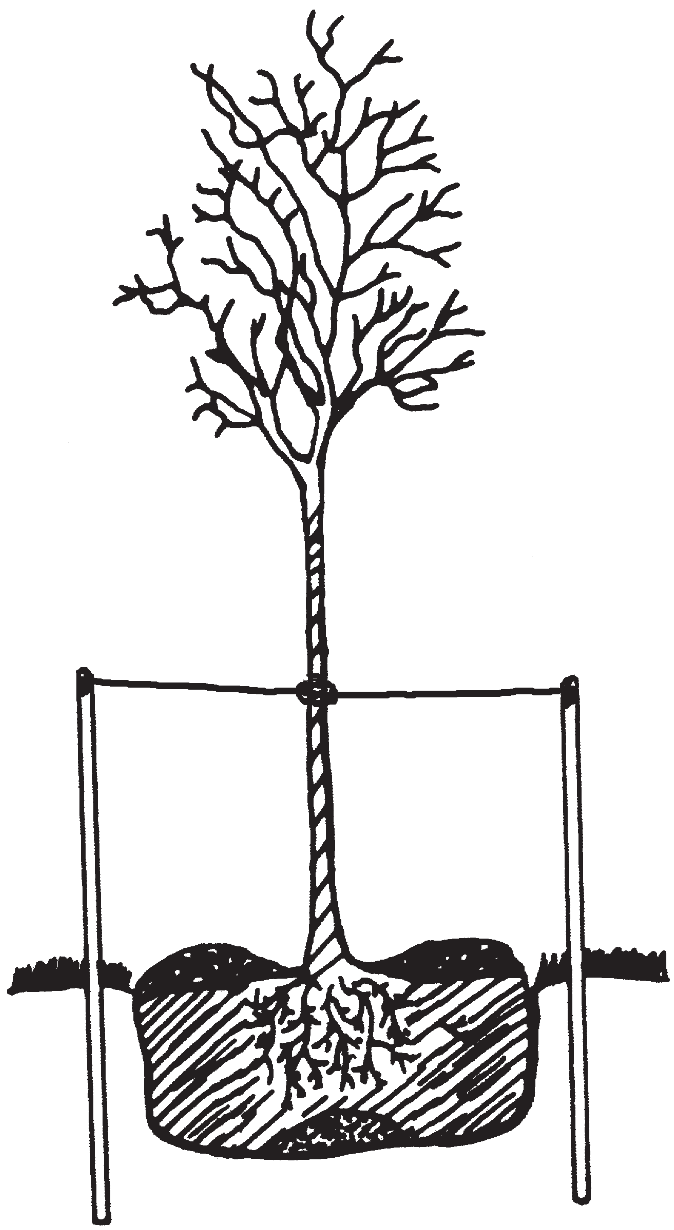

Figure 16.4. Staking a newly planted tree.

Transplanting Established Plants

Careful selection and placement of a plant should make transplanting at a later date unnecessary. Occasionally you may need to move a plant. Plants often die after transplanting because of root damage or poor handling. Generally the younger the plant and the more careful you are, the better your chance of success.

Timing

The best time to move evergreens is spring, followed by early to mid-autumn. Move deciduous plants while they are dormant (usually from late fall to early spring, anytime the ground is not frozen).

Preparation

If time allows, root-prune the plant a year or more before digging. The fall before you plan to move the plant, divide the circumference of the root area into six segments and prune every other segment by driving a sharp spade into the ground to the full length of its blade. (Make the circle of cuts slightly smaller than the size of the ball you'll eventually dig.) New roots will grow at the cut edges. The following spring, prune the remaining segments. When you dig the plant for transplanting, make the root ball larger than the root-pruned area to retain the maximum number of new roots.

Moving the Plant

It is best to ball and burlap both deciduous and evergreen plants before moving them to minimize damage. Dig a trench around the plant, just beyond the spread of its branches (or just beyond your root- pruning cuts). Cut through woody roots, but leave fibrous roots intact if possible. Use a garden fork to loosen the soil around the outer edge of the root ball to reduce its size and weight.

Next, cut under the ball and tip it to the side so you can work a sheet of plastic or burlap under it. Tip the ball from side to side carefully. Do not use the trunk of the plant as a lever to tip the root ball to prevent excessive damage. Wrap the ball tightly with plastic or burlap, lift the plant from the hole, and move it to its new location. It is always best to move the plant by lifting the root ball, not by lifting or dragging by the trunk. Unwrap the ball and plant it as you would a B&B plant.

Fertilizing

Woody ornamental plants require moderate soil fertility to thrive. High soil fertility stimulates excessive and possibly undesirable growth. Low fertility is likely to make plants grow poorly and lack vigor. Plants stressed by low fertility are more susceptible to insect pests, diseases, and other problems, such as lack of hardiness.

If plants are growing well in fertile, well-drained soil, they may not require regular fertilization. If plants are growing in areas with a lawn fertilization program, additional fertilization will probably be unnecessary for the woody plants. Fertilizers can be expensive, and many are manufactured using nonrenewable fossil fuels. If leaching and erosion occur, they can enter water supplies. Thus, remember these important tips:

- Fertilize woody plants only when needed.
- Apply the correct amount of fertilizer at the right time of the year.
- Place fertilizers where they will be available to the plant's roots.

Determining the Need for Fertilizer

Whether or not you carry out a yearly fertilizer program for landscape plants should depend on the inherent fertility of your soil, how well the plants are growing, and whether you recycle nutrients (e.g., grass clippings or leaves). Very sandy soils, for example, may lack sufficient clay and organic matter to hold nutrients and may be prone to low fertility. This situation is not common in most areas of Kentucky. Landscape plants growing in such soils often exhibit nutrient deficiency symptoms unless they are fertilized regularly. On the other hand, trees and shrubs in regularly fertilized turf areas may not need supplemental nutrients.

If plants are not doing well, fertilization may be helpful, but only after you determine the cause of the problem. Some possible indicators of a need for fertilization are:

- Smaller than normal leaves
- Light green or yellowish leaves (if the plant's leaves normally are dark green)
- Shorter than normal annual shoot growth
- Dead twigs and branch tips

However, these symptoms also may be caused by environmental, insect, disease, or other cultural problems. It is prudent to rule out any such causes before embarking on a fertilizer program. In Kentucky the most common cause of yellow foliage is not lack of fertilizer but the attempt to grow acid-loving plants on alkaline soils.

Research indicates that nitrogen may be the only nutrient that improves growth of woody landscape plants. In most cases, potassium and phosphorus soil reserves are sufficient for woody plants. Having your soil tested through the county Extension office or by a reputable laboratory can help you determine the levels of phosphorus and potassium. Very low readings of these two minerals may indicate the need to add these nutrients to your fertility program. A soil pH imbalance may also affect woody plant growth. For example, hollies become deficient in iron when soils are alkaline. To the untrained eye, the yellow leaves seem nitrogen deficient, but the real issue is lack of available iron, often caused by incorrect soil pH. A soil test will reveal soil pH.

Fertilization is appropriate in some specific cases. For example, it may help newly planted trees and shrubs reach their potential. Fertilizing also benefits trees and shrubs that have been partly or completely defoliated by insects or disease, those that are stressed by digging or trenching in their root zones, or those that may have suffered severe limb damage due to weather. Appropriate fertilizer application also may stimulate recovery from winter injury.

Types of Fertilizer

The three numbers on fertilizer packages refer to the percent of nitrogen (N), phosphorus (as phosphate, P_2O_5), and potassium (as potash, K_2O), always in that order. Many fertilizer formulations are available, but since woody plants generally respond only to nitrogen, it is appropriate to use formulations consisting only of nitrogen or ones in which nitrogen is predominant. Some examples are 16–8–8, 21–7–14, 20–10–5, 21–0–0 (sulfate of ammonia), 33–0–0 (ammonium nitrate or urea), and 45–0–0 (urea). Lawn fertilizers without weed killers are acceptable for fertilizing woody landscape plants.

How Much Fertilizer to Apply

Calculating by Area

Deciduous, broadleaf evergreen, and needleleaf trees (conifers) can be fertilized each year with one to three pounds of actual nitrogen per 1,000 square feet. If your soil is very poor or plants are not growing well, consider using the higher amount. If plants are growing well and you know the soil is fairly fertile, use the lower end of the range or none at all.

For flowering trees and shrubs, particularly crabapples, use no more than two pounds of actual nitrogen per 1,000 square feet. Too much nitrogen may stimulate shoot growth at the expense of flowers.

Once you know how much actual nitrogen you need, it's easy to calculate the amount of fertilizer to use. To apply three pounds of actual nitrogen per 1,000 square feet using a 21–7–14 fertilizer, divide the desired amount of nitrogen (three pounds per 1,000 square feet) by the percent of nitrogen in the formulation (21 percent, or 0.21). For example, 3 ÷ 0.21 = 14 pounds of fertilizer to achieve 3 pounds of nitrogen for a 1,000-square-foot area. See Table 16.1 for approximate amounts based on other formulations.

The area beneath a tree usually is not exactly 1,000 square feet. To find the area beneath a tree or shrub, put four stakes in the ground to form a square that encloses the dripline or extends beyond it (Figure 16.5). Measure the distance between the two stakes along one side of the square and multiply this number by itself to get the area in square feet. Divide this number by 1,000, then multiply the answer by the pounds of fertilizer needed per 1,000 square feet. The result is the amount of fertilizer needed for the tree.

For example: if one side of the square is 20 feet, then the area under the tree is 20 feet by 20 feet, or 400 square feet. Four hundred square feet divided by 1,000 square feet equals 0.4. If you need three pounds of actual nitrogen per 1,000 square feet, and you want to use a 21–4–4 fertilizer, you need 14 pounds of fertilizer per 1,000 square feet (from Table 16.1). Multiply 14 pounds times 0.4 (400 square feet) to get 5.6 pounds, or roughly 6 pounds of 21–4–4. This is the amount to spread under the tree. The calculations for this example are:

20 ft x 20 ft = 400 sq ft
400 sq ft ÷ 1,000 sq ft = 0.4
3 lb N ÷ 0.21 = 14 lb (or read from Table 16.1)
14 lb N x 0.4 = 5.6 lb fertilizer

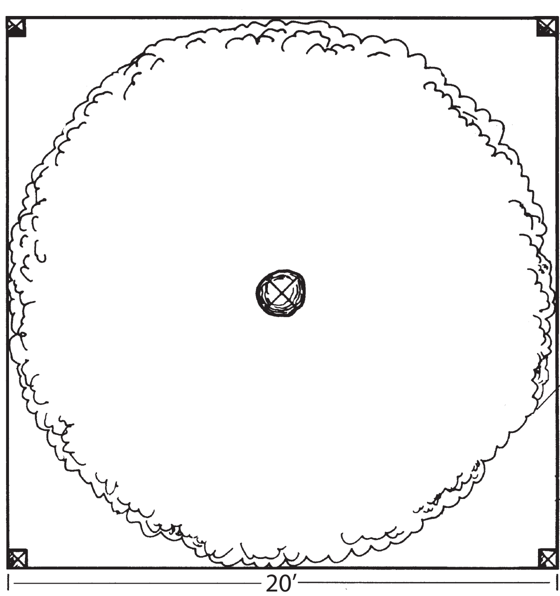

Figure 16.5. Finding the area beneath a plant.

Table 16.1. Approximate amounts of fertilizer needed to provide 1, 2 or 3 pounds of actual nitrogen per 1,000 square feet.

Type of fertilizer*	Amount of fertilizer to apply per 1,000 sq ft		
	1 lb N	2 lb N	3 lb N
10–6–4	10	20	30
12–3–6	8	16	25
16–8–8	6	12	19
21–0–0	5	10	14
21–4–4	5	10	14
24–4–8	4.5	8.3	12.5
33–0–0	3	5	9
46–0–0	2	4	6.5

*These are examples. Availability may vary by location.

Calculating by plant size

You also can determine how much fertilizer to apply based on a plant's trunk size, height, or spread. For example, shade trees with a trunk diameter of less than six inches (measured at 54 inches (4.5 feet) above ground) should receive from one-eighth to one-third pound of nitrogen per inch of trunk diameter. Trees greater than six inches in diameter can receive one-third to two-thirds of a pound of nitrogen per inch of trunk diameter.

Flowering trees and large shrubs can receive from one-eigth to one-third of a pound of nitrogen per inch of stem diameter. Shrubs often are fertilized according to their height or spread. Use one-twentieth to one-tenth of a pound (about one to one and a half ounces) of nitrogen per foot of height or spread.

The following example shows how the amount of fertilizer to be applied to a shade tree with a diameter of eight inches can be calculated. Divide this number (2.4) by the percent nitrogen expressed as a decimal (0.21 for 21–4–4 fertilizer). Thus:

1/3 (0.33) lb x 8 in = 2.4 lb actual nitrogen
2.4 lb ÷ 0.21 = 11.4 lb of 21-4-4
Round off to 11 or 12 lb.

How to Apply Fertilizer

Apply fertilizer throughout a tree or shrub's drip zone (the area from the trunk to the edge of the canopy in Figure 16.5). You can broadcast fertilizer over the soil surface and water it in immediately. However, water-soluble nitrogen with a high salt index applied to the soil surface may damage turf or other plants growing under the tree, and these plants may use the nitrogen before it reaches the tree's roots. Placing fertilizer in holes or pounding in spikes is *not* recommended as the fertilizer is placed below many of the roots. On steep slopes, it may be necessary to place fertilizer into the soil to keep it from entering streams.

When to Fertilize

Research indicates the most effective time for established deciduous plants is late fall. For trees or shrubs planted in turf areas, it may be better to split the amount into several applications to avoid burning the grass. If you apply fertilizer during winter when turf is likely to be dormant, it may not be necessary to split the application.

In Kentucky, where most trees and shrubs grow among cool-season turfgrasses (Kentucky bluegrass and fescue), fall applications are best to avoid excessive growth of turfgrass in spring.

Fertilizing landscape plants with high-nitrogen fertilizer after mid-July is not recommended. It may stimulate growth that will not have time to harden off before fall; consequently, the plant may be damaged by winter freezes. Wait until plants are dormant, between Thanksgiving and New Year's Day.

Fertilizing Hints

- Never put any type of herbicide-containing fertilizer (such as weed-and-feed products offered by various companies) into planting holes, on the soil covering plant roots, or into soil near woody plants.
- Fertilizer applications do no good without moisture. If conditions are dry, irrigate soon after applying fertilizer.
- Do not apply dry fertilizer to wet turf.
- Fertilizers containing water-insoluble, organic nitrogen sources may take three to eight weeks to break down to a usable form. Time applications accordingly.
- Do not put fertilizer onto frozen soil. Precipitation and/or snow melt will cause wasteful and environmentally hazardous runoff of the nutrients being applied.

Watering

Watering landscape plants is one of the most misunderstood and challenging tasks facing gardeners. The average Kentucky climate generally supplies enough water for woody plants. However, our summer and fall seasons are often drought prone and windy. Plants may occasionally benefit from supplemental irrigation during extreme droughts. Water-stressed landscape plants may be more susceptible to other problems such as insects, diseases, and winter injury.

A good rule of thumb for watering is to fill the entire root zone with water and then allow the soil to dry partially before watering again. How much the soil should dry out between irrigations depends on plant species and size. For large trees and shrubs, allow the top several inches of soil to dry before rewatering. Water small, newly established, or extremely shallow-rooted plants before very much soil drying occurs. Become familiar with how long it takes to completely moisten the root zone of various plants in your landscape and how deeply the soil can dry before plants begin to show signs of stress.

Some situations may require more frequent watering than the rest of your landscape. Check these areas and water them more often. For example:

- Shrubs and groundcovers near house foundations, under eaves, or in hot afternoon exposures may receive little water from natural precipitation or may transpire water rapidly, so they may be stressed during hot summer days.
- Mounds or berms have much more soil surface exposed to evaporation than does the natural soil profile, so they dry out more quickly. Runoff is also more rapid.
- Some plants, such as rhododendrons, azaleas, and ferns, demand more moisture or have shallow roots that dry out quickly during warm, sunny weather.

Many native woody plants that are drought tolerant should not be watered during the summer once they are established, and some may be damaged by summer moisture.

How to Water

Water trees and shrubs just under and outside their dripline or outer edge. For foundation or border plantings, water the entire area.

Hoses, soaker hoses, or various kinds of sprinklers are common watering methods. For deep-rooted trees, try a root needle or fertilizer-feeding needle (without the fertilizer) for deep watering. This is a tedious process, but it gets water into areas of the root zone that may take a long time to reach with a sprinkler.

In soils that are slow to accept water, try building a dish-like or berm-enclosed area around the base of newly planted trees or shrubs. Fill this area with water. After the first growing season, remove the basin rims to avoid directing too much water into the root zone.

Watering Container Plants

Plants in containers need special care because both the volume of soil and amount of available water in containers are limited. Water these plants more often than those in the ground. The frequency and amount of water needed depend on the medium, exposure to sun or wind, temperature, humidity, size, and type of plant. Plants growing in plastic or ceramic containers need water less often than those in porous fiber or clay pots.

Water when the medium surface feels dry. If a container completely dries out, you may need to soak it to rewet the soil.

A potted plant that uses a lot of water, such as a fuchsia, or one that is pot-bound may need to be watered daily or even several times a day during dry weather. For most container-grown plants, however, a thorough watering every two to three days is sufficient.

Be careful not to keep the root system soaking wet, and do not allow the pot to sit in water. Disease problems occur more often when soil is constantly wet.

Watering Hints

- Remember that most woody plants of native origin to Kentucky will require extra supplemental water as they are established, but normal rainfall will usually suffice once plants are established.
- A quick, light watering does not wet the entire root zone properly. Frequent, shallow watering leads to shallow roots. Shallow roots suffer more stress during drought or hot weather and may freeze in very cold weather.
- You can water any time of the day, but it is more efficient to water at night, when evaporation losses are less. However, sprinkled water on surrounding plants may promote disease. Early morning watering is better in this situation.
- Too much water is as bad as or worse than too little. Excess water can run off, leach nutrients, and promote root diseases.
- Do not apply water faster than the soil can absorb it.
- Fertilizer does absolutely no good unless it is dissolved in water. Always water after applying fertilizer if it doesn't rain at least a half inch over the following six hours.
- Conserve water where possible. Clean water is a valuable resource that should not be wasted.
- Winter drought conditions are uncommon in Kentucky, but trees still require water in winter. If you need to apply water in winter, make sure that the soil is not frozen, which would cause the water to run off.

Woody Landscape Plant Problems

If cared for properly, landscape plants can live a long, healthy life. However, they can suffer damage from a wide variety of causes. Microorganisms cause problems such as root rots and foliage diseases. Insects also cause injury. However, most plant problems are due to adverse weather or cultural conditions that stress the plant. These conditions include freezing, drought, overwatering, and improper use of fertilizers. Tree thinning and construction activities such as grading also contribute to stress by compacting soil, submerging roots, and injuring plants with equipment.

Symptoms of plant damage resulting from stress sometimes do not show immediately. In fact, they may not be obvious for years. Symptoms may result from the accumulation of several stress conditions. In addition, the older a plant is, the less likely it is to successfully adapt to change or difficult conditions.

Root Problems

The root systems of partially to fully mature trees and shrubs normally extend far beyond the plant's dripline. The rooting depth normally is fairly shallow—usually only to the depth of good soil. Sometimes roots grow very close to or above the soil surface. This condition may be caused by any of the following:

- A high water table
- A hard soil layer (hardpan) just beneath the surface
- Shallow, frequent watering

Several root problems are discussed in this chapter. Keep in mind that the symptoms of these problems may show up in other plant parts, especially leaves.

Trunk Girdling (Strangling) Roots

Symptoms—This problem eventually limits water and nutrient transport up the trunk, causing slow deterioration of the plant. The plant is stressed and top growth diminishes.

Causes—It can result from impurities (such as sheetrock or lumber) in the soil; twisting the plant during the planting process; and failing to spread roots properly during transplanting.

Remedies—Remove debris and foreign materials from the soil before planting. Prune girdling roots and spread roots when planting.

Circling Roots

Symptoms—General decline of plant vigor is noted over a period of time.

Cause—The plant remained in its container too long at some stage of development (not necessarily the last).

Remedy—Spread the roots, butterfly the root ball, or slash and spread the roots when you plant.

Kinked Roots, One-Sided Root System

Symptoms—General decline of plant vigor is noted over a period of time.

Causes—Improper production methods, jamming the plant in the pot or planting hole, or dragging with a mechanical planter (J-shaped roots) can create this problem.

Remedy—Cut off kinked roots and carefully spread and straighten the remaining roots when planting.

Root Rots

Symptoms—Roots are mushy, brown, and partially to totally decayed. The plant usually wilts and partially or totally dies.

Causes—Variable causes are possible, depending on susceptibility of the plant to disease organisms, poor soil aeration, amended backfill soil, inadequate drainage, and overwatering.

Remedies—Increase downward and lateral drainage. Plant higher in raised beds. Plant flood-tolerant species or resistant varieties. Do not amend backfill when planting. Monitor watering.

Suffocated Roots

Symptoms—Tree or shrub trunk shows no buttressing or flaring out at the point where it enters the soil. Leaf and branch growth declines from the top down.

Causes—The addition of fill soil, planting too deep, plants that were grown in the nursery too deep in the soil ball, or paving around the plant's base decreases the air supply to roots and changes water movement patterns. Susceptibility varies with species.

Remedies—Remove the excess soil covering the roots of established plants. Replant newly installed tress and shrubs at the correct depth. Improve the drainage. Consult an arborist about whether an air well around the trunk base of mature, established trees might help.

Cut Roots

Symptoms—Death or decline in growth occurs from the top of the plant downward.

Cause—Digging trenches within the plant's root zone severs the roots.

Remedies—Avoid cutting large roots; tunnel under roots where possible. Cut back damaged roots cleanly. Water the plant. Fertilization is of questionable benefit and often increases decay in cut roots.

Compacted Soil

Symptoms—A decline in growth develops from the top down.

Cause—Soil is compacted or roots are damaged by foot or machine traffic after the plant is in the ground. This is especially serious when traffic occurs on wet soils.

Remedy—Buffer the area with a thick (two to three inches) layer of organic mulch. Direct traffic away from plants. Protecting the critical root zone of established plants prior to construction is less expensive and more effective than mitigation of soil compaction after it has occurred.

Plastic Bag, Synthetic Burlap or Other Materials Left on the Plant's Root System

Symptoms—Wilting, stunted growth and eventual death will occur.

Cause—Plant was not removed from pot before planting, or synthetic burlap or twine remained after planting.

Remedy—Take the pot and other materials off the plant before planting.

Stem Problems

Stem maladies usually arise from improper care or stress.

Heart Rot

Symptoms—Heartwood or other internal portions of the trunk or branches decays.

Causes—Improper pruning, broken branches, storm damage, wounded stems, or root damage can lead to the problem.

Remedies—Filling cavities and using pruning paint is of no value and can actually increase the rate of decay. If decay is in advanced stages, remove the tree for safety. Avoid problems by using proper pruning techniques.

Stem Wounds, Cankers, or Girdling of Trunk and Branches

Symptoms—Bark wounds are visible.

Causes—Damage can be caused by rope left on after planting, careless use of lawn mowers or weed trimmers, or staking ties or wires left on too long.

Remedies—Remove all ties when planting. Stay away from plant stems and trunks with mowing and weed-cutting equipment. If damage occurs, cut away the loose bark in a rounded ellipse. Painting or spraying the wounded area provides no benefit and may even be detrimental.

Fork Pockets, Bark Inclusions, or Narrow Crotches that May Split

Cause—Two or more branches compete to be the central leader (codominant leaders).

Remedy—Prune out all but one of the leaders if the tree is young. If the tree is old, consider subordinating the weaker branch, cabling, or cabling and bracing the competing limbs. Failure to mitigate the problem may result in branch failure and the potential for damage.

Bark Scald, Sunscald, or Southwest Disease

Symptoms—Bark is dead, usually on the south or southwest side of the trunk.

Causes—Hot sun, or alternate freezing and thawing of bark, can be the cause. Newly transplanted and young trees are very susceptible.

Remedies—Shade the southwest side of the trunk with a loose layer of plastic window screen. Wrapping is of questionable benefit on mature trees, although it may be helpful for newly planted trees. If you do wrap a trunk, use wrap that is a light color (to reflect sunlight) and woven (to allow air passage). If damage occurs, cut loose bark back to firmly attached bark. Remove all wraps after the danger of winter freezes has passed.

Graft Failure

Symptoms—Large overgrowths appear above or below a graft union, or the plant breaks cleanly at the graft union. Leaves change color early in autumn.

Cause—The grafted scion and stock are incompatible.

Remedy—Purchase plants rooted from cuttings (not grafted). Avoid stock–scion combinations with known problems.

Leaf Problems

Symptoms of stem and root maladies may show up in leaves. Many insects and diseases also affect leaves.

Wilted Leaves

If a plant is wilted, the leaves are losing water faster than it can be supplied by the roots. Plants vary in how much water they need. The exact cause of wilting must be determined by observing symptoms and the plant's environment. Some possibilities are discussed below.

Drought or Lack of Water

Symptoms—Soft growth wilts. Extended periods of dryness can cause early leaf drop, marginal and interveinal chlorosis (yellowing), and necrosis (tissue death).

Cause—There is not enough water in the soil.

Remedies—Supply water. Increase soil water-holding capacity. Mulch. Plant drought-tolerant plants.

High Temperature and Bright Sunlight

Symptoms—Leaf browning and blotch necrosis occur.

Cause—Plants have been exposed to hot sun.

Remedies—Shade the plant. Use plants tolerant to heat and low humidity. Periodically syringe leaves with water for temporary cooling.

Lack of Roots

Symptoms—Wilting, early leaf drop, chlorosis, necrosis, poor growth, and death are common symptoms..

Causes—Rot or decay (caused by poor drainage), trenching, transplanting, or insects (e.g., root weevils) can be the cause.

Remedies—Determine the cause, then take appropriate action. Watering may help if the problem is not due to poor drainage.

Flooding

Symptoms—Plant is wilted or droopy.

Cause—Too much water limits available oxygen to roots, thereby reducing or stopping water uptake.

Remedies—Improve drainage. Decrease water supply. Plant on a berm or raised bed.

Plugged Vascular System

Symptom—Plant wilts.

Cause—Diseases such as verticillium wilt can be the culprit.

Remedy—Determine the cause and take appropriate action (e.g., apply a registered fungicide or use resistant plants).

Salt Damage

Symptoms—Marginal to interveinal chlorosis or necrosis occurs, and rootlets are brown instead of white. In containers, the soil surface or edge of the pot may be covered with white salt deposits.

Cause—Soil can accumulate excessive salts from fertilizers, manures, and deicing materials. This problem may be more prevalent in containers than in gardens. It also is more common in arid areas than in regions where winter precipitation leaches away excess salts.

Remedy—Leach salts from soil by applying irrigation water in excess of the water-holding capacity of the soil. See Chapter 4, Soils and Fertility, for more information.

Yellow (Chlorotic) Leaves

Nitrogen Deficiency

Symptoms—Plant shows overall yellowing, with older leaves changing first.

Cause—Not enough nitrogen is available in the soil.

Remedy—Fertilize with a nitrogen fertilizer.

High pH

Symptoms—Interveinal chlorosis occurs, appearing in newer leaves first. Chlorotic regions may die.

Cause—Alkaline soil may cause iron and/or manganese to become unavailable.

Remedies—Decrease soil pH with elemental sulfur, iron sulfate, or ammonium-based fertilizers. Spray the plant or drench the root system with iron or manganese chelate as a temporary measure. This will cause the plant to become greener, but does not improve the vigor or health of the plant, only the aesthetics.

Other Causes

Chlorosis also may be caused by drought, misuse of herbicides (see "Herbicide Damage" section of this chapter), bright sunlight, or natural leaf maturity. Some plants naturally have variegated or light green leaves.

Herbicide Damage

Herbicides have specific toxicities to weeds, but also may damage desirable plants. Almost all herbicide damage results from misuse. Few problems arise when label directions are followed closely. The key is to read the label and think.

If many plants in one area show symptoms, suspect herbicide damage. Severity and type of damage depend on the type of herbicide, amount applied, plant species, and stage of growth at the time of application.

Some herbicides act as plant hormones, causing twisted and distorted growth. Others inhibit photosynthesis and chlorophyll production, causing chlorosis.

Table 16.2 lists some common herbicides and their possible effects.

Even if only part of the root system is affected by an herbicide, damage may spiral up the plant. Know where the root zones of your desirable plants are. Take special care when applying turf herbicides for broadleaf weed control within the root zones of desirable plants.

Dormant oil used for insect and mite control may damage needled evergreens if applied during freezing weather or if not well mixed. Dormant oil will also wash off the blue color of Colorado blue spruce (*Picea pungens*) but does not otherwise harm the plant.

Winter Injury

Causes

Winter injury may be caused by a complex combination of circumstances rather than a single factor. Factors involved include:

Weather

- Deviation from normal minimum winter temperatures
- Dramatic fluctuations in winter temperatures
- Length of a severe cold period
- Time of year when a cold period occurs
- Bright, sunny days with frozen soil
- Depth to which the soil freezes
- Drying winds
- Low humidity
- Lack of snow cover, mulch, or other insulating materials

Site Influences

- Distance from a large body of water
- Solid fences, hedges, or barriers that trap cold air and create frost pockets
- Soil moisture availability before a freeze
- Soil conditions, soil type, and mulch
- Raised beds or containers
- Windbreaks

Plant

- Genetic hardiness of the species
- Genetic adaptation to a different geographic area (ecotype)
- Differences in hardiness of different plant tissues
- How well the plant is established
- Condition of the plant, including dormant or partly dormant state or stress from drought, fertilizer burn, or insect damage
- Growth stage of the plant
- Protective reactions of the plant (e.g., leaf drop or leaf rolling)

Why Winter Injury Happens

Winter injury to landscape plants occurs in various ways. By understanding how plants react to winter temperatures, you sometimes can predict the type and extent of damage that might occur and take actions to protect your plants.

The limits of winter hardiness are controlled genetically and vary greatly among species and even among plants within the same species. For example, Douglas firs (*Pseudotsuga menziesii*) that evolved in the Rocky Mountains are hardier than those that evolved in the Cascades (Pacific Northwest). Likewise, flowering dogwoods (*Cornus florida*) from New York are hardier than those from Florida or Georgia, even though they are the same species.

Table 16.2. Herbicide effects on plants.

Herbicide	Damage Symptoms
Dichlobenil (Casoron)	Broadleaf plants: Chlorosis or necrosis of tips, margins, or interveinal areas. Sometimes more severe on leaves exposed to the afternoon sun. Conifers: needle tip chlorosis or necrosis.
Phenoxy compounds (2,4-D, MCPP, triclopyr)	Broadleaf plants: Twisted, distorted leaves and stems. Bark blistering on London plane trees. Grapes, Mahonia, and tomatoes are very sensitive. Conifers: Misshapen, distorted needles. Note: These herbicides are particularly susceptible to drift.
Dicamba (Banvel)	Broadleaf plants: Twisted, distorted new growth, chlorosis, necrosis, death of trunk tissue. Conifers: Distorted, twisted needles; needle necrosis from the base to the tip; club-shaped growth.
Glyphosate (Roundup)	Broadleaf plants: Death of part or the entire plant, strap-shaped new leaves, purplish cast to plant. Conifers: None noted.
Triazines, atrazine (AAtrex), simazine (Princep)	Broadleaf plants: Chlorosis, leaf tip to margin to interveinal; may become necrotic. Conifers: Needle tip chlorosis.
Long-term residuals	May cause plant damage or death if applied over the (chemical sterilants) root system of desirable plants.

Plants native to a geographic region have evolved in response to the area's climate and weather patterns. The hardiest plants survive and produce offspring, passing on their genetic hardiness. Thus, plants native to an area are usually able to survive winters characteristic of that area.

Many landscape plants are introduced (often called exotics). They may be adapted to completely different environments than they encounter here. Exotic or introduced plants often respond differently to local climatic patterns than native plants.

Cold hardiness develops each fall in an organized pattern as physiological changes take place in a plant. These changes are driven by the arrival of shorter days and cooler temperatures. The rate of acclimation varies by species and the extent of cooling. If fall temperatures remain warm, plants may fail to adequately acclimate to cold.

Deacclimation or dehardening is the loss of hardiness. It is a plant's response to warming temperatures in late winter and early spring. Typically, deacclimation is gradual, but it can be rapid during an extended warm period. Some species, but not all, require a chilling requirement to exit dormancy. The chilling requirement is satisfied when the plant accumulates a set amount of exposure to low, non-freezing temperatures (45°F) during dormancy. Only after this requirement is met can plants deacclimate. The chilling requirement of a given species will vary depending on where it originated.

Cold temperature damage may occur at any time, depending on the severity of the cold and the stage of hardiness of the plant. Damage is most common during:

- A sudden, dramatic drop in temperature following a relatively warm fall. Plants may not yet be acclimated to cold.
- Very cold midwinter temperatures. Even after a good acclimation period, marginally hardy plants may suffer damage.
- A sudden, severe temperature drop after a warm spell in late winter or early spring. Plants may have started to deacclimate.
- A late freeze after growth starts in the spring. New, soft growth usually cannot tolerate frost. Plants that bloom or start to grow early in the season, such as flowering cherries, magnolias, photinia, and some very early-blooming rhododendrons, are susceptible to damage from spring freezes.

Types of Winter Injury

Bud and Stem Damage

Buds and stems die or are damaged if a plant is not genetically hardy or has deacclimated. Some buds or tissues may be killed, while others remain healthy. On some tender hydrangeas, cold may partially or completely kill flower buds. Thus, there may be fewer flowers than normal on these plants after a colder-than-normal winter.

Frozen Roots

The medium in an aboveground container or B&B tree may freeze, killing a plant's roots. In most plants, stem tissue is much hardier than roots, so the top of the plant may not be damaged. It may leaf out in spring and then, for no apparent reason, wither and die. Check the roots to see whether this type of injury has occurred. Dead roots usually are brown or black and may be soft. Live roots have a white growing tip and are white to greenish under their bark.

You can reduce this type of damage by putting containerized plants in a protected area such as a cool garage or greenhouse during winter. It may be sufficient to bury containers in sawdust, ground bark, or soil to insulate roots during winter.

Scald of Leaves by Sun and Wind

During periods of severe cold combined with bright sunshine, the leaves of some broadleaf evergreens deacclimate. When the sun sets, the deacclimated leaf tissue freezes. Ice forms in the cells, rupturing their membranes and walls, and the cells die.

Damage usually is worse on leaves exposed to the afternoon sun (on the south or southwest side of the plant). Plants vary in their susceptibility to sunscald.

Winter wind and sun, alone or in combination, can damage evergreens by causing them to transpire (lose water) through their leaves or needles. The water is not replaced because roots cannot take in water from cold or frozen soil. Affected leaves turn brown, starting at the edges or tips and progressing between the veins or down the needles.

Prevent these maladies by protecting plants from wind or shading them.

Sunscald of Bark

Trees can suffer sunscald on sunny winter days. Damage usually occurs on a trunk's exposed southwest side. Sunscald is more prevalent on stressed, recently transplanted, smooth-barked, or thin-barked trees. It occurs when bark and cambial tissues deacclimate and do not reacclimate quickly enough when the sun sets and the temperature drops abruptly. The result is tissue damage or death. Sun-scalded bark often cracks open or separates from the tree without splitting.

To prevent sunscald, wrap trunks of recently transplanted trees and those that were stressed during the growing season. Use light-colored wrapping and wrap from the soil line to the first set of branches. Leave the material on for the first winter and remove it at the beginning of the first growing season.

Leaf Droop and Leaf Rolling

Drooping and rolling of leaves are protective reactions to cold. They reduce the amount of leaf surface exposed to cold and drying winds. Leaves return to normal as temperatures warm. On some rhododendron varieties, the leaves fold back flat against the stems or roll up tightly. If leaves are not killed by extreme cold, the plant will return to normal when the weather improves.

Limb and Branch Breakage

Branches may break because of heavy snow or ice loading. Prune the broken portion back to an undamaged branch or the main trunk. On large branches, make pruning cuts just outside the branch collar.

Delayed Symptoms

The results of winter injury sometimes take months or years to appear. Sometimes, leaves live until their reserves are depleted, which occurs slowly in cool weather but rapidly when the weather suddenly warms.

Graft unions may be sensitive to damage from cold. Only a portion of the graft may be injured. It may function for years until another kind of stress causes it to fail.

Winter-damaged tissue may allow disease organisms and insects to enter. Again, these problems may not be evident for years.

Root systems, especially of shallow-rooted plants such as rhododendrons and blueberries, may be injured by cold. When damaged roots fail, the plant's top starts to die.

Preventing Winter Injury

- Select plants adapted to your local climate and soil conditions.
- If possible, place evergreen plants in areas that minimize their exposure to sun and wind. Otherwise, provide a windbreak or shading during winter.
- In the fall, wrap the trunks of young and recently transplanted trees with a white or light-colored woven wrap.
- Keep plants healthy by proper planting, fertilizing, watering, and pest control.
- Do not fertilize, prune, or water heavily late in the growing season. Doing so can encourage late-season growth that may not acclimate well.
- Protect shrubs from heavy snow accumulation.
- Water landscape plants, especially evergreens, during fall and early winter dry spells. Pay close attention to plants under overhangs or in other places where they may not receive rain or snow.

What to Do for Winter-injured Plants

Don't do anything until new growth begins on live wood, usually in late spring. It is easier to determine which stems actually are dead after growth begins. Sometimes, faded green branches begin to regrow and do not die. Even if leaves are dead, stems and vegetative buds still may be alive.

Before pruning a sad-looking plant to almost nothing or pulling it out altogether, check for signs of life. Scrape the bark away with a fingernail or make a shallow cut just under the bark with a pocketknife. Live branches are bright green or white just beneath the bark. Dead branches are brown and may look water soaked.

Check the plant in several places: at the twigs, farther down the branches, and at the crown or soil line. If the outer twigs are dead, move toward the trunk until you find live tissue; older wood may be hardier than young wood.

Once you determine the extent of the damage consider the following steps:

- Prune out and remove dead and severely damaged wood. Prune properly, leaving no stubs. Prune back to live, green, healthy wood: a bud, live stem, or trunk. Do not prune live wood.
- Water properly during the following growing season. Pay particular attention to plants beneath eaves.
- If the soil lacks adequate amounts of basic plant nutrients, add fertilizer. If growth appears normal, fertilize only lightly, if at all.
- Use a loose, organic mulch to maintain soil moisture and protect the upper roots from temperature extremes.
- On damaged fruit trees, remove as much developing fruit as possible to allow the plant to recover and rebuild reserves rather than produce fruit.

In short, the best thing you can do for a winter-injured plant is to avoid further stress during the coming season by giving it special attention and care.

Construction Damage

When clearing a building site, developers often leave large, well-established trees to enhance the property's aesthetic value. Often, however, these trees soon decline. They may exhibit stunted leaves or needles, short internodes, or dead branches and foliage throughout the plant.

Change of Grade

When preparing a building site, developers often move soil, sometimes to level areas that once were sloping, or to develop slopes where the soil was originally level. If trees are left standing, soil may be added over their roots. Reducing the soil grade removes tree roots along with the soil. These changes can cause significant damage and even death of trees.

Raising the grade can suffocate roots. The damage may depend on the kind of tree, the depth of the soil fill, and the texture of the fill. Most trees are adversely affected if several inches of soil fill are placed over their roots. Sandy or gravelly fills are less damaging than heavier textured soils such as silt or clay.

Placing asphalt paving or concrete over a root system can have the same suffocating effect as raising the grade around a tree. These processes usually cause significant root damage.

Lowering the grade also can be detrimental. Most feeder roots, which supply the tree with water and nutrients, are located in the top six to eight inches of soil. Removing soil removes or injures many of these roots. If enough large roots are lost, the tree may lack anchorage and fall. Also, damaged or broken roots sometimes rot back to and into the stem.

Grade changes also may affect the water table, either lowering or raising it in response to soil changes. Also, paved areas may direct more or less water into a tree's root zone. The larger and older the tree, the more difficult the recovery can be.

Soil Compaction

Heavy equipment or repeated human or animal traffic compacts soil. Compacted soil is less open to air and water movement, thus creating adverse conditions for root growth. Sandy soils or soils high in organic matter tend to compact less than heavy, clay soils.

Mechanical Injury

Bulldozers and other equipment may gouge the bark off a tree's trunk or root crown and can damage roots simply by moving over them. If bark is completely knocked off around its trunk, a tree will die. In less severe cases, decay organisms may enter wounds. Large, untreated stem wounds eventually can cause internal rot, sometimes called heart rot.

Digging trenches for foundations, pipes, and cables causes serious root loss and damage. The closer the trench to a tree, the more severe its effect will be. Damaged trees may die or fall.

Tree Thinning

Sometimes builders or homeowners remove selected trees to create space, decrease shade, or give desirable trees more room. When trees are thinned, the remaining trees are exposed to more wind. They may suffer damage ranging from a few broken limbs to completely blowing over. A stand's vulnerability increases when the larger trees (with large crowns) are taken out or blow down.

Preventing or Lessening Construction Damage

Before land clearing and construction begin, mark off the dimensions of the building, driveway, and other major construction areas. Decide which trees to save (or transplant) based on their proximity to the construction area, health, age, and species. Then build a barrier to keep equipment away from the remaining trees. If trenching near desirable trees is necessary, tunnel under, rather than through, the root system. If you must raise the grade around a desired tree, construct a dry well around it. Consult an ISA-certified arborist for advice.

Care after Construction

Care for Damaged Trees

Usually the owner of a new house or other structure is not involved in land- clearing and construction decisions and has no idea what changes have taken place. Often, developers and builders do not take proper precautions with regard to trees. Thus, the owner may not be aware of damage until trees begin to show signs of stress. By that time, chances of saving them may be slim.

Even with prompt treatment, severely damaged trees may die. The sooner treatment is begun, the better the chance of recovery. Water and fertilize damaged and possibly damaged trees and shrubs properly. In this case, water is much more important than fertilizer. If you fertilize, use a complete fertilizer containing nitrogen and phosphorus in about equal proportions. Late fall and early winter are the best time for fertilizer application to damaged trees. See "Fertilizing" section earlier in this chapter for more information.

If trees are wounded, remove loose and dead bark from around the wounded area and shape the wound margin with a sharp knife. If callus tissue (the ridge of tissue that forms around and eventually covers a wound) has started to form, do not cut into it. Wound dressing (wound paint) serves no useful purpose and may be detrimental.

Pruning—particularly excessive pruning—diverts carbohydrate production to a plant's top (shoots) at the expense of root growth. Thus, pruning is not a good idea if there is root loss. Otherwise, prune dead and damaged wood back to sound wood. Use thinning cuts.

Remove dead trees. If live trees are a hazard, remove or cable them. Have ISA-certified arborists do all pruning and removal of large trees.

Care for Protected Trees

Even with proper land clearing and building, good tree care following construction is vital to continued life and growth of trees and large shrubs. Proper watering and fertilizing are necessary. Additional pruning may be necessary to direct future growth. Keep trees under observation for 8 to 10 years after construction and treat promptly if needed.

For More Information

Hundreds of species of trees, shrubs, vines, and groundcovers can be used as landscape ornamentals, specimen plants, container plants, or in countless other ways. A wealth of information is available to help you better understand specific plants and how to use them. Check with local bookstores or ask your county Extension service for publications about growing plants in your area.

UK Extension Publications

Planting Balled and Burlapped Trees and Shrubs in Your Landscape (HO-91)
Botanical Diversity in the Landscape (HO-92)
Trees and Compacted Soils (HO-93)
Trees with Minimal Insect and Disease Problems for Kentucky Landscapes (HO-94)
Recognizing Trees of Significance (HO-95)

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Additional Resources

American Nursery and Landscape Association. Resource Catalog. 250 I St. NW, Suite 500, Washington, DC 20005-3922.
American Nurseryman Publishing Co. (distributes many books of horticultural interest). Suite 2100, 77 W. Washington St., Chicago, IL 60602-2904.
International Society of Arboriculture. www.treesaregood.com.

Chapter 17

Care of Woody Plants

Adapted from The Virginia Master Gardener Handbook. Edited by Ray McNeilan, Extension agent emeritus, Multnomah County, Oregon State University. Adapted for the Kentucky Master Gardener Manual by Richard Durham, consumer horticulture Extension specialist and state Master Gardener coordinator, University of Kentucky..

In this chapter:

To prune or not to prune? This is a question that often faces gardeners. Most feel they ought to prune but are not sure why or how. Pruning is an accepted practice in orchards and frequently is done in rose gardens, but it is used haphazardly elsewhere. Ornamentals are most often pruned only when a shrub or tree begins to encroach on its neighbors, a walkway, or a building.

Pruning often is thought of as a way to make a barren tree fruitful. If carried out correctly, it eventually will do so. However, years of neglect cannot be corrected in one season. Gardeners who don't know how to prune but do so because they think they should often end up with no flowers at all, because they either prune excessively or prune at the wrong time of the year. Keep in mind that pruning will not compensate for lack of fertilization, poor weed control, or drought conditions.

What, then, is pruning? Why, when, and how should it be done? Pruning can be described as the removal of part of a woody plant for a specific purpose. This chapter explains the reasons for pruning, the proper techniques and tools to use, and how to prune various types of plants.

Reasons for Pruning

Reasons for pruning can be grouped into four general categories:

- Training a plant
- Maintaining plant health
- Improving the quality of flowers, fruit, foliage, and stems
- Restricting growth

Training a Plant

Prune trees and shrubs after transplanting only to remove dead, broken, crossed, or pest-infested branches. Contrary to common belief, it is not necessary to prune away one-third of a tree's top growth to compensate for root loss as long as you use properly pruned, nursery-grown plants. According to research, excessive pruning at transplanting reduces plant size and does not aid in survival.

However, pruning should begin during a tree's first growing season. The main purpose of early pruning is to train a tree so it will develop a strong, well-balanced shape. When training a new tree, follow these guidelines:

- As a rule, do not prune the central *leader* (main growing axis) unless you don't want to keep it. Pruning the leader is appropriate for some naturally low-branched trees or if you want to develop a multi-stemmed plant.

  Trees with a central leader, such as linden, sweetgum, or pin oak, may need little or no pruning except to shorten or head back branches competing with the central leader. Some pruning may be necessary to maintain desired shape and to shorten overly vigorous shoots.
- The height of the lowest branch can range from a few inches above the ground for a screen or windbreak to more than 12 feet above the ground for a canopy. Lower limbs usually are removed over a period of years until the desired height is reached, beginning in the nursery and continuing for several years after transplanting,
- For greatest strength, branches selected for permanent *scaffolds* (the framework of the tree) must have a wide angle of attachment with the trunk (*crotch angle*). Branches with less than a 30° angle frequently break, while those with angles between 60° and 70° rarely do.
- For shade trees, choose branches for major scaffolds that are at least eight inches apart vertically, and preferably 20 to 24 inches (Figure 17.1a). Closely spaced scaffolds will have fewer lateral branches, resulting in long, thin branches with poor structural strength.

Pruning Terminology

Apex—The tip of a shoot.

Apical dominance—The influence of a growing shoot tip on the buds and shoots below it. The shoot tip produces hormones that move with gravity toward the earth. This chemical message prevents growth of most lateral buds below the tip and reduces growth of lower shoots. This effect is inhibited if a branch is growing horizontally.

Bud—An undeveloped shoot, leaf, or flower, or a combination of leaves and flowers, formed on the sides or ends of shoots and in leaf axils (the angle formed where a leaf joins a shoot).

Collar—A swollen area at the base of a branch where it connects to a trunk. Contains special tissue that prevents decay from moving downward from the branch into the trunk.

Crotch angle—The angle formed between the trunk and a main scaffold limb. The best angle is 45° to 60°.

Head—The part of a tree from which the main scaffold limbs originate.

Heading—Cutting off part of a shoot or limb rather than removing it entirely where it attaches to another branch.

Leader—The uppermost portion of a scaffold limb. The terminal is the tip (apex) of the leader.

Root sucker—A shoot that arises from the root system.

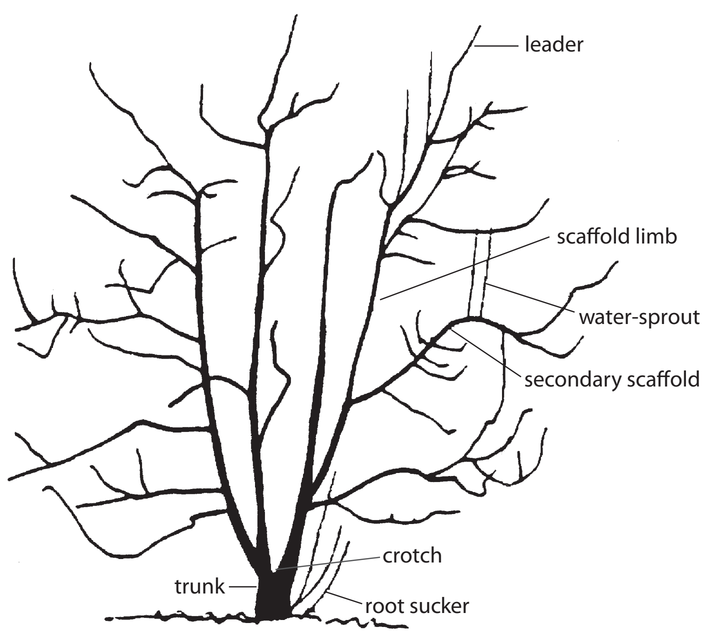
Scaffold limb—A large limb that forms the framework of a tree.

Shoot—One season's branch growth. The bud scale scars (ring of small ridges) on a branch mark the start of a season's growth.

Spur—A short shoot that bears flower buds and often fruit, either on the end (terminally) or sides (laterally).

Thinning—Removing an entire shoot or limb where it originates.

Water sprout—A long shoot that grows in an undesirable location on a trunk or a major limb. Vertical water sprouts often arise on the upper side of horizontal limbs.



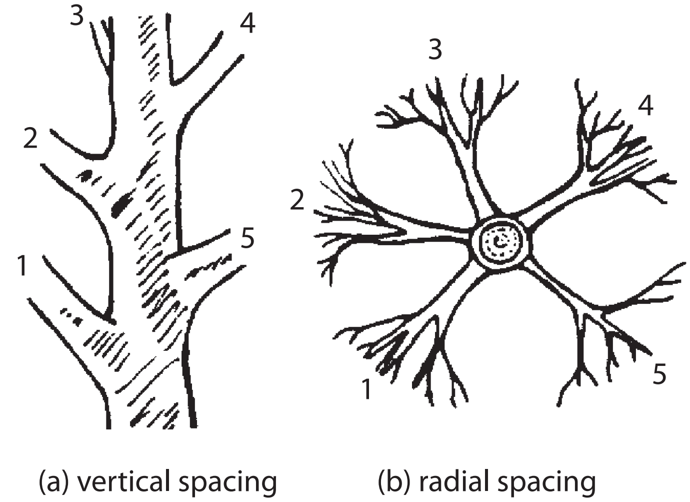


Figure 17.1. Proper vertical spacing (a) and radial spacing (b) for scaffold branches.

- Five to seven scaffolds should fill the circle of space around the trunk (Figure 17.1b). This arrangement prevents one limb from overshadowing another and reduces competition for light and nutrients.
- Remove or prune shoots that are too low, close, or vigorous in relation to the leader and scaffold branches.

Maintaining Plant Health

In pruning to maintain plant health, first consider sanitation, which includes eliminating dead, dying, or diseased wood. Any dying branch or stub could be an entry point or buildup chamber for insects or fungi that could spread to other parts of the tree.

When removing wood infected with disease, such as a fungal canker or blight, it is important to make the cut in healthy wood beyond the infection. Sterilize pruning tools with alcohol or a mild bleach solution after each cut to prevent transfer of disease to healthy stock.

Keeping a shrub or tree from growing too densely can help prevent disease. Evergreen shrubs, in particular, usually benefit from occasional thinning, which allows light and air to penetrate throughout the shrub and results in even growth of healthy foliage.

Improving Flowers, Fruit, Foliage, and Stems

The more flowers and fruit a plant produces, the smaller they are, as is evident on an unpruned rosebush or fruit tree. Pruning reduces the amount of wood and diverts energy into production of larger, though possibly fewer, flowers and/or fruit. Most flowering shrubs bloom on either last year's growth or new growth. More flower-bearing wood is produced with properly timed pruning.

Some deciduous shrubs have colored bark that is attractive in winter. Because the best color is produced on young wood, hard pruning produces not only longer stems, but also more intensely colored ones.

Other plants are grown for their foliage. Proper pruning can increase the quality and quantity of foliage produced.

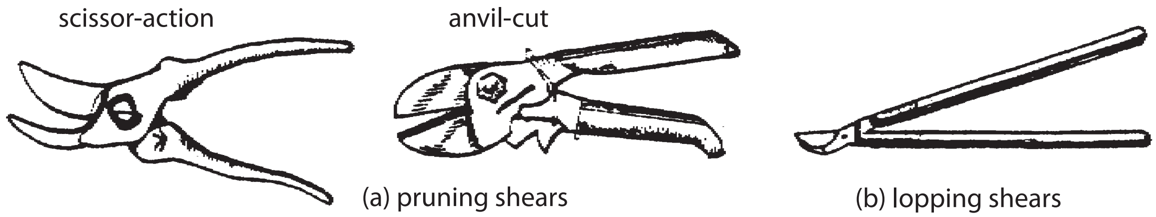


Figure 17.2. Pruning shears (a) and lopping shears (b).

Restricting Growth

Over time, trees and shrubs often grow too big for their space, and regular pruning is necessary to keep them in bounds. Formal hedges are pruned to maintain a uniform growth rate. To reduce labor, select plants that will not exceed their allotted space.

Pruning Tools

Hand Shears

Hand pruning shears are good for branches up to one-half inch in diameter. If you use them to cut larger branches, you risk making a poor cut and/or damaging the shears.

There are two styles of hand shears: scissor-action (or bypass) and anvil-cut (Figure 17.2a). *Scissor-action* shears have a thin, sharp blade that slides closely past a thicker, but also sharp, blade. This type usually costs more but makes cleaner, closer cuts. *Anvil-cut* shears have a sharpened blade that cuts against a broad, flat blade.

Lopping Shears

Lopping shears have long handles and are operated with both hands (Figure 17.2b). Even the cheapest can cut material one-half inch in diameter. The better ones can slice through branches two inches thick or more, depending on species and condition. For example, pin oak wood is tougher than linden, and until decay sets in, dead wood is tougher than live wood.

Pole Pruners

Pole pruners have a hooked blade above and a cutting blade beneath (Figure 17.3). The blades are on a pole and are operated by pulling down a long piece of cord.

The poles can be in sections, which either fit together or telescope. They can be made of several materials. Poles made of fiberglass or a plastic compound probably are best. Wooden poles are heavy. Aluminum poles are light but can conduct electricity if they touch an overhead wire.

Poles can be fitted with saws, but saws are usually frustrating to use.

Pole pruners can be dangerous. Material that is cut overhead can fall on the operator unless it hangs up in other branches. Be careful and wear head and eye protection when using these tools.

Hedge Shears

Manual hedge shears have long, flat blades and relatively short handles, one for each hand (Figure 17.4). Heavy-duty shears with one serrated blade are good for difficult jobs.

Power hedge shears also are available. For home use, electric models are most common.

Saws

Many makes and models of hand pruning saws are available (Figure 17.5). Fineness of the cutting edge is measured in points (teeth per inch). Average saws are about 5½ to 6 points. Use an 8-point saw for delicate, close work on small shrubs and trees and a 4½-point saw for fairly heavy limbs.

If a saw suddenly folds while in use, it can injure the operator's fingers. Folding saws have either a slotted-head holding screw or a wingnut that secures the saw blade open or closed. A fixed-blade saw with a leather scabbard is safer.

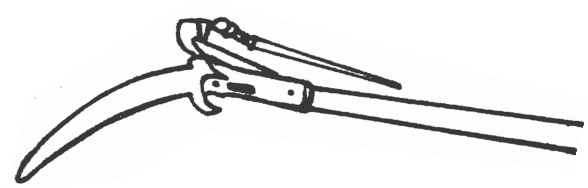


Figure 17.3. Pole pruner.

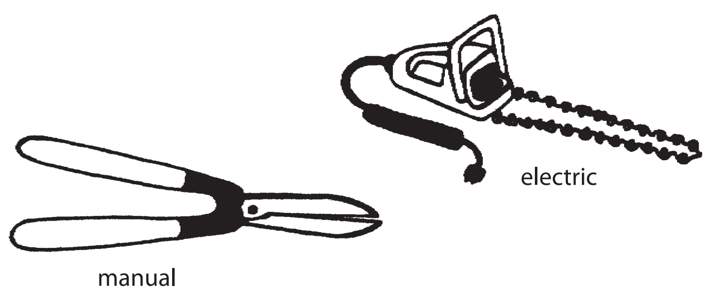


Figure 17.4. Hedge shears.

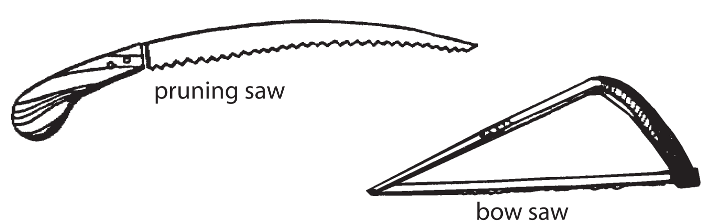


Figure 17.5. Saws.

Saw blades can be either straight or curved. Many people prefer a curved blade that cuts on the draw stroke. A double-edged saw has fine teeth on one side, is coarse on the other, and is difficult to use in densely branched plants.

Bow saws are good only where no obstruction exists for 12 inches or more above the area to be cut.

Chainsaws come in a variety of sizes, both gasoline and electric. However, in general, chainsaws are not appropriate for pruning live plant material. They are better suited to removing trees and cutting firewood.

Caring for Tools

Clean and oil tools regularly by wiping an oily cloth on blades and other surfaces. Several passes with a good oilstone usually suffice. Keep cutting edges sharp. Paint or varnish wooden handles or regularly treat them with linseed oil.

Use tools properly. Don't twist or strain pruners or loppers. Keep the branch to be cut as deeply in the jaws and near the pivot as possible. Don't use pruning tools to cut wires.

Basic Pruning Techniques

There are only two types of cuts: heading cuts and thinning cuts. Figure 17.6 shows the effect of each.

Heading involves cutting off part of a shoot or limb (Figure 17.6a). It increases the number of new shoots and stiffens branches, holding them in position.

Thinning removes undesired wood (Figure 17.6b). In thinning, a branch or twig is cut off at one of the following places:

- Its point of origin from the parent stem
- A lateral side branch
- The "Y" of a branch junction
- Ground level

Thinning results in a more open plant and does not stimulate excessive new growth. By thinning, you can remove considerable growth without changing the plant's natural appearance or growth habit. Thus, you can maintain plants at a given height and width for years while allowing room for side branches to grow.

Twigs and Small Branches

When pruning twigs and small branches, always cut back to a vigorous bud or an intersecting branch.

When cutting back to a bud, choose a bud that is pointing in the direction that new growth is desired. Be sure not to leave a stub over the bud or cut too close to the bud.

When cutting back to an intersecting (lateral) branch, choose a branch that forms an angle of no more than 45° with the one to be removed and has a diameter of at least one-half that of the branch to be removed (Figure 17.7).

Make slanting cuts when removing limbs that grow upward; this technique prevents water from collecting in the cut and speeds up healing.

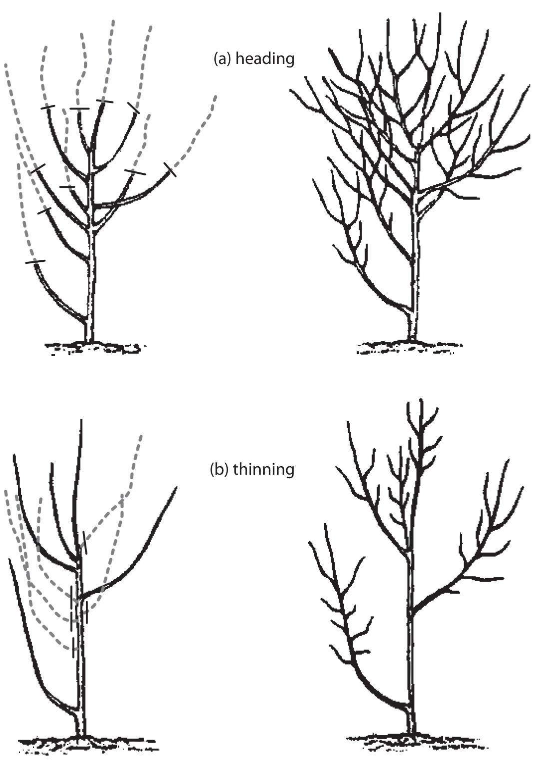


Figure 17.6. Heading cuts (a) increase the number of new shoots formed and stiffen the branches, holding them in position. Thinning cuts (b) reduce the number of new shoots and direct growth.

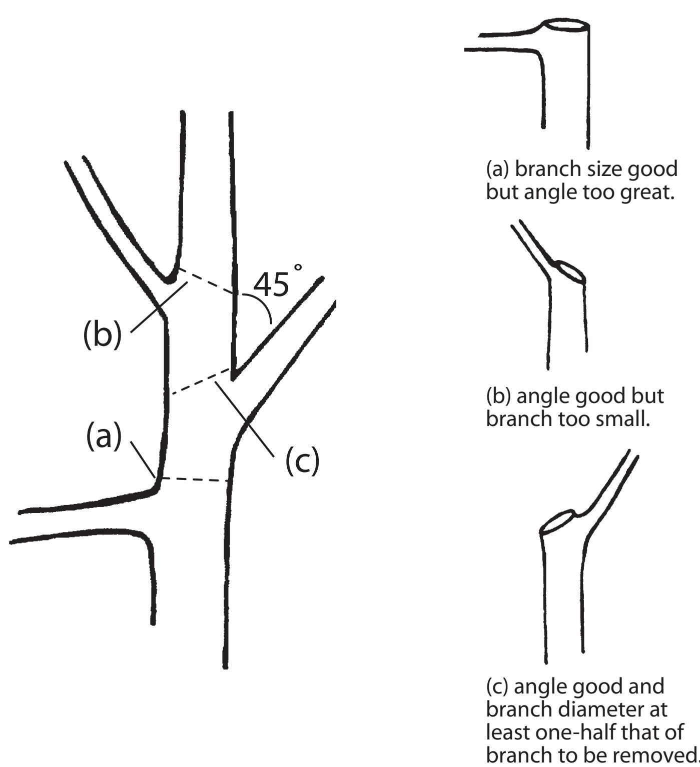


Figure 17.7. Proper branch selection.

Thick, Heavy Branches

Remove thick, heavy branches flush with the *collar* at the base of the branch, not flush with the trunk (Figure 17.8). The collar contains chemically protected tissue. When a dead branch decays naturally, the decay advances downward until it meets this internal protected zone. When it reaches this area of very strong wood, the branch falls away. The remaining small zone of decayed wood is walled off within the collar. If a branch's collar is removed, the protective zone is lost, causing a serious trunk wound that wood-decay fungi can easily infect.

Removing the collar causes injury whether the pruned branch is living or dead.

For more than 50 years, the recommended method of pruning was to cut flush with the trunk and paint. These recommendations have no basis in scientific fact. The flush cut, by damaging the collar, increases a tree's injury. Painting merely hides the wound and makes the person doing the pruning feel that he or she has done something to "help" the tree. In fact, paints or wound dressings may trap moisture and increase disease problems.

The proper method for cutting branches larger than 1½ inches in diameter is shown in Figure 17.9:

1. Undercut the bottom of the branch about one-third of the way through, six to 12 inches out from the trunk (Figure 17.9a). If there is danger of the branch damaging lower limbs or objects on the ground, rope it and support it.
2. Make a second cut from the top, about three inches farther out from the undercut, until the branch falls away (Figure 17.9b). If you roped the branch for support, carefully lower it to the ground after the second cut.
3. Cut back the resulting stub to the branch collar (Figure 17.9c).

Roots

After several years, a tree may develop long roots running 15 to 25 feet or more away from the trunk. These roots, along with many branched side roots, physically support the tree. Most of the small feeding roots that gather nourishment branch off the main roots far from the trunk.

If a tree is balled and moved, most of its feeding roots are cut off, so the tree may die when transplanted. For this reason, nursery growers root-prune plants to force them to grow new feeding roots near the trunk. These new roots are included in the balling operation and ensure growth after transplanting.

To safely move a small tree or shrub, root-prune it a year or so before digging it. In the fall, sever half of the roots to one foot deep by forcing a sharp spade into the soil around the plant, leaving a shovel width of untouched soil between cuts. Make the circle of cuts slightly smaller than the size of the ball you'll eventually dig. The next spring, sever the other half of the roots. Move the tree that fall. Another way to accomplish the same thing is to cut all the roots on one side in the spring, cut the other side the following spring, and move the plant that fall.

Recent research indicates that most new roots grow from the ends of pruned roots. Therefore, you must dig a root ball four to six inches larger than the root-pruned area to get the newly developed roots.

Cutting the roots in a circle early in the spring, as explained above, sometimes forces a tree, shrub, or vine to bloom the following year.

Root pruning also is used to force a vigorously growing fruit tree, wisteria vine, or flowering dogwood into bloom.

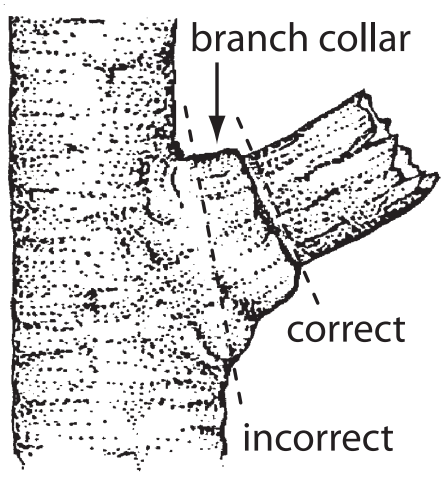


Figure 17.8. Remove branches flush with the collar, not flush with the trunk.

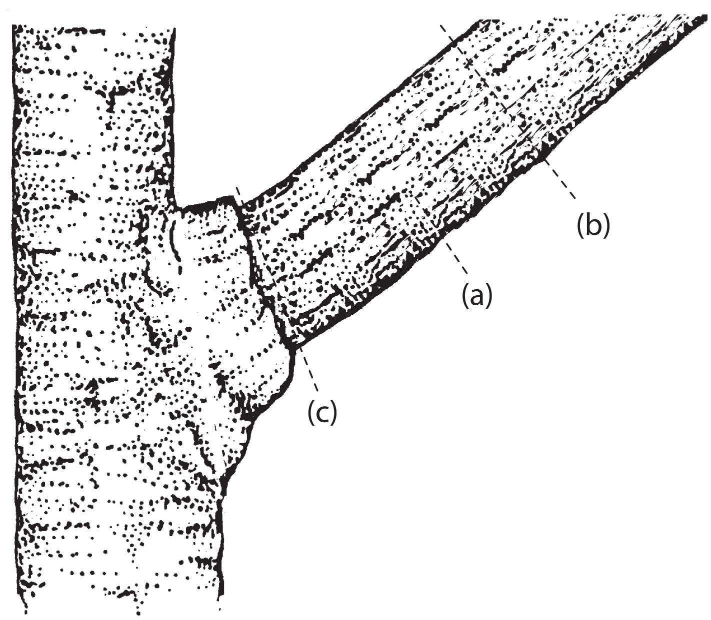


Figure 17.9. Pruning a large branch: (a) Undercut one-third of the way through the branch. (b) Cut through from the top until the branch falls away. (c) Cut back to the collar.

Espaliering

Many gardeners prune for decorative purposes. Numerous training systems are based on the art of espalier, which originated in France and Italy about 400 years ago. Some are quite elaborate and require considerable time and patience as well as detailed knowledge of the plant's growth characteristics. Others are relatively simple.

An espalier system can separate yard areas and produce a large volume of high-quality fruit in a limited area. Fruit trees trained in this fashion should be on dwarfing rootstock. Otherwise, they tend to grow too large.

The easiest espalier system is a horizontal cordon (Figure 17.10). Apples, pears, plums, and some shrubs, such as pyracantha, adapt well to this system. The plant usually is supported by a wall, fence, or wire trellis. Training to a four-tier cordon or four-wire trellis is relatively easy.

You can construct a simple four-wire trellis using two eight-foot posts. Space the posts 12 feet apart and set them two feet in the ground. Run wires through the posts at heights of 18, 36, 54, and 72 inches. Plant two unbranched whips of the desired plant six feet apart between the two posts.

Before growth begins the first spring, cut off each whip just above the highest bud that is below the lowest wire. Three or more shoots should develop near the cut. Retain the uppermost shoot and develop it as the central leader. Train the other two as main scaffold branches along the lower wire, one on each side of the central stem. Remove all other growth.

Tie the two scaffold shoots loosely to the wire as soon as they are 10 to 12 inches long. Use twine, plastic chain link ties, or other suitable material. Tie the shoots so they are nearly horizontal. This arrangement reduces vegetative vigor and induces flower bud formation. If you tie the end of the shoot below horizontal, however, growth at the end will stop and vigorous shoots will develop along the upper side.

By the end of the first season, the lateral branches should be established on the lower wire, and the central leader should have grown above the second wire. At the end of the first winter, while the plant is dormant, cut the central leader back to a bud just below the second wire. Choose two scaffold branches to tie to the second wire and allow the central leader to grow above the third wire.

Repeat this process during the next two seasons, at which time a total of eight scaffolds, four on each side of the trunk, should be firmly established. Bend the leader to form one of the top scaffolds, rather than cutting it off at the top wire. By the end of the fourth season, fruit trees should be producing heavily.

In following years, do all pruning during spring and summer. When new spring growth is about two inches long, cut it off. Remove about one-fourth of the previous season's growth. Do not prune the scaffolds' terminals.

About August 1 or as soon as new growth reaches 10 to 12 inches in length, cut it back to two or three buds. Repeat about a month later, if necessary. This pruning encourages flower bud formation and prevents vigorous growth from getting out of bounds.

Shade Trees

Young shade trees may not need much pruning to develop a good framework. Mature trees generally are pruned only for sanitation, safety, or size restriction.

You can prune shade trees at any time of the year. Late-winter pruning often is preferred because it is easy to shape a tree when foliage is gone. Also, fewer precautions are necessary to avoid garden and flower bed damage, and cleanup is easier. A few trees, such as sugar maples, birches, black walnuts, and flowering dogwoods, bleed profusely when pruned in late winter. The bleeding is unsightly but is not harmful.

Summer pruning may be more effective in directing plant growth. It also may cause fewer suckers or *water sprouts* to grow. (A water sprout is a long, vigorous shoot that grows in an undesirable location on a trunk or major limb.)

Fruit and Nut Trees

The basic objectives in directing and guiding the growth of young fruit trees are to encourage early fruit production and develop an optimum tree structure for supporting future crops. You can meet these objectives by maintaining a proper balance between vegetative and potential fruiting wood. Pruning of mature trees is aimed at producing new growth of fruiting wood. This section discusses pruning of various types of fruit and nut trees.

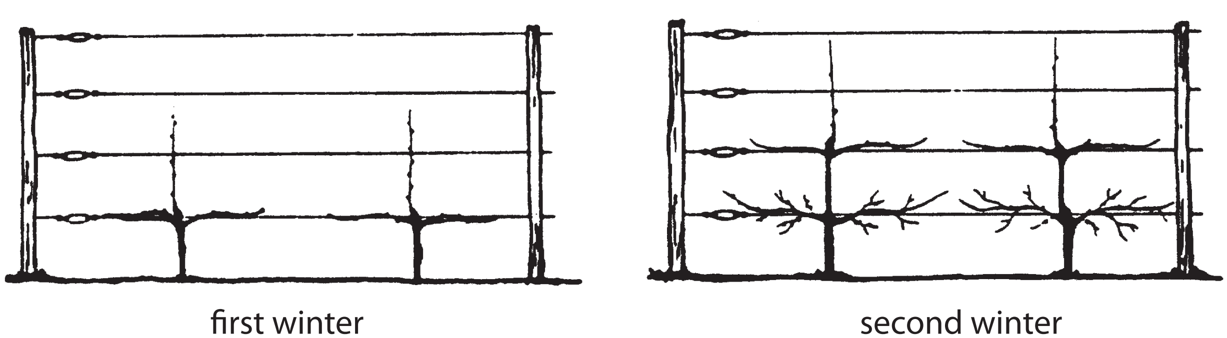


Figure 17.10. Training a tree with an espalier system.

Nonbearing Apple Trees

Avoid excessive pruning of young, nonbearing trees, because it stimulates excessive shoot growth and delays fruiting. Instead, prune to train young trees by redirecting limbs, stimulating branching where desired, and removing growth that is in an undesirable location. To minimize winter injury, do not prune young, nonbearing apple trees before February 1.

Pruning of a mature apple tree is greatly affected by early training, so it's imperative that training begin early. Waiting three or four years after planting results in a poorly developed, weak tree. Correcting such a problem, usually with heavy pruning, only further delays and decreases fruit production.

An integral part of tree training is limb spreading. There are two reasons for limb spreading:

- To develop limb orientation at 60°From vertical, thus balancing vegetative and fruiting growth
- To develop strong, wide crotch angles (greater than 35°)

Limb orientation affects vigor in various ways, as shown in Figure 17.11. Upright or vertical limbs (Figure 17.11a) produce their longest shoots near their tip and tend to have high vegetative vigor. Often, fruits hang down against these limbs and rub against them. On the other hand, horizontally oriented limbs (Figure 17.11b) develop vigorous water sprouts along their upper surface at the expense of potential fruiting spurs.

The ideal limb orientation is about 60°From vertical. These limbs (Figure 17.11c) have less vigorous shoots near the tip, more uniform branching, and more fruiting spurs. Fruits hang down from the limb and are less prone to rub.

Another reason for limb spreading is to develop strong *crotch angles* (Figure 17.12a). Wide crotch angles are strong. Many cultivars, such as Red Delicious (particularly spur types), naturally develop narrow crotch angles. If these crotch angles are not widened to greater than 35°, a condition called *bark inclusion* can develop (Figure 17.12b). In this condition, bark is trapped between the trunk and scaffold, and layers of annual wood are prevented from growing together. Splitting may occur at these narrow crotch angles.

At Planting

Training begins at planting. Early pruning forces the growth of lateral branches from which you'll select future scaffolds.

When planting, cut back spur-type and semidwarf apple trees to a height of 30 to 35 inches. Cut back standard trees to 40 inches. If the tree is branched, head it back to a strong bud to stimulate growth of the central leader. Head back and retain desirably located branches for scaffolds. Remove undesirable side branches.

First Growing Season

Scaffold selection can begin in summer, especially on cultivars that develop narrow crotch angles. Generally, in the first year, you can select two to four good scaffolds (Figure 17.13). They should be evenly distributed and not directly above one another. Vertical spacing between scaffolds can vary from three to 12 inches, depending on the ultimate size of the tree. Remove shoots developing below the lowest desired scaffold (18 to 24 inches above ground).

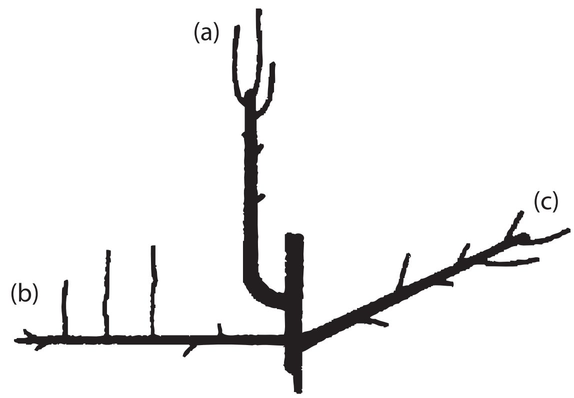


Figure 17.11. Possible limb orientations: (a) vertical; (b) horizontal; (c) 60°From vertical. The 60° limb is ideal.

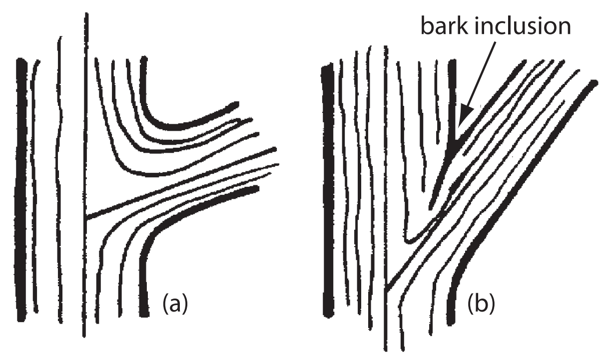


Figure 17.12. Strong, wide crotch angle (a) and narrow crotch angle with bark inclusion (b).

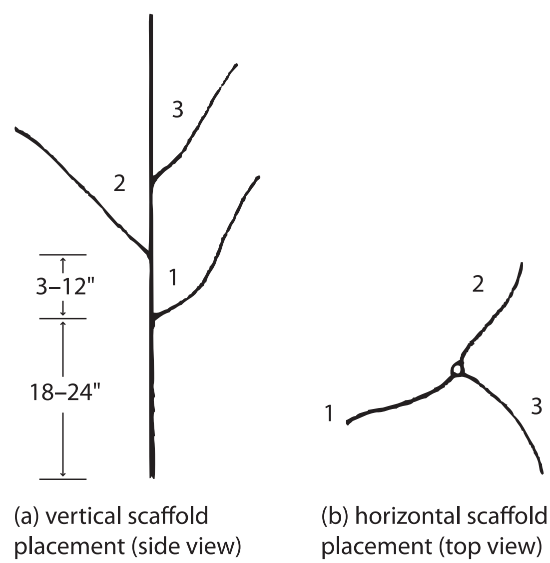


Figure 17.13. Selecting well-spaced scaffolds. Scaffolds should be spaced 3–12 inches apart vertically (a) and as equally as possible around the trunk (b).

Spread or remove limbs with crotch angles of less than 35°. In early summer, while shoots are soft, it's easy to spread limbs. Place a clothespin or short piece of wood with a notch in one end between the trunk and the shoot. Use the notch to push the shoot outward. Weigh down the shoot with a light weight, such as a fishing weight. Remove undesirably located shoots at this time.

First Dormant Season

If you haven't yet selected shoots to retain as scaffolds, do so now. Spread selected scaffolds before doing any pruning, since spreading changes the shape of the tree and may influence pruning decisions. Next, remove shoots that you didn't select as scaffolds. Head the central leader to maintain dominance and induce branching; cut it back three to five inches above the point where you want the next tier of scaffolds.

Scaffolds usually do not need to be headed; generally shoots branch naturally in their second season (Figure 17.14). All you need to do is spread the scaffolds to encourage uniform branching. However, a scaffold often exhibits excess vigor and upsets the balance of a tree's growth, in which case you should head it to shorten and stiffen it. You also can use heading cuts to encourage growth and branching on spur-type trees.

Second Growing Season

Limbs not previously trained can be spread easily early in the growing season, when wood is flexible. Remove fruit developing on the central leader to maintain vigor in the tree's center. Select and train the new tier of scaffold limbs, choosing limbs that are well spaced in relation to lower scaffolds.

Second Dormant Season

Again, spread scaffolds before pruning. Some of the first-year scaffolds may have turned upward and resumed vertical growth. Use longer spreaders to spread them back to the desired orientation. Move the smaller spreaders farther up into the tree. Head the central leader to maintain vigor and stimulate branching.

Succeeding Years

Continue training and pruning following the principles of central leader dominance and proper scaffold selection and training. Keep scaffolds at a 60° angle from vertical.

Maintain a conical tree shape, with upper branches shorter than lower ones. Always prune the top portion of the tree more heavily than the lower. After the third year, you can shorten upper scaffolds with thinning cuts (Figure 17.15), which remove an entire shoot or branch at its junction with a lateral scaffold or trunk. Thinning cuts are less invigorating than heading cuts. They also improve light penetration and can redirect a limb's growth.

Remove crossing branches, vigorous water sprouts, shoots growing up into the tree, and shaded hanging branches.

Once the tree is as tall as you want, cut it back each year to a weak lateral on the central leader (Figure 17.16). This practice maintains vigor in the center top of the tree while maintaining desired tree height.

Bearing Apple Trees

Mature apple trees often need to be pruned vigorously to encourage new growth of fruiting wood. To bear fruit, spurs must be at least two years old. After several years of production, however, they lose vigor.

Good fruiting wood requires both moderate vigor and exposure to good light.

Fruiting may be poor if vigor is too high or too low. Too-high vigor can be the result of inadequate fertilization, no pruning, excessive cropping, or shading of fruiting wood. Too-low vigor can be because the bearing wood is shaded, which can result in small, poorly colored fruits.

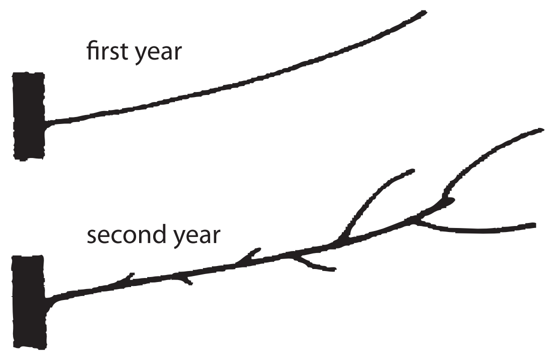


Figure 17.14. Natural branching of a shoot.

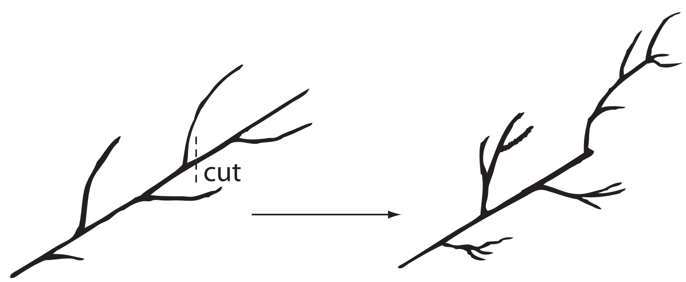


Figure 17.15. Shorten limbs with thinning cuts.

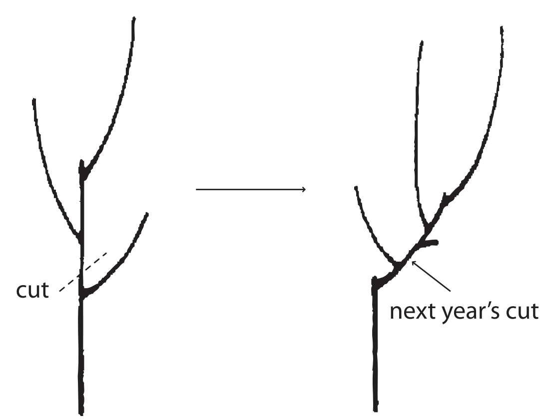


Figure 17.16. Prune to a lateral to maintain height.

Good light exposure is necessary for development of flower buds as well as fruit of optimum size, color, and sugar content.

A typical tree canopy is composed of different layers or zones in terms of light exposure (Figure 17.17):

- The outside zone of leaves and fruit (a), which receives a high proportion of direct light. This zone receives more light than needed for good growth and fruiting.
- The middle zone (b), which receives adequate light
- The inner zone (c), which receives inadequate light and is unproductive

The relative proportion of these zones is influenced by tree size and shape. As tree size increases, the percentage of the tree that is shaded and unproductive increases (Figure 17.18). Trees with wide tops and narrow bottoms also have a high percentage of shaded area (Figure 17.19).

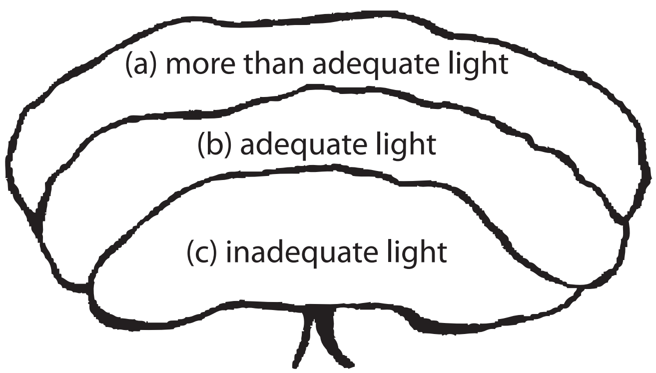


Figure 17.17. Light distribution zones in a large apple tree.

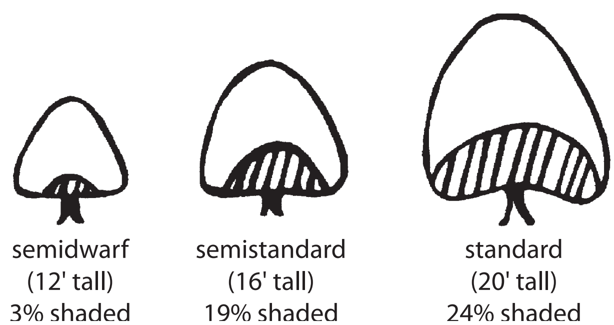


Figure 17.18. The shaded area increases as tree size increases.

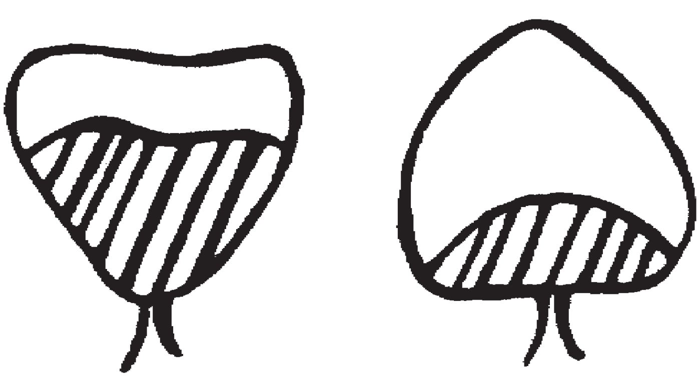


Figure 17.19. Tree shape influences shaded areas.

Use thinning cuts to maintain good light exposure in the canopy. Make moderate cuts throughout the tree to distribute vigor and provide good light penetration. Use heading cuts only where branching is desired or vigor is low.

Another problem with overly dense trees is that spray penetration is reduced and problems such as scale may develop in the dense areas. In this situation, make many thinning cuts throughout the tree, especially in the upper, outer portions. This procedure will open up the tree canopy and reestablish good tree shape.

When pruning mature trees, also remove the following:

- Drooping or low-hanging branches (or prune them to a lateral that is positioned above horizontal—see Figure 17.20)
- Crossed, dead, diseased, or damaged limbs
- Water sprouts, unless some are needed to develop new fruiting wood

Keep the following precautions in mind when pruning bearing trees:

- Avoid pruning terminal shoots back to horizontal branches (often called a bench cut, Figure 17.21). Such cuts result in weak limbs and an umbrella shape that encourages water sprouts.

Figure 17.20. Thin out low-hanging branches.

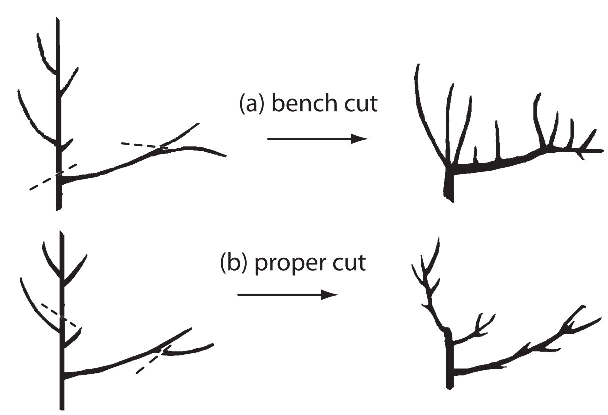


Figure 17.21. Bench cuts (a) and proper cuts (b).

- Remove no more than one or two large limbs per year. If a lot of pruning is required, spread the process over a two- or three-year period. In the one or two years before and after heavy pruning, reduce or eliminate nitrogen application, depending on soil type, tree variety, and your experience.
- The excessive vigor that can result from severe pruning can decrease fruit quality. The effect is much the same as from excessive nitrogen application. It may include excessively large, poorly colored, soft apples that do not store well. Vegetative growth competes with fruit for calcium; thus, under conditions of excessive vigor, cork spot or bitter pit may develop due to calcium deficiency in the fruit.
- Use heading cuts only to maintain tree size when trees are at or near the desired size. Such pruning often is used in an attempt to reduce tree size, but misuse of this technique can disrupt vigor and reduce yield so much that it takes several years for the tree to recover. Heading, especially of one-year-old shoots, induces masses of shoots to grow close to the cuts. These abundant shoots can shade and weaken inner areas of the tree.
- Invigoration from pruning is, in part, a nitrogen response. Pruning alters the balance between the treetop and root system. Removing part of the treetop increases the amount of nitrogen available for the remaining growing points. Always combine a pruning program with a good fertilization program.

Pear Trees

Train pears to have multiple leaders with three to five main scaffold branches. Avoid excessive pruning of young trees, except to stimulate scaffold development.

When trees are mature, use thinning cuts to improve light penetration. Do the heaviest pruning in the treetop. Remove upper horizontal branches so they won't shade the rest of the tree or produce excess water sprouts.

Do not head back trees after their framework has been developed. Doing so encourages the tree to sprout soft terminal shoots, which are highly susceptible to fire blight.

Peach and Nectarine Trees

To train young trees in a vase shape, head back young peach or nectarine trees to 18 to 30 inches at planting time, depending on how much room you want under the tree. Choose two or three scaffold branches evenly spaced around the tree. Head the selected scaffolds to three to six inches and remove all other side shoots (Figure 17.22a). In the first summer, pinch unwanted shoots in order to direct most of the growth into the scaffolds.

In the first dormant season, head the scaffolds 24 to 30 inches away from the trunk (Figure 17.22b). The result will be stiff scaffolds with strong secondary limbs. Thin all vigorous shoots that compete with the secondary scaffolds.

During the second dormant season, select three or four secondary scaffold limbs 12 to 18 inches above the primary scaffolds (Figure 17.22c).

In the third dormant season, thin the fruiting wood. Keep the more outward-growing wood for better sunlight penetration.

Once the scaffold system is established, prune as little as possible until the tree begins to bear. Remove all strong, upright shoots growing in the center of the tree, and lightly head back terminal growth on the scaffolds to outward-growing laterals. The result will be an open-center (vase-shaped) tree (Figure 17.23).

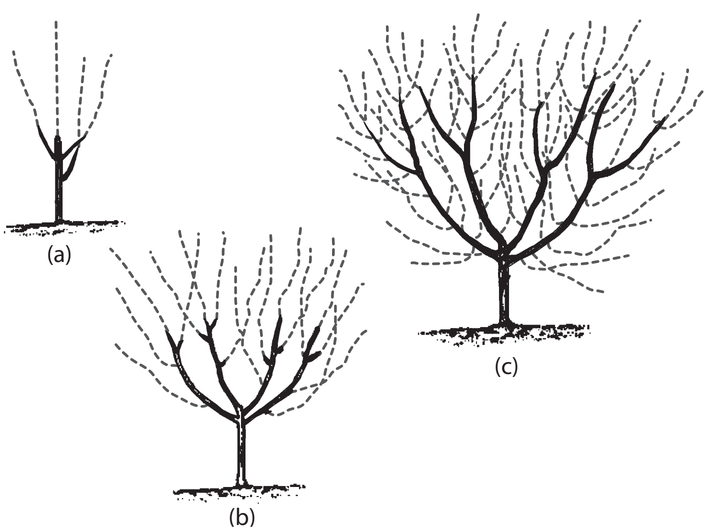


Figure 17.22. Pruning to a vase shape: (a) At planting time, head the tree about 18 to 30 inches above ground. Choose two or three scaffold branches and head the selected scaffolds to three to six inches. (b) In the first dormant season, head the scaffolds 24 to 30 inches away from the trunk. Thin all vigorous shoots that compete with the secondary scaffolds. (c) During the second dormant season, select three or four secondary scaffold limbs 12 to 18 inches above the primary scaffolds.

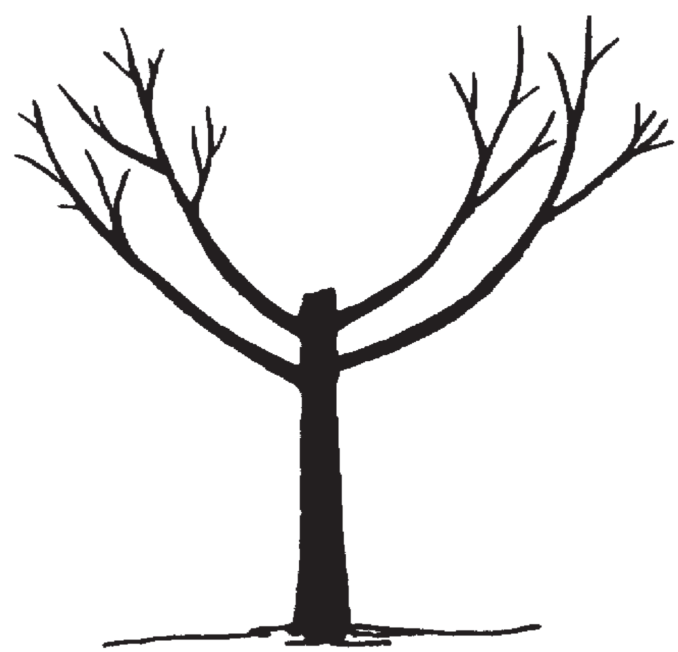


Figure 17.23. A vase-shape tree has an open center and outward-growing branches.

Pruning Bearing Trees

Peach and nectarine trees bear fruit on the previous season's wood. Yearly pruning ensures good fruit production.

During the dormant season, prune to counteract the tendency of fruiting wood to move away from the trunk in an upward and outward direction. The procedure is as follows:

- Remove shoots that fruited the previous year.
- Cut back to shoots of moderate vigor.
- Remove strong-growing shoots in the treetop by thinning them to more upright shoots.
- Thin out the weakest shoots.
- Leave shoots well spaced for good light penetration.
- Prune out dead and diseased wood, particularly that with cankers or severe oozing. (Peach and nectarine trees are notorious for their susceptibility to disease.)

In mid to late summer, head back the upper, outer shoots in order to allow better light distribution throughout the tree. Again, prune out dead or diseased wood.

Plum Trees

To train trees into a vase shape, head plum trees at 18 to 24 inches at planting. The following year, select three or four main shoots to be scaffold limbs. If the scaffold crotch angles are narrow, spread them to 45° to 60° using clothespins or wooden sticks with notches in the ends. Remove the rest of the shoots with thinning cuts, then head the selected scaffolds at 2 to 2½ feet from the crotch to stimulate branching into secondary scaffolds.

In the third dormant season, thin third-year scaffolds to one or two per secondary scaffold. In Japanese plums, thin interior shoots to spread the tree.

Pruning Bearing Trees

Prune European prune trees to lighten the ends of heavily bearing branches to prevent breakage. Cut back annual shoot growth, being careful not to cut away long-lived fruiting spurs. These trees bear on one-year-old shoots as well as older ones.

Fruiting limbs tend to arch under the fruit load. Water sprouts arise from the upper side of these limbs. To renew fruiting wood, cut back to the arch and thin water sprouts. Those sprouts remaining will become fruiting wood.

On Japanese plum trees, thin one-year-old shoots, but leave enough to renew fruiting wood. Thin out a few branches that have old, weak spurs.

Cherry Trees

Sweet

Train sweet cherry trees to the modified leader system recommended for apple trees. Give special attention to selecting scaffold limbs with wide crotch angles. Sweet cherry trees are subject to winter injury, often splitting where limbs join the main stem. It is essential to develop crotch angles as widely as possible to ensure a strong framework.

When planting a cherry tree, head the tree about 18 to 24 inches above the ground. Head all shoots to 24 to 36 inches after the first and second year's growth. Remove the terminal buds of short shoots in order to promote branching (Figure 17.24). In the third and fourth years, head the most vigorous shoots.

When the tree begins to bear fruit, remove all but seven or eight scaffold branches. Head all shoots in the dormant season to develop a low, spreading tree that is easy to manage.

Established trees require minimal pruning. Lightly thin out new shoots and cut out weak wood and interfering branches.

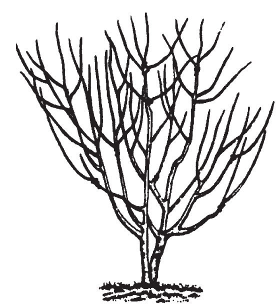
Sour

If a sour cherry tree has no strong branches at the time of planting, head it to about 24 inches above the ground. Select laterals when growth begins the second year.

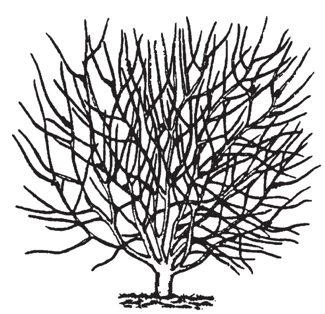
If the tree has some good laterals when planted, remove those lower than 16 inches from the ground. Select about three permanent scaffold limbs along the leader, four to six inches apart and not directly above one another. Do not head them back, since doing so tends to stunt terminal growth.

In following years, select side branches until there are five or six scaffold limbs well distributed along three to four feet of the main stem above the lowest branch. Then modify the leader by cutting to an outward-growing lateral.

After fruiting begins, pruning consists mainly of annually thinning out excessive and crowded growth to allow sunlight into the tree and renew fruiting wood. Sour cherries bear mostly on two- to five-year-old spurs.



(a) untrained



(b) properly trained

Figure 17.24. Training a cherry tree: (a) Without proper training, this sweet cherry tree is too tall and sparsely branched. (b) Heading all shoots of a young sweet cherry tree produces more branches and a lower tree.

Shrubs

Prune both evergreen and deciduous shrubs in late winter before new growth starts. Minor corrective pruning can be done at any time. Specific pruning situations are discussed below.

Deciduous

When deciduous shrubs are planted bare-root, some pruning may be necessary. Lightly prune roots if any are broken, damaged, or dead. Prune branches by thinning (not shearing) to reduce overall plant size by one-half or more.

Balled and burlapped (B&B) or container shrubs require little if any pruning. Occasionally, branches are damaged in transit; remove them at the time of planting. Prune only to develop desired size and shape.

Pruning for most mature deciduous shrubs consists of thinning, gradual renewal, and rejuvenation.

Thinning cuts are used to maintain a shrub's desired height and width (Figure 17.25). Thin out the oldest and tallest stems first. Use hand pruning shears, loppers, or a saw rather than hedge shears.

Gradual-renewal pruning involves annually cutting a few of the oldest and tallest branches back to slightly above ground level (Figure 17.26). Some thinning may be necessary to shorten long branches or maintain a symmetrical shape.

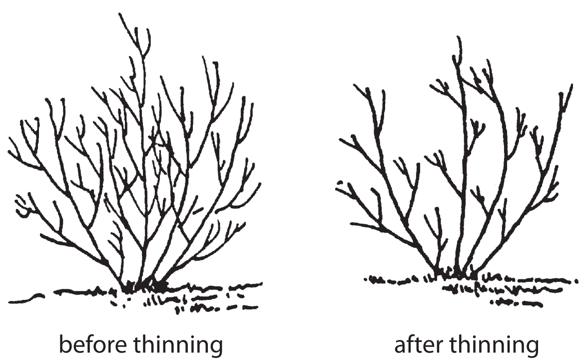


Figure 17.25. Thinning a shrub.

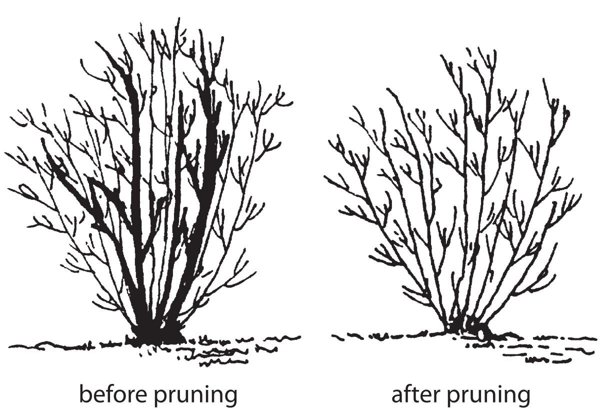


Figure 17.26. Gradual renewal of a shrub. (Dark branches in left-hand illustration are removed.)

To rejuvenate an old, overgrown shrub, remove one-third of the oldest, tallest branches at or slightly above ground level before new growth starts.

Time pruning of flowering shrubs to minimize disruption of blooming. Spring-flowering shrubs bloom on last season's growth (Table 17.1). Prune them soon after they bloom so there is time for vigorous summer growth, which provides flower buds for the following year. Some shrubs that bloom after June do so from buds that are formed on that spring's shoots (Table 17.2). Prune these shrubs in late winter to promote vigorous spring shoot growth.

Table 17.1. Shrubs that bloom on last season's growth.

Botanical name	Common name
Cercis chinensis	Chinese redbud
Chaenomeles japonica	Japanese quince
Chionanthus virginicus	Fringe tree
Daphne spp.	Daphne
Deutzia spp.	Spring-flowering deutzia
Exochorda racemosa	Pearlbush
Forsythia spp.	Forsythia
Kerria japonica	Kerria
Lonicera spp.	Honeysuckle
Magnolia stellata	Star magnolia
Philadelphus spp.	Mockorange
Pieris spp.	Andromeda
Rhododendron spp.	Azalea and rhododendron
Rosa spp.	Rambling rose
Spiraea spp.	Early white spirea
Syringa spp.	Lilac
Viburnum spp.	Viburnum
Weigela florida	Old-fashioned weigela

Table 17.2. Shrubs that bloom on the current season's growth.

Botanical name	Common name
Abelia x *grandiflora*	Glossy abelia
Buddleia davidii or *globosa*	Butterfly bush
Callicarpa japonica	Japanese beauty bush
Caryopteris x *clandonensis*	Bluebeard
Ficus carica	Fig
Hibiscus syriacus	Shrub althea
Hydrangea arborescens	Hills of snow
Hydrangea paniculata	Peegee hydrangea
Hypericum spp.	St. Johnswort
Lagerstroemia indica	Crape myrtle
Rosa spp.	Bush rose
Spiraea bumalda	Anthony Waterer spirea
Spiraea japonica	Mikado spirea
Symphoricarpos	Coralberry and snowberry
Vitex agnus-castus	Chaste tree

Evergreen

Most evergreen trees and shrubs are sold B&B or in a container. Unlike deciduous shrubs, they require little pruning at planting time.

Thinning out is the best way to prune most mature evergreen shrubs. Some evergreens can be sheared to achieve a stiff, formal appearance. However, you'll still need to thin them occasionally.

Hedges

Hedges are plants set in a row so they merge into a solid linear mass. They have been used for centuries as screens, fences, walls, and edgings. A well-shaped hedge is no accident. It must be trained from the beginning.

Establishment of a deciduous hedge begins with the selection of nursery stock. Choose young trees or shrubs one to two feet high, preferably with multiple stems. Cut the plants back to six to eight inches to induce low branching. Late in the first season or before bud break in the second, prune off half the new growth. The following year, again trim off half.

In the third year, start shaping. Trim to the desired shape before the hedge grows to the desired size. Once it reaches its mature size, it will be too late to achieve maximum branching at the base. Do not let lower branches be shaded out; trim so the base of the hedge is wider than the top (Figure 17.27). After the hedge reaches the desired dimensions, trim frequently in order to maintain its size.

Evergreen nursery stock for hedging need not be as small as deciduous material and should not be cut back when planted. Trim lightly after a year or two. Start shaping as the individual plants merge into a continuous hedge. Do not trim too closely, because many needle-bearing evergreens do not easily generate new growth from old wood.

Hedges often are shaped with flat tops and vertical sides and are sometimes conical in shape (Figure 17.28a and b). This unnatural shaping seldom is successful. The best shape, as far as the plant is concerned, is a natural form—a rounded or slightly pointed top with sides slanting to a wide base (Figure 17.28c and d). This shape aids in shedding snow, which otherwise can break branches. Also, by trimming the top more narrowly than the bottom, you enable sunlight to reach all of the leaves.

Before shaping a hedge, think about the plants' natural shape. E.g., common buckthorn, a spreading plant, is easily shaped to a Roman arch (Figure 17.28c). Naturally conical arborvitae does particularly well in a Gothic arch shape (Figure 17.28d).

Two questions often arise: "How often should this hedge be trimmed?" and "When should I trim?" Answers depend on the kind of shrub, the growing season, and the degree of neatness you desire.

In general, trim before new growth begins to shade lower leaves. Trim slow-growing plants such as boxwood when new growth is more than three or four inches long. Yews, for example, may need shearing only once annually. Shear faster growing evergreens before new growth exceeds a foot. Laurel and photinia may need to be sheared every four to six weeks during spring and early summer.

What can be done with a large, overgrown, bare-bottomed, and misshapen hedge? If it is deciduous, the answer is fairly simple. In spring, before leaves appear, prune to one foot below the desired height. Then trim carefully for the next few years to give it the shape and fullness desired. Occasionally, hedge plants in very poor shape do not recover from this treatment and must be replaced.

Rejuvenating evergreen hedges is more difficult. As a rule, evergreens cannot stand severe pruning. Arborvitae and yew are exceptions. Other evergreen hedges may have to be replaced.

Tools

Traditional scissor-action hedge shears are the best all-around tool for trimming hedges. They cut much better and closer than electric trimmers, which often break and tear twigs. Electric trimmers do poorly on large-leafed and wiry-twigged varieties, and sometimes jam on thick twigs, but hand shears work on any type of hedge. Hand shears also are quieter and less likely to gouge the hedge or injure the operator.

Hand pruners are useful for removing a few stray branches and are essential if you want an informal look. Use loppers and/or a pruning saw to remove large individual branches. Chainsaws are not recommended for use on hedges.

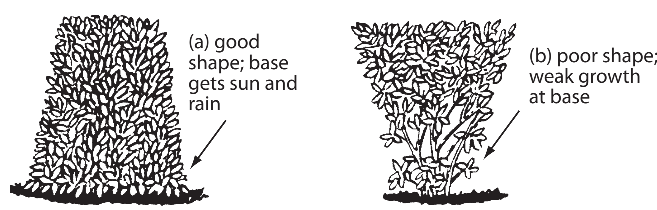


Figure 17.27. Correct (a) and incorrect (b) hedge pruning.

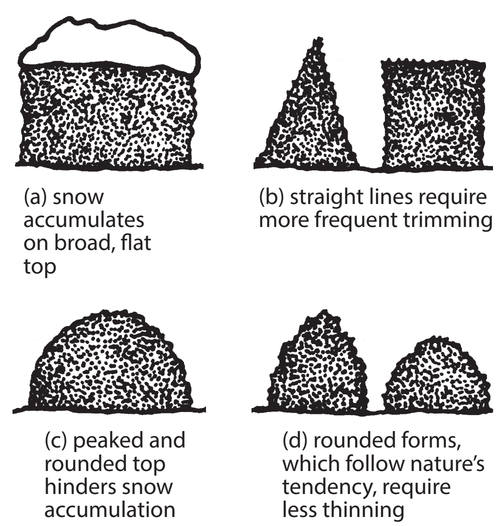


Figure 17.28. Improper (a and b) and proper (c and d) hedge shapes.

Rose Bushes

All rose bushes need some type of pruning. If they are not pruned for several years, they deteriorate in appearance, often develop more than the usual disease and insect problems, and produce smaller and smaller flowers. Proper pruning encourages new growth from the base, makes the plant healthy and attractive, and results in large blossoms.

Hybrid tea, grandiflora, and floribunda roses require annual pruning in the spring after winter protection is removed. As a guideline, prune roses when the forsythia blooms. If you prune too early, frost injury may make a second pruning necessary.

For small pruning jobs, the only tools necessary are sharp hand-pruning shears and gloves. Use loppers to reach in and cut out large, dead canes. A small saw with a pointed blade can also be helpful.

Remove all dead and diseased wood by cutting at least one inch below the damaged area. Remove all weak shoots and those growing toward the center. If two branches rub or are close enough that they will rub soon, remove one of them. On old, heavy bushes, cut out one or two of the oldest canes each year.

Cut back the remaining healthy canes. The height to which a rose should be cut depends on the cultivar. The average pruning height for floribundas and hybrid teas is between 12 and 18 inches, but taller growing hybrid teas and most grandifloras may be left at two feet.

Make cuts at a 45° angle above a strong outer bud (Figure 17.29). Aim the cut upward from the inner side of the bush to push growth outward and promote healthy shoots and quality flowers.

Some types of roses have special pruning considerations, as discussed below.

Standard or Tree Roses

A tree rose is a hybrid tea, grandiflora, or floribunda budded at the top of a tall trunk. Prune tree roses like hybrid teas, cutting the branches to within six to 10 inches of the base of the budded top in order to encourage rounded, compact, vigorous new growth.

Miniature Roses

Miniatures are six to 12 inches high, with tiny blooms and foliage. They do not need special pruning. Cut out dead, diseased, and weak growth and remove the hips.

Ramblers

Old-fashioned rambler roses have clusters of flowers, each usually less than two inches across. They often produce pliable canes 10 to 15 feet long in one season. Ramblers produce best on one-year-old wood, so this year's choice blooms come on last year's growth. Prune immediately after flowering. Remove some of the large, old canes. Tie new canes to a support for the next year.

Figure 17.29. Proper pruning angle (a) and improper angles (b).

Large-flowering Climbers

Climbing roses have large flowers, more than two inches across, borne on wood that is two or more years old. Canes are larger and sturdier than those of ramblers. Some flower only once in June, but some, called everblooming climbers, flower more or less continuously throughout the summer.

Prune these roses in autumn, any time before cold weather sets in. First cut out dead and diseased canes. Next, remove one or two of the oldest canes at ground level to make room for new canes. Shorten laterals (side shoots) by three to six inches after flowering. If the plant is strong, keep five to eight main canes and tie them to a trellis, fence, wall, or other support. If the canes are not strong, keep only a few.

Vines and Groundcovers

Pruning procedures for ornamental vines are similar to those for ornamental shrubs. Be sure to prune flowering vines at the right time. Prune those that flower on new wood before growth begins in spring. Prune those that flower on last season's growth immediately after flowering.

Prune vines that are grown for foliage to control growth and direction. Timing is less critical than for flowering vines.

Groundcover plants require very little pruning. Remove dead or damaged stems whenever you notice them. Some trailing groundcovers, such as English ivy, may need pruning to prevent encroachment on lawn areas or other plants. The appearance of St. Johnswort, a woody, yellow-flowered groundcover, is improved by trimming it back every three or four years in early spring. For large plantings, a lawn mower set to cut three to four inches above the crowns makes fast work of this job.

For More Information

See the following publications from the UK Cooperative Extension Service:
Pruning Landscape Trees (HO-45)
Pruning Landscape Shrubs (HO-59)

Chapter 18

Annual and Perennial Flowers

By Mary Robson, retired Extension agent, King and Pierce counties, Washington State University. Adapted for Kentucky by Sharon Bale, floriculture extension specialist (ret.) and Richard Durham, consumer horticulture Extension specialist and state Master Gardener coordinator, University of Kentucky.

In this chapter:

Can you imagine a world without flowers? Their textures, colors, scents, and forms inspire gardeners, artists, and writers. The desire to grow flowers often motivates novices to take up gardening and moves experienced gardeners to become flower specialists. Annuals, biennials, and herbaceous perennials offer variety and interest to all styles of gardens.

Not so long ago, flowers often were separated from other parts of the garden. Masses of colorful annuals filled park and home display beds only in summer. Herbaceous perennials, laid out in long borders, demanded intense management without providing year-round interest. Since the 1980s, however, American garden design has moved away from flower displays that are attractive for only a few months, and gardeners now plan landscapes for all seasons. In today's smaller gardens, often entirely visible from inside the home, combinations of evergreen and deciduous shrubs, conifers, and perennial flowers keep the scene fascinating year-round. Gardens often include spring-flowering bulbs, containers of annual flowers, herbs for cooking or tea, and grasses for winter texture.

Plants in contemporary gardens are selected not only for their flowers but for multiseason characteristics, such as leaf form, foliage texture, and color. Flowers remain important, but the gardening world is taking advantage of new possibilities offered by an enormous range of ornamental herbaceous plants. These include annuals, biennials, perennials, and bulbs.

Types of Herbaceous Ornamental Plants

Annuals

Annuals live briefly. They germinate, grow, bloom, and go to seed in one year. Because they die at the end of this cycle, they must be replanted the following season.

Many annuals come up on their own from the previous year's seeds. Some, such as California poppies (*Eschscholzia californica*) and bachelor's buttons (*Centaurea cyanus*), can become weedy by reappearing from seed so prolifically. Whether or not this characteristic is desirable depends on your garden's style. Informally designed cottage-style gardens gain from self-seeded plants, but formal gardens, which require precise balance and layout, do not, and volunteer annuals must be removed.

Colorful, long-blooming, and easy to grow, annuals offer much to gardens. They often produce flowers or decorative leaves steadily from early summer until they set seed or are killed by frost. Annuals are particularly useful for colorful window boxes, container plantings, hanging baskets, and school or youth gardens. Their quick growth from seeds or transplants is gratifying for young gardeners.

Some cool-season annuals such as pansies (*Viola wittrockiana*) and ornamental kale (*Brassica* spp.) can be planted in fall to replace summer annuals in containers, window boxes, and gardens. Table 18.1 lists the height and bloom color of common annuals.

Biennials

Biennials often confuse gardeners. They require two full years to complete their growth cycle and die after the second year. The first year, they grow foliage and roots but do not flower. The second year, they flower and go to seed. Their garden uses are closer to those of annuals than perennials, but many are cherished components of perennial gardens.

Some biennials are spectacularly showy because the inflorescence (flower stalk) can be huge, as on the gray-leafed *Verbascum olympicum*, which reaches eight or nine feet tall. Foxgloves (*Digitalis purpurea*), forget-me-nots (*Myosotis sylvatica*), and hollyhocks (*Alcea rosea*) are common biennials.

Provide undisturbed space for biennial plants, because they require a summer growing season and winter rest before flowering. Many biennials need winter protection in cold climates. Some gardeners start biennials in a nursery bed and move them to permanent positions in their second year when they are ready to flower.

Know how to identify the first-year leaves (the vegetative stage) to avoid pulling the plants as weeds before their second-year flowering period.

In some cases, newer cultivars of some biennials have been bred to produce blooms the first season. Hollyhock 'Queeny Purple' and digitalis 'Camelot' are just two examples. When choosing a plant, be sure to read the information about that particular cultivar.

Table 18.1. Height and bloom color of common annuals.

Plant	Height (inches)	Bloom color
African daisy	6–12	White, yellow, salmon
Ageratum	4–24	Blue, white
Amaranthus	48–96	Red, red and green
Arctotis	24	White with bluish eye
Aster *(Callistephus chinensis)*	18	Yellow, pinkish red, blue, white, lavender
Bacopa	6–10	White, blue
Balsam *(Impatiens balsamina)*	12–18	Rose, purple, white
Basil, purple (foliage)	15	Red-purple foliage
Begonia	6–12	Pink, red, white
Browallia	8–12	Blue, violet, white
Calendula	12–24	Yellow, gold, orange
Cabbage, flowering	8–14	Red to white
Calilbrachoa	6–12	Various
Castor bean (foliage)	72–96	Red, inconspicuous flowers
Capsicum	6–24	Red, orange, purple fruit
Cockscomb *(Celosia)*	18–36	Blue, red, yellow, orange
Cornflower *(Centaurea cyanus)*	36	Pink, blue, white
Coleus (foliage)	8–20	Variegated foliage
Cosmos sulphureus	18–24	Red, orange, yellow
Cosmos bipinnatus	48+	White, lavender
Dusty miller *(Artemisia stelleriana)*	24	Silvery foliage, yellow flowers
Evolvulus 'Blue Daze'	6–10	Blue
Fan flower *(Scaevola aemula)*	6–8	Blue, white
Forget-me-not *(Myosotis)*	12	Blue, pink
Four o'clock *(Mirabilis)*	24	Pink, white, yellow
Gaillardia pulchella	15–24	Yellow, orange, red
Geranium	12–18	pink, red, white, salmon, lavender
Gomphrena	12–36	Lavender, purple, red, white
Heliotrope	10	Rose
Impatiens	8–24	Red, pink, white, orange
Lantana	12–36	Red, yellow, white, lavender
Licorice plant	6–10	Grey, lime-green
Lobelia	4–18	Blue, violet, white, pink
Mandevilla	Vine	Pink
Marigold (Tagetes)	8 - 48	Yellow, orange to red-brown
Melampodium	24	Yellow
Mimulus	12–30	Yellow, red
Nicotiana	24–48	Red, pink, white
Nigella	12–15	White, blue, violet
Pansy (Viola)	8–12	Blue, purple, white, yellow
Petunia	6–12	White to rose, purple
Portulaca	8	Yellow, white, rose, orange
Salvia	18–36	Blue, red, white
Salvia farinacea (mealycup sage)	14–18	Blue, white
Snapdragon *(Antirrhinum)*	6–18	Blue, purple, yellow, orange, red
Statice, *(Limonium) sinuatum*	18–24	Yellow, rose, violet, white
Strawflower *(Helichrysum)*	36	White, red, yellow
Sunflower *(Helianthus)*	12–108	Yellow to red-brown
Sweet alyssum *(Alyssum maritimum)*	3–10	White, purple
Sweet potato vine	vine	Green, purple
Tithonia	48	Orange
Torenia	12	White, blue, violet
Verbena	8–24	White, pink, blue, red
Vinca	8–12	White, lavender, pink
Zinnia	6–36	Red, pink, yellow, orange, white, lime green

Perennials

Unlike annuals and biennials, perennial plants live year after year. Trees and shrubs are woody perennials. Mature garden, park, and arboretum landscapes often are composed mostly of woody perennial plants.

Many familiar garden flowers are perennials, such as peonies (*Paeonia* spp.) and Shasta daisies (*Leucanthemum maximum*). These plants are called herbaceous because they do not form permanent woody branch structures as do shrubs and trees.

Hardy perennials live through winter in the ground, reviving from their crowns in spring. They send up new shoots, often through the remains of the previous year's dead stems, leaves, and flowers. Some perennials, such as peonies *(Paeonia* spp.), may survive for decades, long outliving the gardener who planted them. Some may only live a few years in the garden, if at all. It is very important to choose perennials that are appropriate for the location's hardiness zone and general climate conditions. Some hardy perennials may live for several years in this area and then mysteriously die when no obvious disease or insect problem is apparent. This type of death is often attributed to the "weather." When we have wide temperature fluctuations during the winter, the hardiness of the plant may be affected.

Tender perennials won't survive outdoor winter conditions even with protection. They must be lifted before frost, stored, and replanted after danger of freezing weather passes. Dahlias, gladiolus, and tuberous begonias are just some examples.

How a perennial is classified depends on the climate zone the plant is being grown in. For example, a lantana is an annual

Table 18.2. Bloom season, height, and bloom color of common perennials.*

Botanical name	Common name	Height (inches)	Color
Late winter, spring			
Chionodoxa luciliae	glory-of-the-snow	4	blue
Crocus (species and hybrids)	crocus	4	various
Endymion hispanicus	Spanish bluebell	12-15	blue, white
Eranthis hyemalis	winter aconite	3	yellow
Galanthus nivalis	common snowdrop	6-12	white
Helleborus (species and hybrids)	Lenten rose	15-18	various
Hyacinthus orientalis	hyacinth	12-14	various
Iberis sempervirens	candytuft	3-6	white
Iris danfordiae	danford iris	4-6	yellow
Leucojum vernum	spring snowflake	10-12	white
Mertensia virginica	Virginia bluebells	12-14	blue
Muscari armeniacum	grape hyacinth	6-8	blue
Narcissus pseudonarcissus	narcissus, daffodil	varies	various
Scilla siberica	Siberian squill	3-6	blue
Tulipa (species and hybrids)	tulip	varies	various
Late spring, early summer			
Achillea filipendulina	fern-leaf yarrow	24-36	yellow
Amsonia tabernaemontana	amsonia	12-36	blue
Aquilegia (hybrids)	columbine	varies	various
Aurinia saxatilis	basket-of-gold	12	yellow
Armeria maritima	common thrift	6-12	pink
Astilbe arendsii	astilbe	24-36	various
Baptisia australis	false indigo	36-48	blue
Brunnera macrophylla	heartleaf brummera	12-18	blue
Campanula glomerata	clustered bellflower	12-18	blue, purple
Convallaria majalis	lily of the valley	10-12	white, pink
Dianthus barbatus	sweet William	10-18	various
Dianthus gratianopolitanus	cheddar pink	9-12	rose, pink
Dicentra spectabilis	common bleeding heart	18-24	pink
Galium odoratum	sweet woodruff	4-9	white
Heucherella tiarelloides	foamy bells	15-24	pink
Hemerocallis (hybrids)	daylily	varies	various
Iris (hybrids)	tall bearded iris	12-24	various
Iris sibirica	Siberian iris	24-36	various
Leucanthemum x superbum	shasta daisy	18-24	white
Paeonia suffruticosa	tree peony	varies	various
Paeonia (hybrids)	peony	varies	various
Papaver orientale	Oriental poppy	18-36	various
Phlox subulata	moss phlox	6-9	various
Summer			
Achillea millefolium	common yarrow	12-18	various
Asclepias tuberosa	butterfly weed	24-36	orange
Coreopsis grandiflora	tickseed	12-24	yellow
Coreopsis verticillata	thread leaf coreopsis	18-36	yellow
Echinacea purpurea	purple coneflower	24-36	purple, various
Echinops ritro	globe thistle	12-36	blue
Heliopsis helianthoides	sunflower heliopsis	36-48	yellow, orange
Heuchera sanguinea	coral bells	12-18	red
Hosta (species, hybrids)	hosta	6-36	purple, white
Liatris spicata	spike gayfeather	24-36	mauve
Limonium latifolium	sea lavender	24-30	lavender
Iris kaempferi	Japanese iris	34-30	various
Lilium (species, hybrids)	lily	varies	various
Perovskia atriplicifolia	Russian sage	48+	blue
Phlox paniculata	garden phlox	36-48	various
Rudbeckia fulgida	orange coneflower	18-30	yellow
Late summer and early fall			
Anemone x hybrida	Japanese anemone	24-36	white, pink
Aster novae-angliae	New England aster	48+	violet, purple
Aster novi-belgii	Michaelmas daisy	12-48+	violet
Eupatorium purpureum	Joe-Pye weed	48+	purple
Sedum spectabile	showy stonecrop	12-24	pink
Tricyrtis hirta	common toad-lily	24-36	lilac

*Bloom times are only an estimate, because location and spring temperatures can cause plants to bloom earlier or later than expected.

in Kentucky. In southern Florida, it has become an invasive perennial. When purchasing perennials, look for those plants that are hardy in Zone 6 or less. Some parts of Kentucky are Zone 7, but plants that are labeled as Zone 7b may have some hardiness problems.

Using Herbaceous Perennials in Garden Design

Because perennials reappear year after year, they have advantages over annuals. The plants can fill space rapidly if grown in proper conditions. Many reach their mature size several years after planting, expanding gradually into large, showy clumps. There are hundreds of different perennials, each with a distinct texture, color, scent, and form, which makes choosing plants an intriguing adventure.

Most perennials bloom for a fairly short time, from one to three weeks, although some, such as coreopsis (*Coreopsis verticillata*), can bloom persistently for as long as six weeks. Careful perennial plant selection can provide garden interest from early spring to frost and even through winter.

Italian arum (*Arum italicum*) is an example of a plant that produces winter interest. The foliage appears in late fall and persists over the winter. The bright orange-red berries that are produced on strong stems also provide color well into the winter.

Successful flower gardening depends, as does any other aspect of gardening, on understanding your site's characteristics and matching them to the needs of individual plants. Annual and perennial flowers have been hybridized for centuries, chosen from wild plants originating in bogs, sunny prairies, alpine meadows, woodland shade, and many other growing conditions. Understand your garden environment before selecting herbaceous plants. Analyze the hours of daylight, soil texture, drainage, water availability, and winter frost conditions. Choose plants that have cultural needs matching your garden's characteristics.

For a low-maintenance perennial garden, consider several basic plant characteristics:

- Is the plant long-lived (lasting at least four seasons)?
- Does it grow strongly but not overwhelm other plants?
- Will it have a long bloom time?
- Is it attractive when out of bloom?
- Is it generally pest-resistant?

Peonies (*Paeonia* spp.), purple coneflower (*Echinacea purpurea*), and Autumn Joy sedum (*Sedum spectabile* 'Autumn Joy') are among the many herbaceous perennials that meet these criteria.

Garden design (which should be based on harmonious color patterns), bloom throughout the seasons, and intriguing year-round texture depend on the gardener's taste. Because herbaceous plants are used intensively in modern gardens, many books have excellent suggestions on how to design with them. Visiting gardens and nurseries and keeping an idea notebook also will help you develop design confidence and improve your garden choices.

Table 18.2 lists perennials by season of bloom and gives their height and bloom color. Figure 18.1 illustrates how plants can be arranged according to height, while Figure 18.2 shows arrangement by season of bloom. Figure 18.3 is an example of a garden design that combines perennial and annual flowers with a variety of bloom seasons, colors, heights, and textures.

Selecting Plants

Select annual and perennial plants for the best possible growth qualities. The popularity of flower gardening encourages plant hybridizers and growers to offer improved plants with more vigor, larger flowers, longer bloom periods, and more attractive leaves. For instance, pansies have been selected for color and form, production of pink flowers, orange/purple combinations (*Viola wittrockiana* 'Jolly Joker'), and diminutive yellow forms, as well as the familiar, large, purple-whiskered faces.

When a design specifies a particular plant, look for cultivars that may have improved characteristics over the parent plant. Often this means seeking a named variety rather than simply a straight species. Association garden sales, specialty nurseries, mail-order catalogs, and knowledgeable local gardeners are good sources for extraordinary plants.

Soil Preparation

If you follow some sensible basic steps when installing a new garden, you'll have good results. For perennial gardens, soil preparation is a key to strong future growth. Later applications of fertilizer can't compensate for poorly prepared soil.

First, get rid of weeds, especially perennials such as quackgrass, dandelions, morning glory, and thistles. Then dig thoroughly, loosening the soil to at least 12 inches. (Double-digging often is recommended for herbaceous perennial gardens. This process involves digging 20 to 24 inches deep, loosening the soil, and moving the top layer down about one shovel's depth.

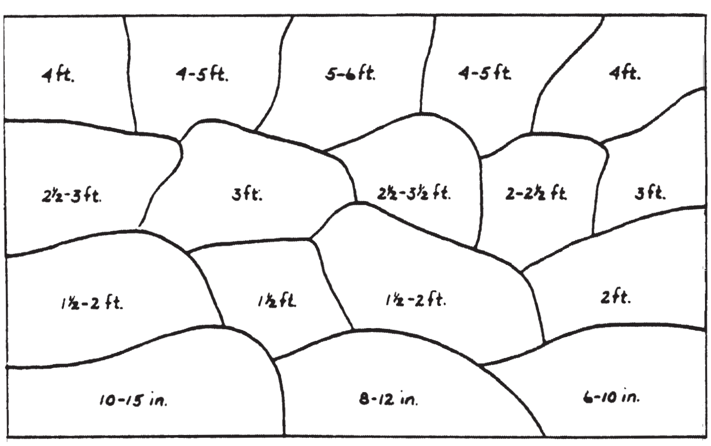


Figure 18.1. Flower border divided into bold plant groupings according to height. Background: large groups of tall plants. Foreground: shallower, wider groupings of small plants.

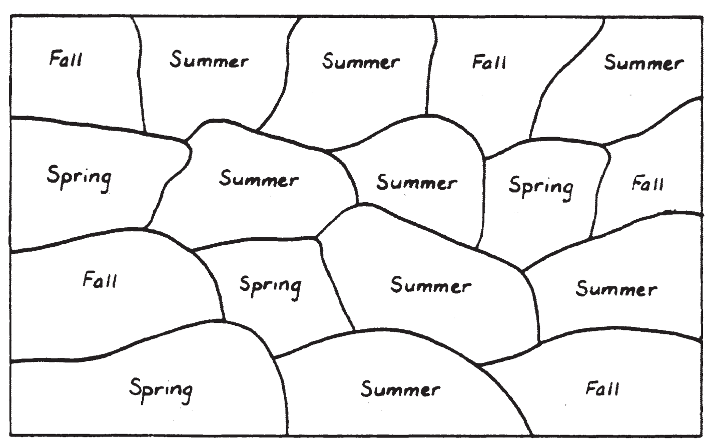
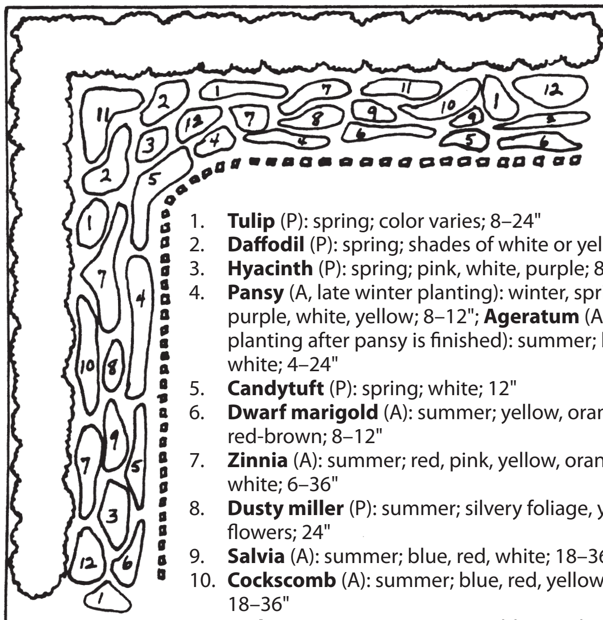


Figure 18.2. Flower border designed for continuous bloom from spring through fall.



1. **Tulip** (P): spring; color varies; 8–24"
2. **Daffodil** (P): spring; shades of white or yellow; 8–24"
3. **Hyacinth** (P): spring; pink, white, purple; 8–12"
4. **Pansy** (A, late winter planting): winter, spring; blue, purple, white, yellow; 8–12"; **Ageratum** (A, June planting after pansy is finished): summer; blue, white; 4–24"
5. **Candytuft** (P): spring; white; 12"
6. **Dwarf marigold** (A): summer; yellow, orange to red-brown; 8–12"
7. **Zinnia** (A): summer; red, pink, yellow, orange, white; 6–36"
8. **Dusty miller** (P): summer; silvery foliage, yellow flowers; 24"
9. **Salvia** (A): summer; blue, red, white; 18–36"
10. **Cockscomb** (A): summer; blue, red, yellow, orange; 18–36"
11. **Larkspur** (A): spring, summer; blue, pink, white; 18–36"
12. **Globe amaranth** (A): summer; white, pink, purple; 15–30"

Figure 18.3. Sample perennial/annual bed with a mix of bloom seasons, flower colors, and heights. In spring, blocks 1, 2, 3, 4, and 5 will bloom. In summer, blocks 4, 6, 7, 8, 9, 10, 11, and 12 will bloom. A=Annual; P=Perennial.

This practice increases air and nutrients available to roots and can produce a fine garden site capable of sustaining plants for many years.)

Spread three to four inches of organic material across the soil surface and dig it in well. This addition will help increase the soil's water-holding capacity and improve root penetration and aeration. Commercial compost, homemade compost, chopped or composted leaves, composted sawdust, fine bark, and composted manure make good amendments.

Recognize that many perennials form large, heavy root structures, which can rot if the site isn't well-drained, particularly if there is a high water table in winter. If you face this situation, improve drainage or choose plants suitable for damp conditions (for instance, cardinal flower [*Lobelia cardinalis*]).

Soil testing is helpful when starting a garden on an unfamiliar site or when expanding an existing garden. Many herbaceous perennials grow well in slightly acid soil, but some need supplemental lime if the soil pH is below 6.0. A soil test will provide a recommendation for adjusting the pH if it is required. Generally, sulphur can be added to lower the pH and lime can be added to increase the pH.

Propagation

Annuals and biennials

These flowers generally are started from seed or are purchased as small plants. Many annual seeds can be sown directly in the garden. For annuals that are hard to transplant, such as Shirley poppies (*Papaver rhoeas*), direct seeding is necessary. When choosing flowers for children's gardens, seeds such as nasturtiums (*Tropaeolum majus*) and sunflowers (*Helianthus annuus*), which sprout quickly and are large enough to handle, inspire satisfaction.

Many other annuals and biennials do best if started in a propagation bed or tray and then transplanted as small plants. Marigolds (*Tagetes* spp.), violas and pansies (*Viola* spp.), and snapdragons (*Antirrhinum majus*) transplant well. Start seedlings indoors four to six weeks before they will be planted in the garden. Provide ample light, using auxiliary light if necessary, to grow stocky, healthy transplants. Beware of starting seedlings too early; they grow poorly if left too long in low light and crowded indoor conditions.

Buying seedlings from nurseries is very convenient, especially for annuals with very fine seeds, notably petunias, impatiens, and fibrous begonias. Unless you have excellent propagation facilities, plants are difficult to grow from fine seed.

Perennials

Perennials grow more slowly than annuals, and many do not bloom the first year, although some will. You can start them from seed in a nursery bed and transplant them to a final location when they are sturdy enough. Often they are ready to transplant late in their first season.

Keep in mind that starting perennials from seed can be a slow process and may require waiting several years before any blooms appear. The cost of purchasing perennials is often directly related to the number of years the plant has been in production. While some of the newer cultivars of certain perennials have been bred to produce blooms the first season from seeding, others require several years of growth before any blooms will be produced.

Division—As herbaceous perennials develop established root systems, they spread into large clumps, so many can be propagated by division.

Divide perennials as part of your general garden maintenance, because growth and performance decrease when plants get crowded. Centers die out on many plants, such as Siberian iris (*Iris siberica*). Division rejuvenates plants and results in extra plants to share with friends or donate to plant sales.

The proper time to divide perennials depends on the particular plant. In general divide fall-blooming plants such as aster (*Aster* spp.) in very early spring. Spring bloomers such as iris (*Iris* spp.) can be divided in late summer or early fall.

Select vigorous shoots from the outer part of a clump. Discard the center. Divide the plant into several sections of three to five shoots each. Make large divisions, because small pieces will not bloom much the first year after planting. Before replanting, add compost or other organic materials to the soil.

Cuttings—Many plants can be propagated from either tip or root cuttings. Generally, tip cuttings are easier to grow than root cuttings.

Take two- to six-inch-long tip cuttings from perennials such as candytuft (*Iberis sempervirens*) or lavender (*Lavandula angustifolia* and others). Remove all foliage from the lower one-third of the cutting. Insert cuttings in a clean planting mix such as one-half sharp sand and one-half peat moss.

Professional growers supply bottom heat and provide moisture through automatic misting systems that keep cuttings moist while roots form. If you don't have these systems, rooting will be slower and require more care, but you still can be successful. Cover cuttings with a sheet of clear plastic to retain moisture. Support the plastic to keep it from touching the foliage. Place the cuttings in a light area but out of direct sun. In direct sun, high temperatures can build up under the plastic on warm days and can kill cuttings.

When cuttings resist a slight tug, they have begun to root. The plants then start to take up water and nutrients. Poke holes in the plastic to provide more air circulation to the rooting plants, gradually adding holes as more roots grow. When the plants have formed good root balls, transplant them to a nursery bed or container and begin fertilizing.

Root cuttings also work to propagate some plants, such as Oriental poppies (*Papaver orientalis*), phlox (*Phlox paniculata*), and baby's breath (*Gypsophila paniculata*). Dig plants in late summer after they have bloomed and are going dormant. Choose pencil-sized roots and cut them into four-inch sections. Shoots will not appear until the following growing season.

Flower Garden Maintenance

Regular, planned maintenance keeps plants healthy and a garden looking attractive.

Fertilizing

Annuals need regular fertilizing. Well-prepared soil and organic mulch help make nutrients available to plants, but annuals grow so rapidly that supplemental fertilizer helps. When planting, incorporate about five pounds per 100 square feet of 5–10–5 or 5–10–10 fertilizer. Then fertilize at regular intervals, about every three weeks. Don't add fertilizer to dry soil; be sure to water before and after fertilizing.

When planting a new perennial garden, add about five pounds of 5–10–5 or 5–10–10 per 100 square feet and dig it in thoroughly before planting. Fertilize established herbaceous perennials as they start growth each year. Perennial plants that bloom in late summer or fall, such as asters, need regular fertilization before bloom, so feed them monthly until September. Perennials such as peonies that complete their bloom and growth by June do not need fertilizer in midsummer. In general, two light applications of fertilizer per year are sufficient for supplying extra nutrients if soil conditions are good. Always water after applying fertilizer.

Weeding

Keep annuals and perennials free of weeds. A combination of hand weeding and mulch is effective. Weed regularly to prevent seeds from becoming established. Herbaceous plants shade out some weeds when mature but require extra vigilance while they are too small to compete.

Use herbicides with great care in herbaceous plantings, if at all. Always read the label of any herbicide before using. The label will list plants that will not be damaged as well as list those plants that may be severely damaged by that particular chemical. Use them only around woody plants established in the landscape for more than six months.

It's best to remove annual weeds at the seedling stage by hoeing lightly, avoiding the roots of desired plants. You can spot-treat persistent perennial weeds such as morningglory with a postemergent herbicide such as glyphosate (sold as Roundup and many other trade names), but take great care to keep herbicides off the leaves of all desirable plants.

Watering

Most annuals need regular water because they don't make deep root systems. However, some annuals, such as cosmos (*Cosmos bipinnatus*), tolerate summer dry spells.

Do not allow herbaceous perennials to dry out in their first season. Many tolerate dry soils once established, however. Interest in water conservation causes many gardeners to choose plants that need little supplemental water. Plants such as artemisia, echinacea, Jerusalem sage (*Phlomis* spp.), and santolina use only moderate amounts of water.

To use water efficiently, group plants according to water needs. Till the soil deeply and amend it with compost or other organic material.

When you water, use efficient methods such as soaker hoses or drip irrigation systems, and apply water slowly and deeply.

Mulching

Organic mulch is useful in perennial and annual flower beds. Use compost (commercial or homemade), composted sawdust, chopped or composted leaves, or other materials for mulching.

Two applications of mulch each year are helpful. Apply two to three inches in spring after weeding and fertilizing to retain soil moisture, suppress annual weed seeds, and improve the bed's appearance. Apply mulch again in late fall. As it breaks down over winter, this material will provide some winter protection and weed suppression.

Do not cover a perennial plant's crown (the central growing area above the roots) with winter mulch, but do bring it up to the edge of the crown. In cold locations, you can cover the entire plant after the soil freezes or after several freezing nights. If you cover plants too soon, they may begin to grow under the mulch and may be killed by severe cold. Evergreen boughs make a good mulch, particularly in cold winter areas.

Pull mulch off plants in early spring when weather warms, allowing new growth to emerge.

Staking

Many tall herbaceous flowering plants must be tied to stakes or provided with another support system, especially in windy and exposed areas. Dahlias, for example, may require support. Wind, rain, or the weight of foliage and blossoms will bend or break these plants' stems and ruin the display. Broken stems also can lead to disease problems.

Many short perennials such as peonies require support to keep flower heads upright. A plant that flops over onto adjoining plants will smother its neighbors and destroy a garden's attractiveness.

Commercial systems such as grates with legs work fine, but you also can improvise supports from bamboo stakes, twigs, or branches. Choose staking material that is about six inches shorter than the plants' ultimate height.

Whatever method you use, put support systems in place while plants are small and tie plants loosely to the stake as they grow (Figure 18.4). Rapid growth will hide the stake, wires, or strings.

Deadheading and Disbudding

Regular maintenance for annuals includes removing flowers before they go to seed. This process is called deadheading. By preventing seed formation, you can extend the bloom period on many plants, such as pansies, marigolds, and petunias.

Deadheading not only might prolong the bloom period, but it improves a garden's appearance. Some early summer-blooming perennials such as certain daylilies (*Hemerocallis* spp.) produce a second flush of flowers in fall if stems are cut to the ground after bloom and before seeds set. In other cases, however, seeds may be part of the garden show. Gladwin iris (*Iris foetidissima*), for example, is grown for its showy seed pods.

Plants such as dahlias produce larger flowers if disbudded. A stalk may have five or six buds; to disbud, snap off all but one on each stem.

Fall Cleanup

Late fall maintenance generally includes cutting back dead stems of herbaceous perennials and pulling out annuals after they are killed by frost. Some gardeners leave seed heads for birds. Goldfinches love cosmos seeds, and chickadees eat sunflower seeds right off the plants if squirrels don't get them first. The seeds of many perennials, such as purple coneflower (*Echinacea purpurea*), attract birds in late summer and fall.

Pest Management

All flower gardens eventually have some pests or diseases. Learn to use the principles of integrated pest management and concentrate on growing healthy plants. Strong plants resist disease and insect problems better than weak ones. To reduce disease infestations and cut down on hiding places for insects and other pests such as slugs, space plants properly to allow good air circulation, clean up litter and dead leaves, and control weeds.

Several diseases commonly affect annuals, bulbs, and herbaceous perennials. Powdery mildew (a fungus) attacks peonies, zinnias, roses, pansies, and many other flowering plants, producing a gray, fuzzy coating on leaves and blossoms. Tulips, lilies, and peonies contract botrytis, which affects buds and stems and destroys flowering. Pruning out diseased plant parts can help control this disease.

Whenever possible, choose disease-resistant cultivars. Check with nurseries for new cultivars of phlox and bee balm (*Monarda*) with powdery mildew resistance.

Some insects damage a wide variety of plants. For example, aphids suck juices from many flowering plants. Learn the life cycles of garden pests so that you can protect beneficial predators and minimize use of broad-spectrum insecticides. Aphids, for example, have many natural enemies, including lady beetles, lacewings, wasps, and birds.

Slugs and snails attack tender shoots of bulbs, lilies, and young transplants and are often a problem where hostas are planted. Hand picking and selective use of baits can help you manage slugs. Place baits in traps rather than broadcasting them.

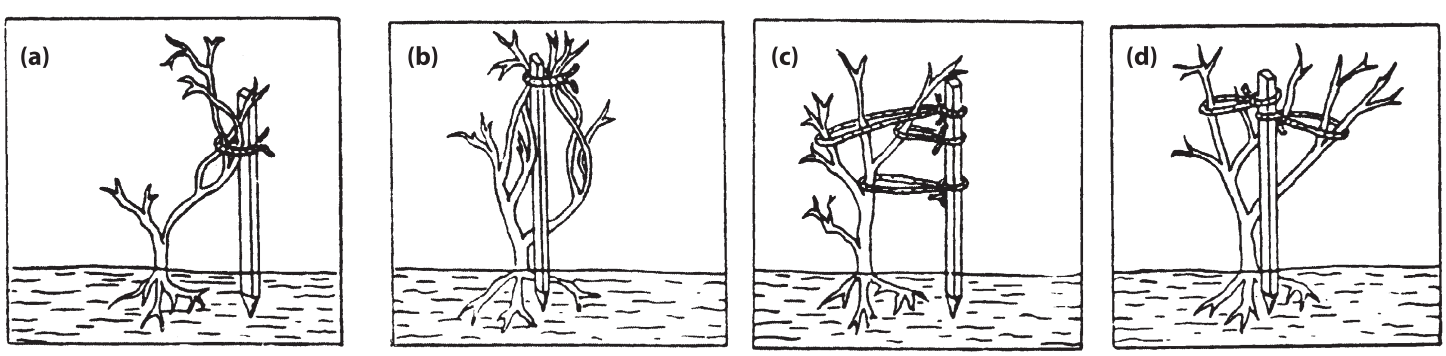


Figure 18.4. Staking plants: In (a) and (b), plants are tied too tightly. In (c) and (d), principal branches are tied loosely, which is better.

Consult relevant publications and experts for specific controls. Make sure you have properly identified the problem before applying any control.

Bulbs, Corms, Rhizomes, Tubers, and Tuberous Roots

Many garden plants are classified botanically as bulbs, corms, rhizomes, tubers, or tuberous roots. All of these have underground organs that store food for the plant. Many, such as hyacinths, tulips, and crocuses, can survive for a time without soil around their roots, which enables them to be stored and shipped easily. Figure 18.5 illustrates flowers of several types of bulbs and corms.

Bulbs are composed of a thin, flattened stem surrounded by fleshy, dried leaf bases called scales. Roots grow from a basal plate. Onions, garlic, narcissus, tulips, and lilies are examples of plants that form bulbs. Slicing an onion vertically and observing the interior gives a good look at a bulb's anatomy.

Corms have solid interiors, developed from swollen stems. If you cut one, you see a homogenous mass inside. Roots form at the base. Some examples of plants that form corms are crocus, watsonia, and gladiolus.

Tubers are swollen, modified, underground stems. They don't have basal plates where the roots originate. Tubers come in various shapes and include caladium.

Tuberous roots are composed of root tissue. Dahlias and tuberous begonias are examples of plants with tuberous roots.

Rhizomes are specialized stems that grow horizontally at or just below the soil surface. German iris, lily-of-the-valley, and bamboo have rhizomes.

Gardeners often lump these different botanical structures under one heading, calling them all "bulbs." This loose classification works for general purposes, but the distinctions between the types make a difference in how each is propagated and stored.

Like other herbaceous ornamentals, bulbs, corms, and tubers are classified as hardy or tender. Most hardy bulbs and corms are planted in fall for early spring bloom. Crocuses, narcissus, tulips, hyacinths, and grape hyacinths define spring for many people. Lilies, which bloom in early or midsummer, may be planted in fall or early spring.

Tender bulbs, tubers, and corms generally bloom in mid-to-late summer. Examples are dahlias, tuberous begonias, and gladiolus. Plant them when the ground warms after the last frost. To keep these plants for more than one season, dig them up in the fall and store them in a frost-free location.

Selection and Storage

Choose solid, healthy plants. With lilies, tulips, and narcissus, larger bulbs yield larger blossoms. Some bargain bulbs are not worth the price, no matter how inexpensive, because they are too small to bloom well.

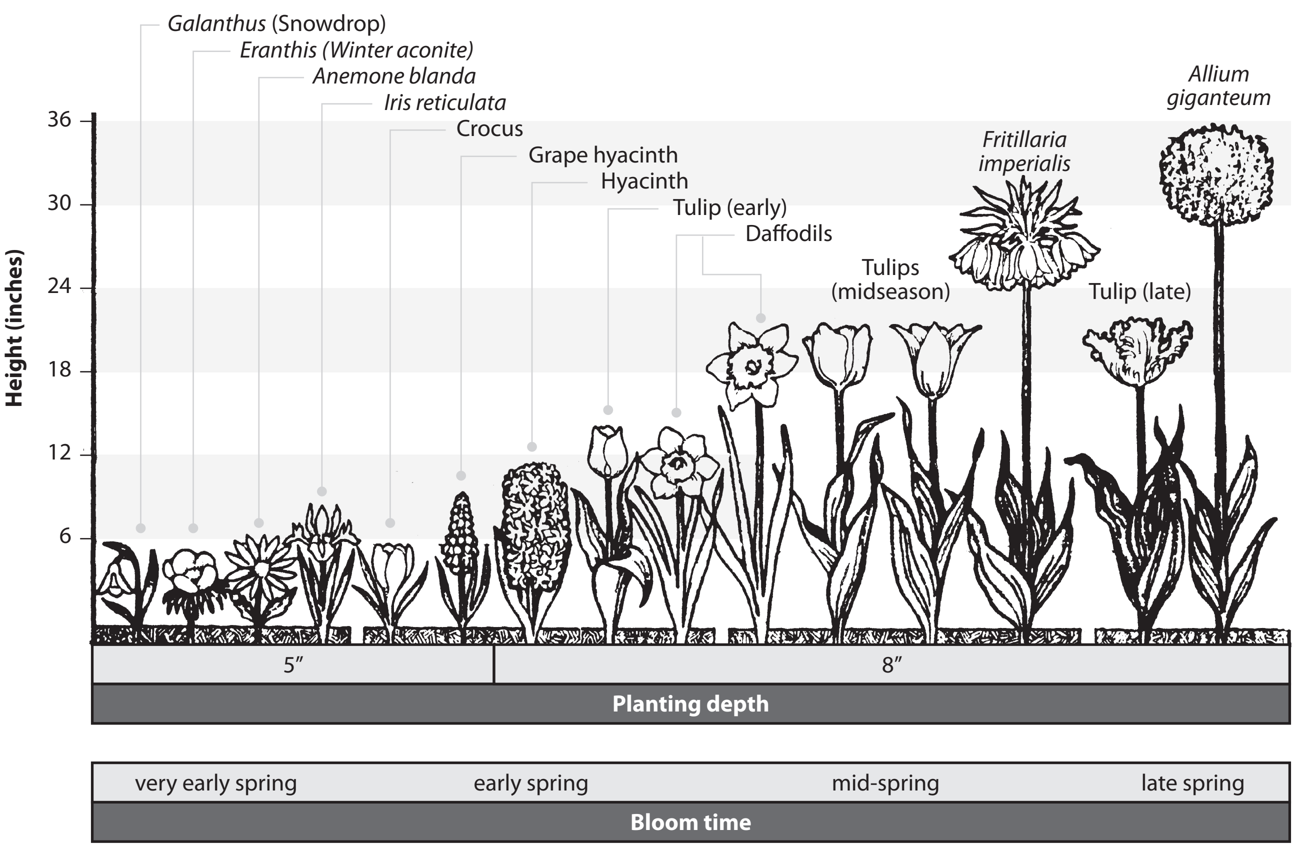


Figure 18.5. Bulbs and corms offer a variety of blossoms.

Purchase hardy bulbs in the fall. Don't leave bulbs in a hot car trunk while shopping; the plants may be damaged or killed. If you can't plant bulbs immediately, keep them cool and dry. Temperatures below 65°F are best for storage. Use paper sacks rather than plastic bags, since mold may develop if moisture accumulates inside the package.

After digging plants such as dahlias and cannas in the fall, store them in slightly damp peat or perlite. Do not let them completely dry out; check them regularly and dampen them if necessary.

Site Preparation and Planting

Drainage is vital for most bulbs, corms, tubers, rhizomes, and tuberous roots. With a few exceptions, such as Japanese iris (*Iris ensata*), they rot in wet soil. Snowdrops (*Galanthus nivalis*), crocuses, narcissus, tulips, and lilies must have excellent drainage. If your garden site drains poorly, place bulbs in containers or raised beds.

Dig the soil as for annual or perennial flowers and add organic amendments such as compost. Remove all perennial weeds before planting, and watch for emerging annual weed seedlings after planting.

When planting, excavate the planting area, place fertilizer below the root level, and mix it thoroughly with soil. Slow-release fertilizers or general 5–10–10 formulations work well for fall-planted bulbs. Do not place bulbs directly on fertilizer.

Don't plant bulbs and tubers in dry soil; roots cannot begin to grow without moisture. If the soil is very dry during fall planting, dig a hole for the bulbs, fill it with water, and allow it to drain before planting.

Planting depth depends on soil conditions. Kentucky Extension publications or local nurseries can give you specific suggestions. Many growers suggest planting about three times the depth of the bulb.

Shallow-planted bulbs may frost-heave and are easily dug out by rodents, which munch on them. To prevent rodent damage, plant them in a hardware cloth "cage."

Mulch hardy bulb and corm plantings lightly with two to four inches of composted leaves, shredded fir bark, or composted sawdust. Keep mulches open and light enough to allow shoots to emerge in spring.

Watering and Fertilizing

After planting, be sure to water the planting bed thoroughly and continue to water during periods of dry weather in the fall. Fall-planted bulbs begin to produce a root system, and lack of water may severely damage the bulbs.

Fertilize spring bloomers when they are about an inch tall, using a 5–10–10 granular formula or a liquid fertilizer. In dry areas, water spring-blooming bulbs after flowering ends. Let the leaves wither naturally and don't pull them out until they are brown. Move spring-blooming bulbs and corms only after all foliage has ripened (usually in late summer).

Specialized Herbaceous Flower Gardens

Specialized herbaceous flower gardens include container plantings, bog gardens, and water gardens.

Container Plantings

Almost all gardeners have some form of container plantings, often in addition to other types of gardens. Containers allow even those with limited space such as a rooftop, balcony, or front stoop to have vigorous gardens.

The potting material contributes vitally to the success of container plants. Plant roots must get sufficient air. If the soil is too dense, it packs down, contributing to root rot or other difficulties. Be sure to use a potting material that contains sufficient gritty particles in the form of pumice, perlite, or vermiculite. Garden soil doesn't work well in containers because watering packs it and reduces available oxygen.

Choose a container suited to the plant's eventual size, and be sure it has sufficient drainage holes in the bottom. Scrub pots well. Do not add a layer of gravel or other material to the bottom of the pot; this practice actually reduces drainage. Fill the clean pot full of potting soil.

You can reuse potting mixes year after year unless the plants in them were seriously diseased. Before replanting, dump the mix out of the pot, aerate it, and add new grit if necessary.

Annuals grown in containers will require more frequent fertilization. Regular watering will leach the initially applied nutrients from the soil. Follow the package directions for slow-release fertilizers. An additional application may be necessary midway through the growing season. If water-soluble fertilizers are being applied, follow the label recommendations for how frequently this should be applied. Remember, plants grown in containers will require regular watering. When watering plants, be sure to water thoroughly and then allow the plants to dry out before watering again. Smaller containers such as hanging baskets may require watering twice a day to maintain vigor during the heat of the summer. Generally, the larger the container, the less frequently it will need to be watered.

Bog and Water Gardens

Small fountains, pools, and other water features are increasingly popular in gardens. Many herbaceous perennials adapt well to water gardening. A pool can be surrounded with Japanese iris (*Iris ensata*), ligularia (*Ligularia dentata*), rodgersia (*Rodgersia podophylla*), and adapted native plants. A barrel with a fountain bubbler can hold water lilies, many of which are winter-hardy, even in cold climates.

Some gardeners place a simple, shallow bowl of water in the garden to reflect the sky. Water features also attract wildlife, especially birds.

For More Information

UK Extension Publications

Annual Flowers (HO-65)
Perennials for Sunny Locations (HO-76)
Perennials for Shady Locations (HO-77)
Spring, Summer, and Fall Bulbs (HO-80)

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Chapter 19

Indoor Plants

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In this chapter:

Cultivating plants inside the home is both a popular hobby and an interior decorating technique. More than 75 percent of all American families use living plants as part of their home decor or cultural expression.

To keep plants healthy and attractive, you must control a number of environmental factors such as light, temperature, humidity, water, and plant nutrients. The right combination results in healthy plants. Too much or too little of any factor results in poor plant health or death.

A houseplant is simply an outdoor plant that is grown indoors. Not all plants are suitable for indoor culture. Some require environmental conditions that are impossible to duplicate indoors. Others adapt to indoor culture if their minimum growth requirements are provided. The key to successful indoor plant culture is to select plants that are adaptable to the conditions in your home.

The normal home provides a number of different environments. Light varies from sunny windows to dim corners. Plants in living areas receive long hours of light (either natural or artificial) year-round, but those in bedrooms normally receive only minimal supplemental light. Humidity usually is much higher in kitchens and bathrooms than in living rooms. Temperatures vary widely. The overall climate may range from humid subtropical to arid desert in various locations.

Management

The environmental factors of light, temperature, and humidity are to a large extent determined by how you manage your home environment for family comfort. Other environmental factors, such as water and nutrient availability, can be managed solely for your plants' sake. By selecting the best site for each plant and managing the supply of water and nutrients, it is possible to grow most common houseplants in any home.

Each plant has its own set of desired environmental conditions. There are many sources of information for specific cultural requirements. Check with the store that supplied the plant or with local county Extension agents. Houseplant books (there are hundreds, many available at libraries) and garden encyclopedias (also available at libraries) are also a source of information.

In general, a plant needs an environment as similar as possible to that in which it grows naturally. Understory plants (those that live on the forest floor) can grow in diffuse light. Plants from deserts or other open environments require strong light. Tropical and subtropical species generally do best in humid conditions, and desert species require arid conditions. Cool-climate species prefer cool nights and warm days, while tropical species prefer warm temperatures at all times. Learn about the specific plants you are growing (or plan to acquire) and place them in a location that provides the best combination of environmental factors for their needs.

Cultivating houseplants is enjoyable and rewarding. The basic culture is not difficult, and most plants require only a few minutes of attention each week once their basic environmental requirements are satisfied. They do, however, require this minimal care on a regular basis. Plants are living things and must be managed so that their life-support systems function properly at all times. The following sections discuss several important aspects of plant care.

Light

Perhaps the major environmental factor limiting plant growth indoors is lack of adequate light. As natural light enters homes, it decreases very quickly. For example, a plant one foot away from a window may receive 100 foot-candles of light. If it is moved two feet away from the window, it will receive only 25 foot-candles of light. At three feet it receives only 11 foot-candles, and very few, if any, houseplants do well at such low light intensities.

The most expedient method of adjusting light intensity is to move the plant closer to or farther from a light source such as a window. Unfortunately, this may place the plant in an inconvenient spot.

To increase light intensity, you can try these measures:

- Move the plant to a lighter room (southern versus northern exposure).
- Place the plant near an electric light.
- Provide separate artificial light for the plant.
- Provide reflected light with a light-colored wall or mirror.
- Keep leaves free of dust and grime.

To reduce light intensity, you can take these steps:

- Place a lace curtain between the plant and window.
- Use venetian blinds to intercept and divert direct sunlight.
- Reduce reflected light with a dark backdrop.
- Shade the plant with another plant.
- Move the plant back from a strong light source (for example, a south-facing window).

Temperature

Home temperatures are adjusted for the comfort of people, but temperatures vary considerably in most homes. Bedrooms usually are cooler than bathrooms or living areas. Southern-exposure rooms usually are warmer during the day than northern-exposure rooms. Fortunately, most plants tolerate a fairly broad range of temperatures and thrive at normal home temperatures if other environmental factors are satisfactory.

Humidity

Many plants require a more humid climate than the average home. Ferns, ivies, and other humid-climate plants may grow best in bathrooms or kitchens, where the air usually is more humid. You can increase relative humidity around a plant by placing its pot on a shallow tray of moist gravel (Figure 19.1a). The gravel will evaporate water into the air around the plants.

Damp sphagnum moss packed between pots in planters also evaporates water into the air (Figure 19.1b). Moss has the added advantage of acting like a wick to draw up and dispose of excess water in the bottom of the planter box.

Grouping plants together in the same room raises the relative humidity for all. Plants transpire (emit moisture) water continuously. The more plants you grow, the more water they transpire into the air.

A humidifier is another way to raise humidity. The higher relative humidity that plants prefer also is healthier for people.

Misting plants does not significantly increase humidity. It may, however, help keep leaves clean, which also is desirable.

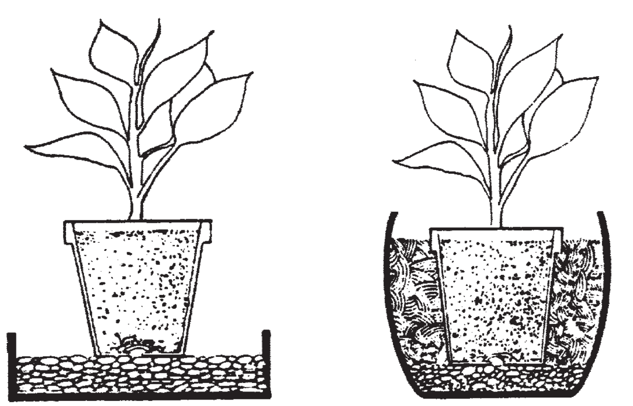

Figure 19.1. Two ways to increase humidity around a plant: (a) A layer of moist gravel or pebbles in a tray beneath the pot and (b) a pot inside a large planter filled with moistened sphagnum peat moss.

Water

Watering is the most important (and most often abused) cultural practice. Plants must have a continuous and adequate supply of water, but they can absorb water from the soil only under certain conditions.

First, there must be available water in the soil. Soil particles hold some water too firmly for plants to take up. The water available to plants is water in excess of that required to satisfy the soil itself. The quantity and type of soil mix will determine how much water the pot retains for plant use.

Second, some air must be in the soil for plant roots to function and absorb water. Therefore, the soil must not contain so much water that no room is left for air. A good potting soil will not hold too much water if a hole in the bottom of the container allows excess water to drain away.

The difference between these two extremes (no available water versus saturated soil) is called the available water supply. Proper water management avoids both extremes and maintains a supply of available water at all times.

The following guidelines may help you establish a satisfactory watering schedule:

- Use a well-prepared potting soil to assure good water-retention capacity as well as space for air.
- Make sure containers have at least one drainage hole so excess water can drain away.
- When watering, apply enough water to run out the drainage hole. This usually assures that you have replenished the available water supply and also reduces salt buildup.
- Do not let pots sit in excess water. Pour it away or raise pots so they always are above the level of drained-out water in the saucer.
- Do not water on a time schedule. Allow the soil to become dry on the surface before you water again. This method maintains a good balance of air and water in the soil.
- If some plants require frequent watering, move them into slightly larger pots (with greater water-holding capacity).
- Some plants, such as desert cacti and succulents, should be watered only a little, if at all, during the short days of winter. With the exception of seedlings and very young plants, these plants need no water from about mid-November to mid-March. Most cacti and many succulents are best kept bone-dry and quite cool during the winter.
- Highly organic soils are difficult to rewet once they dry out. They also tend to shrink away from container sides. This can allow water to run between the soil and the inside of the pot without ever moistening the soil. If this happens, submerge the entire pot in water until the medium is fully moistened.
- Flush soluble salts from pots on a regular basis, about every six months. Water three times at 30-minute intervals to wash salts out the drainage hole.
- Keep these additional factors in mind when watering:
- Chlorine in tap water will not harm plants.

Table 19.1.—Houseplant problem symptoms, possible causes, and treatments.

Symptoms (What You See)	Possible Causes	Treatment (Corrective Action)
Plants are spindly, and stems grow abnormally long. Leaves lack color, are undersized, and may fall off.	Too little light	Move plant closer to a window or other light source. Don't fertilize when plants are dormant (winter).
Old leaves curl under. New leaves are smaller than old leaves. Leaves may brown around margins.	Too much light	Move plant farther from window or light source, or filter light through a curtain.
Yellow, brown, or white (bleached) spots on leaves (particularly on upper leaves).	Sun scorch caused by sudden increase in light intensity	Shade plant. Move plants from shade to sun gradually so they can adapt. Some always require shade.
Leaves turn yellow, curl downward, or wilt.	Too much heat	Move plant to a cooler spot. Avoid placing plants near heat registers or hot-air outlets.
Plants wilt even if soil is moist. Margins and tips of leaves burn. White crust may appear on leaf edges and on the soil surface when dry.	Salt buildup in soil	Water three times at 30-minute intervals to wash the salts out the drainage hole. Do not use soft water.
White crust on rim and sides of porous pots. Leaves touching rim wilt and die.	Salt accumulation on pot	Leach soil as above. Wash excess salts off pot with clear water. Wax the rim of the pot to prevent future salt deposits that might touch leaves.
White or yellow spots on leaves of African violets, gloxinias, and other hairy-leafed plants.	Cold water on leaves or in soil	Use room-temperature to lukewarm water for watering plants.
Dark brown spots around leaf margins of tropical foliage plants (especially philodendrons).	Raw natural gas or incompletely burned gas in home	Check gas lines and fittings for gas leaks. Adjust gas burners for blue flame. Have furnace checked for leaks or adjustments.
Plants wilt between waterings. Roots fill pot and may grow out drainage hole. Growth slow.	Plant is too big for its pot	Repot in a larger container with a good potting soil mixture.
Sudden wilting or shedding of foliage during cold weather.	Chilling	Move plant away from chilling drafts.
Wilting and loss of foliage after repotting or initial potting.	Transplant shock	Give optimum care until plant adjusts to its new situation.
Tips of leaves turn brown, and leaves wilt. Lower leaves turn yellow and fall off.	Not enough water	Water until some water runs out the drainage hole, or submerge the pot in a pail of water for five minutes. Drain off excess water. Repeat when soil is dry to touch.
Lower leaves curl and wilt. Stems become mushy and rot. Soil in pot usually is wet.	Too much water	Water less frequently. Use pots with drainage holes in the bottom. Do not allow pot to stand in water more than 30 minutes.
Leaf edges are crinkly and brown. Tips of new leaves often dry up.	Lack of humidity	Increase humidity around plants by standing pots on a bed of moist gravel or placing them in planters with moist sphagnum moss packed around the pots. Use a humidifier or move plants to a more humid area (such as a bathroom or over the kitchen sink).
Plants grow rapidly with lots of foliage but few, if any, flowers.	Too much fertilizer	Fertilize less often or at half the suggested rate. Use low-nitrogen fertilizer during blooming season. Do not fertilize when plants are dormant.
Lower leaves lose color and may drop off. New leaves are progressively smaller than previous leaves. Stems are stunted.	Too little fertilizer	Fertilize regularly when plants are growing. Use a soluble fertilizer and apply per package directions.
Brown or black spots on leaves. Tip and marginal burning. Spider plants *(Chlorophytum),* corn plants *(Dracaena),* and palms are especially sensitive.	Fluoride in water supply	Use rain or distilled water. Keep pH up to 6.5.

- Fluoride in tap water can damage sensitive plants. (See Table 19.1.)
- Room-temperature water is best. Plants such as African violets and their relatives may require even warmer water.

Nutrients

Plants growing in containers have a limited volume of soil from which to extract mineral nutrients (fertilizer). The supply of nutrients rapidly becomes exhausted when the plant is actively growing. Replenish nutrients regularly. The easiest way is to water them with a solution of soluble fertilizer.

Many soluble fertilizers are available in garden stores. Since they vary in strength (percent of fertilizer nutrients), dilute or dissolve them in your watering can according to the label directions. Mix only enough solution to water your plants once each time you fertilize.

During the long days of the year (Easter to Thanksgiving), when plants are actively growing, fertilize about every other week. During the short days of the year (Thanksgiving to Easter), fertilize only every four to six weeks. If plants are totally dormant, do not fertilize until new growth starts.

Here are some fertilizing hints:

- Slow or time-release fertilizers are a good way to fertilize houseplants. Follow label directions.
- Plants grow best with small amounts of nutrients constantly available.
- Do not apply fertilizers to dry soil.
- Do not overfertilize. More is *not* better. Plants can die from too much fertilizer. It's better to underdo than overdo.
- Both organic and synthetic fertilizers are acceptable sources of plant nutrients.

Potting and Repotting

Cultivating plants in containers requires occasional replanting from one container to another. Small, rapidly growing plants may require repotting into larger containers every three to four months. You can repot mature houseplants on an annual basis or allow them to remain in containers until they have outgrown them or become pot-bound (Figure 19.2). If a plant is not doing well, and no obvious reason can be found, it may benefit from repotting.

Handle plants carefully when potting or repotting to avoid injury and to provide optimum growth in the new container. When transplanting, consider such factors as size and condition of the plant, size and type of container, type and amount of soil mixture, and prevention of damage to the plant.

Plant Size

Small plants transplant more easily than larger ones; however, any plant that already is established in a container can be repotted. When first planting into pots, select small plants so you do not have to remove many roots to fit the plant into the container. Pot rooted cuttings when the roots are about one-half inch long. Seedling plants transplant most readily as soon as the first true leaves have formed.

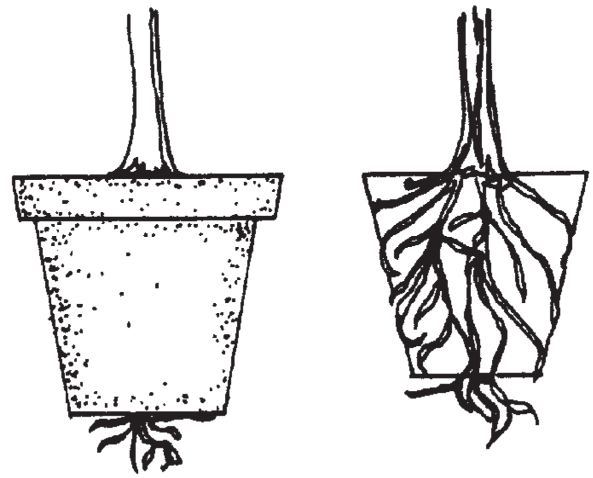

Figure 19.2. If roots are growing out of the drainage hole, it's time to repot.

Plant Condition

Most plants transplant best when they are actively growing. Dormant plants or those in flower may not produce root growth and establish themselves in the new pot as readily. Plants should not be wilted when transplanted. Be sure your plants are well watered and free of insects before repotting.

Container Type

Plants can be grown in almost any container, but it is best to use containers with drainage holes. To establish plants in decorative containers without drainage holes, pot the plants in draining pots that fit inside the other containers. You can combine several small pots in a larger planter by packing sphagnum moss around the sides of the pots for support and to help evaporate excess water. Clay pots are no better than plastic ones, but porous and nonporous pots require different management. For one thing, soil in clay pots dries more rapidly and requires more frequent watering than that in plastic pots.

Container Size

Normally it is best to keep a plant in the smallest container needed for its current stage of development. This practice conserves growing space, reduces the likelihood of overwatering, allows for gradual increases in pot size (and new soil) as the plant develops, generally looks better (small plants in large pots look lost), and allows more versatility in moving plants or arranging them in groups.

Adjust container size to manage irrigation schedules. Move plants that need more frequent watering to larger pots with more water-storage capacity.

Potting Soil Mixtures

Plants growing in containers require specially prepared soils or growth media. A container-grown plant cannot extend its root system to gather water and nutrients; it is limited to the small volume of soil in the container. Potted plants use the soil in their pots much more intensively than they would if growing unrestrained outdoors. Even the most fertile garden soil will not sustain this intensive use for more than a short time.

Ready-to-use potting soil mixes are available in garden stores. Some of these commercially prepared potting soils are excellent but expensive. If you have only a few houseplants, prepared mixes are convenient and probably the most practical. However, if you grow numerous houseplants, it may be more economical to prepare your own potting soil.

Good potting soil differs from garden soil. It should contain a much higher proportion of coarse mineral particles to maintain sufficient pore spaces in the soil for air, water, and root growth. It must have enough organic matter to hold water and condition the soil (keep it from compacting). It also must contain sufficient mineral nutrients to supply a large part of the plants' needs. (All houseplants need supplemental fertilizer on a regular basis.)

Good potting soils can be prepared by mixing garden soil, coarse sand, pumice or perlite, and peat moss. Most potted plants grow quite well in a mix containing equal parts of these ingredients if you adjust management techniques (watering and fertilizing) to suit their different needs. You can modify this general potting mixture with additional coarse mineral material or peat moss to satisfy specific plant requirements. The instructions in this section can be used to create some common potting mixtures.

General Mixture

- one part garden soil (not clay)
- one part washed builder's sand, perlite, or pumice
- one part horticultural peat moss
- one quart steamed bonemeal per bushel (eight gallons) of mixture
- one pint dolomitic lime per bushel of mixture

Mix all ingredients thoroughly by shoveling them from one pile to another at least three times. Pulverize any large lumps or clods as you mix. When the mix is thoroughly blended, add sufficient water to moisten it. Then store it in a sheltered spot until you are ready to use it. A garbage can, wastebasket, or large bucket makes a handy storage container.

This general potting mixture provides a suitable growth medium for most container plants, including vegetables, bedding plants, geraniums, begonias, fuchsias, and ivy.

High-Organic Mix

- one part general potting mixture
- one part horticultural peat moss

Many houseplants, such as African violets, gloxinias, philodendrons, rubber plants, and most other tropical foliage plants, may do better in a mix containing a higher proportion of organic matter. Adding extra peat moss to the general potting mixture adjusts the mixture to their needs.

Desert Plant Mix

- one part general potting mixture
- one part sand or coarse perlite

Cacti and other succulents grow best in a soil mixture with a lower proportion of organic matter that dries rapidly and, therefore, does not retain large quantities of water. Mix the general soil mix with an equal volume of sand or perlite to create an appropriate potting mixture for these plants.

Orchid Plant Mix

- two to three parts fir bark (medium to course grade)
- one part perlite
- one part sphagnum moss, with large fibers chopped into quarter- to half-inch pieces

Most orchids grown as houseplants are epiphytes, meaning that they typically grow attached to the trunks and limbs of tropical plants. Therefore, orchid planting mix should be composed of relatively large particles to allow for air movement into and through the medium. A few orchids are terrestrial, meaning they grow in soil. Terrestrial orchids will usually do well in a general mixture or a high-organic mix.

Sterilizing Soil

It normally is unnecessary or even undesirable to sterilize potting soils. Garden soils contain millions of beneficial living organisms. Only rarely do they contain disease organisms that might damage houseplants. Seedlings are most susceptible to attack by soilborne disease organisms during their first two to four weeks of growth. To prevent damping-off disease on seedlings, it may help to heat-treat the soil used for seedling production.

Baking soil in an oven is the easiest method of heat-treating. Place slightly moist soil in a heat-resistant container, cover it, and bake it in an oven at 250°F. Use a candy or meat thermometer to ensure that the mix reaches 140°F for at least 30 minutes.

Using Potting Mixes

By making a supply of general potting soil mixture and retaining a small quantity of additional peat moss and sand, you can adjust your mixture for any type of plant. This arrangement requires only a minimal amount of storage space, and your potting soil is ready to use at any time. Before using it, be sure it is damp. Dry soil mixture is difficult to handle and may damage tender roots before the plant is watered.

The Potting Process

It is not necessary to cover drainage holes. Any item that might inhibit free drainage of surplus water from the pot is best avoided. Plants will not suffer if a bit of potting mix comes out with the first irrigation or two. Do not use a gravel layer or other so-called drainage material at the bottom of the pot. It actually slows down drainage by shortening the soil column. Different layers of material also are likely to lead to perched water tables (restricted drainage) in the container. Always fill the entire pot with the growing medium—right to the bottom.

If you are repotting from another pot, gently remove the plant and crumble some of the old soil ball away (Figure 19.3).

If you are potting a new plant, trim the root system if necessary to fit the pot (Figure 19.4). Do not bend or wind roots into the pot. It is better to prune them to fit without bending.

Place the resulting ball in the center of the new container and fill around it with potting soil while holding the plant in the desired position (Figure 19.5). To help settle the medium, slap the sides of the container as the soil filters around the plant roots. Thumping the bottom of the pot on the potting bench also aids in this process. Avoid pressing or tamping the soil down too hard. This often eliminates air space in the mix and causes drainage problems.

Finish filling the pot to approximately one-half inch from the top. In standard flower pots, fill to one-half the depth of the rim. This leaves enough space for applying sufficient water to saturate the soil.

As soon as you finish potting or repotting plants, fill the pot to the brim with water. Keep adding water until it comes out the drainage hole to be sure you have completely filled the reservoir capacity of the potting soil.

If extensive root pruning was necessary, keep the plant away from strong light or heat until new roots grow. Increasing the humidity around the plant will help in reestablishment.

Propagation

Many houseplants are easily propagated by cuttings. For further information on propagating houseplants, see Kentucky Cooperative Extension publication *Propagating Plants in and around the Home* (HO-67) or refer to Chapter 3, Plant Propagation.

Houseplant Problems

Most houseplant problems are related to cultural or environmental stress. Table 19.1 shows symptoms, possible causes, and treatments to help you recognize and deal with some of the many houseplant problems. Unhealthy container plants usually return to normal, healthy growth once they receive acceptable growing conditions. This recovery may require a few weeks to several months. If you find you cannot achieve proper conditions for certain types of plants, it may be best to discard them and get varieties that grow successfully in the conditions you are able to provide.

Other problems are caused by insects. Some of the more common ones are described in the "Major Pests" section of this chapter. Prevention is a key to managing houseplant pests. If your plants develop a pest problem, there are various chemical and nonchemical controls available. The key to success against pests is to get control of all their life stages. Consistent application of a pesticide every five to seven days for a period of a month or more may be necessary. Nonchemical controls also must be consistent.

Diseases normally are not a problem for plants grown in homes or other typical indoor environments. (An exception is powdery mildew on a very few species of plants, such as grape ivy.) Plants grown in greenhouses, however, are susceptible to several disease problems.

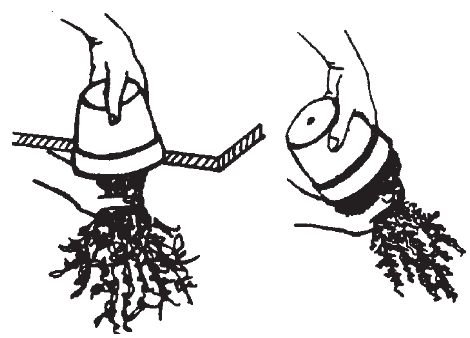

Figure 19.3. Removing plants from pots.

Figure 19.4. Trimming roots before repotting.

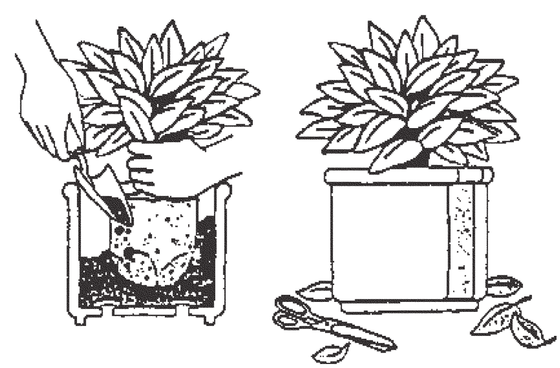

Figure 19.5. Repotting a plant.

Major Pests

Aphids

Aphids are small insects about one-sixteenth to one-eighth of an inch long. They are six-legged and variously colored, and some look powdery or woolly. Both wingless and winged forms can be found on plants. Under the right conditions, aphids multiply rapidly and can spread quickly to other plants in the house. Aphids have sucking mouthparts that pierce plant tissue and suck out juices. Damaged leaves lose their green color and look stunted, distorted, or curled. Heavy infestations may damage or actually kill plants.

The excreta (honeydew) given off by aphids is another problem associated with this pest. This material is sticky, gives leaf surfaces a shiny look, and provides food for the development of sooty mold.

Whiteflies

Whiteflies are tiny insects about one-tenth to one-sixteenth of an inch long that resemble tiny moths. Their bodies and wings are covered with a white, powdery substance. When at rest, they hold their wings rooflike over their bodies. Both the immature stages and adults have sucking mouthparts. There are five distinct stages in the whitefly's development:

1. The egg, which is laid on the underside of a leaf and often is covered with a powdery material
2. The newly hatched or "crawler" nymph, which is flat, nearly transparent, and can move
3. The intermediate nymph, which has no antennae or legs and therefore cannot move
4. The dark nymphal stage, which is somewhat segmented
5. The adult

A single female can lay up to 400 eggs, and whiteflies continuously breed in homes and greenhouses. Damage by whiteflies resembles aphid damage. In addition, the adults are active fliers and become a household nuisance.

Scales

Several different scales infest houseplants. The adults generally are quite small, ranging from one-sixteenth to one-eighth of an inch in diameter, and may be white, black, brown, gray, or tan. They attach rigidly to plants. Many scales are shaped somewhat like a ball and have no distinctive features except for being flat or slightly bulging. Some have distinctive shapes, such as oyster shells (that is, oystershell scale), while others look like turtle shells. The scale actually is a hard or soft covering that protects the insect. The adult male is the only winged member of the scale group.

Damage by scales is similar to that from aphids and whiteflies. Honeydew and sooty mold often are present. Severe plant injury or death may be the final result of poor control.

Chemical control of adults often is impossible. The female usually lays eggs under a scale. When eggs hatch, tiny crawlers emerge and begin to move about in search of a place to feed. The crawler stage is the most easily killed with chemical sprays.

Mealybugs

Several different mealybugs are among the most serious pests of houseplants. Most appear powdery. They are about three-sixteenths of an inch long, flat, and slender. Some have waxy filaments extending from their bodies. Most species move freely but slowly on plants. Females are wingless, while males have a single pair of wings. Eggs are laid in clusters and are covered by waxy or fuzzy material.

Mealybugs attack all plant parts. Damage is similar to that caused by aphids. Honeydew and sooty mold frequently occur on plants infested with mealybugs.

Spider Mites

Mites often are referred to as insects. However, they are not insects, since they have eight legs, only two body regions, and no wings. They are, in fact, closely related to spiders. Spider mites are extremely small. A hand lens of at least 10X magnification often is needed to see them.

Usually, mite damage appears long before the mites themselves are noticed. Plants damaged by mites lack vigor, lose color, and have speckled leaves. Webbing is characteristic of spider mites. The web helps them spread to other plants, often on air currents.

There are three stages in a mite's development: egg, a series of nymphal stages, and adult. All stages except the egg stage damage plants.

Cyclamen Mites

Although named for cyclamens, these mites also damage many other plants. Adults are too small to see with the naked eye. Under a magnifying glass, they are seen as oval, amber or tan-colored, semitransparent, and glistening. The young are even smaller and milky white.

These mites are found mostly in protected places on young, tender leaves, young stem ends, buds, and flowers. They crawl from plant to plant where leaves touch. They also can be transferred to other plants by hands or clothing.

Damage consists of twisted, curled, and brittle leaves, deformed buds, and flowers that often are streaked with darker color. Blackening of leaves also is common.

Minor or Less Common Pests

These pests are uncommon in the home but if houseplants are moved outdoors during the summer they may be exposed or you may inadvertently bring these pests along when you move your houseplants back indoors come fall. Always inspect new plants for pests when you are introducing plants to your home environment. See below for more information on preventing pest problems.

Leafminers

Many different insects commonly are called leafminers. Members of the fly, sawfly, and moth/butterfly groups are the most common. The larval stage is responsible for the leafmining damage, which appears as a winding, discolored trail or an irregular blotch within leaf tissue. Damage from these insects rarely is serious; it usually is merely unsightly. Simply remove and destroy the infested leaves to solve the problem.

Fungus Gnats

These small, black flies are first noticed around windows. The larvae feed on decaying matter and therefore most often are found in highly organic soils. Most species seldom damage plant roots unless a great many insects are present. Generally, they are merely annoying.

Caterpillars

The larvae of many moths and some butterflies sometimes feed on houseplants. They range from very tiny (one-eighth of an inch or so) up to one and one-half inches long. Color of adults and caterpillars varies, although gray, whitish, and brownish are most common. Caterpillars may have stripes, spines, or bumps in any combination according to species. They have three pairs of true legs and also may have a series of false legs along the tail end.

Their presence usually is the result of an uninvited, fertile female moth who slips past a screen door and lays eggs inside. Caterpillars, as well as other pests, also can develop on plants that have been placed outdoors during the summer. Remove and destroy the eggs or caterpillars when you notice them.

Beetles

Flea beetles and other leaf-feeding beetles are potential houseplant pests. These beetles have chewing mouthparts. Beetles have four life stages: egg, larva, pupa, and adult. In many species, both adults and larvae feed on plant tissue.

In most species, the adults can fly, which in some cases may explain their presence in homes. Again, the likelihood of beetle infestation increases when plants are placed outdoors. Removal of the insects probably is the most convenient and effective control.

Thrips

Thrips are small, slender insects about one-sixteenth of an inch long. Many have two pairs of fringed wings, which are folded flat over the back when at rest. Some are predators and some are scavengers, but most are serious plant pests. Their mouthparts are used for rasping leaf surfaces. Damage appears as whitening or speckling of leaves. Small, black droplets also may be noticeable, and some plants may have a silvery appearance. Flowers also are damaged.

Leafhoppers

Leafhoppers are small to moderate-sized sucking pests (one-sixteenth to one-quarter inch long) related to aphids. Only occasionally are they pests of houseplants. They vary in color and are wedge shaped. Damage usually appears as mottling or speckling of leaves and may be confused with mite injury.

Springtails

Springtails are small (one-fifth of an inch or less) and vary in color. They are wingless, and as the name implies, many are capable of jumping. Although they may chew on small seedlings or tender plant parts, they mostly prefer to feed on decaying organic matter. They can become a nuisance when numerous.

Slugs and Snails

These soft-bodied, fleshy, legless creatures are related to clams. They can be very destructive to a wide variety of plants. They usually require a moist environment. Houseplants may become infested when they are placed outdoors. Slugs and snails are voracious feeders and frequently devour whole plants or plant parts. Their presence is marked by the slime trails they leave behind.

These animals lay small, round, milky white eggs in the soil. Some commercial slow-release fertilizer pellets closely resemble slug eggs and often are identified as such even by professionals.

Hand removal of slugs usually is all that is necessary. Look for them under mulch, pots, and pot rims. Placing shallow dishes of beer near plants is helpful, as slugs are attracted to beer and will crawl in and drown.

Millipedes

Millipede populations can build up in potted plants. They sometimes feed on plant parts, but more frequently on decaying organic material. They become a nuisance when present in large numbers. Many species can occur on plants. They vary in color and can be tiny or up to one and one-half inches or more in length. They are easily identified by their many legs, round shape, and slow movement.

Centipedes

These animals are not plant pests. They feed on many insects and insect relatives and thus are beneficial. While they resemble millipedes because of their many legs, they are very flat and fast moving. They vary in size (one-quarter to two inches) as well as in color. Some of the larger ones often bite when disturbed. If their presence is annoying, remove them carefully and place them outdoors where they can continue to be useful in nature's scheme of things.

Preventing Pest Problems

Routine precautions will help you avoid unhappy encounters with houseplant pests. First, when you buy plants, inspect the leaves and stems carefully. Even those that seem clean might harbor pests. Isolate new plants for a week or two in a separate room or garage to prevent pests from flying from the new plants to your existing ones. Keep close watch on the plants to see whether a pest population is building up.

Putting houseplants outdoors in the summer can invite a whole series of pest problems. If you put your plants outside, treat them as newly purchased when you bring them back indoors.

Sometimes pests come indoors on their own. Good screen windows keep out most flying insects such as moths and beetles.

Using soil from outdoors is another source of infestation; you might bring in uninvited members of the soil fauna such as mites and slug eggs. Commercially prepared potting soil might be a better choice. If you use outside soil, pasteurization at 140°F is an option; it normally eliminates undesirable organisms but does not harm desirable ones. (See "Sterilizing Soil," earlier in this chapter.)

Pests are transferred from plant to plant in a variety of ways. Some of the more subtle ways are through human activity. Consider the times you handle garden store plants or admire a friend's collection. In doing so, you can pick up scale crawlers or mites and bring them home to your own plants. It is wise to be on the lookout for plant pests before you handle strange plants.

Many pests survive because they have suitable hiding places. Avoid buildup of dead leaf material that might provide such sites.

Controlling Pests

Nonchemical Control

Several techniques can be alternatives to chemical controls. Some require more work than using chemical sprays, but they often give equally good control.

Removal of Infested Parts

If only a few leaves are infested (for example, with leafminers), it is quite effective to simply remove and destroy that portion of the plant. If roots are being damaged by mealybugs or grubs, it is advisable to take a cutting and start over. Discard infested soil and thoroughly clean the pot or container.

Disposal

Some plants may be so badly damaged that they are too far gone to save. Getting rid of them is the simplest answer.

Hand Removal

This method is fairly effective for a number of pests and usually needs no supplemental chemical control. Slugs, caterpillars, many beetles, and other large insects can be eliminated in this manner. Many of these pests feed at night. Thus, this method is most effective if done at night using a flashlight. Where scales or mealybugs are few in number, a thumbnail or toothpick can remove them. After removing pests, watch plants closely for a few weeks in case you overlooked some smaller individuals.

Swabbing with Alcohol

Cotton swabs dipped in rubbing alcohol are effective in controlling aphids and mealybugs. This method is practical for light infestations but is extremely tedious for heavy infestations, particularly on large plants.

Spraying with Soapy Water

Using soapy water gives good control if done correctly. The authors have used soapy water with good results on several kinds of plants.

Some plants may be harmed by this technique, so try it on a small area of a plant first. Use only insecticidal soap that is registered for use on houseplants. Read the label carefully, not only for use instructions but also for information concerning possible plant damage.

This treatment is not totally effective against winged adults (such as whiteflies), since they leave the plant during treatment and return later. Thus, it is necessary to spray the adults with a registered insecticide to get complete control of all stages of the pest.

Chemical Control

Few pesticides are registered for indoor use on houseplants. Read labels carefully for where and how to use a pesticide. If indoor use is not designated, take the plant to be treated outdoors away from child and pet traffic areas. Do not bring it back indoors until the spray has dried. It may be well to leave the plant in the garage a day or two for extra safety. Another solution is to use pesticides that are formulated to be added to the soil as either a granule or drench. Again, be sure the pesticide is labeled for indoor, houseplant use.

Avoid spraying houseplants indoors, even according to label directions, as many sprays have objectionable odors and can cause allergic reactions in some people. Do not use pesticides where spray can drift onto cooking utensils or food.

Plant Damage from Pesticides

Injury to plants from pesticide applications has several common symptoms:

- Total burn, marginal burn, or spotting of leaves or flowers
- Cupped, curled, and yellow leaves
- Distorted leaf or flower buds

As a rule, flowers and flower buds in advanced stages of development are most susceptible to pesticide injury.

Usually, these injuries do not kill a plant. Leaves may drop, but new leaves form and the plant usually recovers.

Soil-applied pesticides also may produce these symptoms or stunted growth because of injury to the root system. Severe root injury causes sudden wilting and death of aboveground plant parts.

Reduce the possibility of damage by applying pesticides during the cooler hours of the day and by letting plants dry in a well-ventilated place. Powders and dusts generally are less injurious to plants than are spray concentrates, although they may leave an unsightly residue.

Carefully read the pesticide label. In many cases, it will indicate specifically which plants are sensitive to the pesticide and those for which it is recommended.

Chapter 20

Home Vegetable Gardening in Kentucky

For the content of this chapter we will use the Kentucky Cooperative Extension service publication ID-128: Home Vegetable Gardening in Kentucky. It is available online at http://www2.ca.uky.edu/agcomm/pubs/ID/ID128/ID128.pdf and a recent version is included in the following pages.

Acknowledgments
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Front cover: Pepper Pot-a-peno F1 is a 2021 Edible-Vegetable Award Winner from All-America Selections (AAS). Pot-a-peno is a jalapeno-type pepper with a compact growth habit of less than 15 inches making it well suited to culture in containers, hanging baskets, and small urban gardens. The plants are loaded with small, 3-4 inch peppers with traditional jalapeno spiciness that some indicate is a little milder than traditional jalapenos. Look for full sized fruit about 45 days after transplanting and red fruit after about 60 days. For more information about this and other AAS Winners visit the AAS web site at: www.all-americaselections.org.

All photos courtesy of All-America Selections

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Tables and Figures

Plans and Preparations

Before You Begin

Every aspiring gardener should follow seven steps to have a successful gardening season:

1. Plan your garden on paper before you begin.
2. Select a good gardening site that is:
   a. in full sun for at least eight hours each day,
   b. relatively level,
   c. well-drained,
   d. close to a water source,
   e. dries quickly from morning dew.
3. Prepare the soil properly, conduct a soil test, and add fertilizer and lime according to U.K. test result recommendations.
4. Plan only as large a garden as you can easily maintain. Beginning gardeners often overplant, and then they fail because they cannot keep up with the tasks required. Weeds and pests must be managed, water applied when needed and harvesting done on time.
5. Grow vegetables that will produce the maximum amount of food in the space available.
6. Plant during the correct season for the crop.
7. Choose varieties recommended for Kentucky.
8. Harvest vegetables at their proper stage of maturity. Store them promptly and properly if you do not use them immediately.

Planning Your Garden

A garden plan helps you grow the greatest amount of produce with the least amount of effort. To use your plan you must expect to harvest each crop as soon as it matures. Then put old plants in the compost pile and plant a new crop. This approach is called succession planting.

Grow only those vegetables that your family will eat. A well-planned and properly kept garden should produce 600 to 700 pounds of produce per 1,000 square feet (Table 20.1) and may include many different crops. Consult *Vegetable Cultivars for Kentucky Gardens* (ID-133) for the latest recommendations on home vegetable varieties.

Draw a scale model of your garden space when planning where to plant. There are also a number of computer programs that can be used to plan your garden. Plant perennials like asparagus, rhubarb, chives and horseradish along one side of the garden since they may produce for six to 12 years. Tall plants such as sweet corn, tomatoes and pole beans should be planted on the north or west side of the garden where they will not shade smaller vegetable crops. However, summer lettuce should be grown in a partially shaded area if possible.

Table 20.1. Average vegetable yields and amounts to plant per person.

Vegetable	Yield per 10 ft of row		Planting: Fresh		Planting: Store/Can/ Freeze	
Asparagus	3	lb	10-15	ft	10-15	plants
Beans, snap bush	12	lb	15-16	ft	15-20	ft
Beans, snap pole	15	lb	5-6	ft	8-10	ft
Beans, lima bush	2.5	lb, shelled	10-15	ft	15-20	ft
Beans, lima pole	5	lb, shelled	5-6	ft	8-10	ft
Beets	15	lb	5-10	ft	10-20	ft
Broccoli	10	lb	3-5	plants	5-6	plants
Brussels sprouts	7.5	lb	2-5	plants	5-8	plants
Cabbage	15	lb	3-4	plants	5-10	plants
Cabbage, Chinese	8	heads	3-10	ft	---	
Carrots	10	lb	5-10	ft	10-15	ft
Cauliflower	10	lb	3-5	plants	8-12	plants
Celeriac	6	lb	5	ft	5	ft
Celery	18	stalks	10	stalks	---	
Chard, Swiss	7.5	lb	3-5	plants	8-12	plants
Collards and Kale	10	lb	5-10	ft	5-10	ft
Corn, sweet	1	dozen	10-15	ft	30-50	ft
Cucumbers	12	lb	1-2	hills	3-5	hills
Eggplant	10	lb	2-3	plants	2-3	plants
Garlic	4	lb	---		1-5	ft
Kohlrabi	7.5	lb	3-5	ft	5-10	ft
Lettuce, head	10	heads	10	ft	---	
Lettuce, leaf	5	lb	10	ft	---	
Muskmelons (cantaloupe)	10	fruits	3-5	hills	---	
Mustard	10	lb	5-10	ft	10-15	ft
Okra	10	lb	4-6	ft	6-10	ft
Onions (plants or sets)	10	lb	3-5	ft	30-50	ft
Onions (seed)	10	lb	3-5	ft	30-50	ft
Parsley	3	lb	1-3	ft	1-3	ft
Parsnips	10	lb	10	ft	10	ft
Peas, English	2	lb	15-20	ft	40-60	ft
Peas, Snow	2	lb	10-15	ft	30-40	ft
Peas, Southern	4	lb	10-15	ft	20-50	ft
Peppers	6	lb	3-5	plants	3-5	plants
Potatoes, Irish	10	lb	50-100	ft	---	
Potatoes, Sweet	10	lb	5-10	plants	10-20	plants
Pumpkins	10	lb	1-2	hills	1-2	hills
Radishes	10	bunches	3-5	ft	---	
Salsify	10	lb	5	ft	5	ft
Soybeans	2	lb	50	ft	50	ft
Spinach	4-5	lb	5-10	ft	10-15	ft
Squash, summer	15	lb	2-3	hills	2-3	hills
Squash, winter	10	lb	1-3	hills	1-3	hills
Tomatoes	10	lb	3-5	plants	5-10	plants
Turnip greens	5-10	lb	5-10	ft	---	
Turnip roots	5-10	lb	5-10	ft	5-10	ft
Watermelons	4	fruits	2-4	hills	---	

Choosing a Site

Your garden site should provide a sunny exposure, adequate moisture and fertile soil. Because of your property's limitations, however, you may be forced to select a less than ideal location. As much as possible, let the following suggestions guide you in choosing your garden site:

Avoid putting the garden in a low spot, at the bottom of a hill or at the foot of a slope bordered by a solid fence. Such areas, where frost settles because of lack of air drainage, are slow to warm up in the spring. High ground will enable the vegetables to escape "borderline" freezes for an earlier start in the spring and longer harvest in the fall.

If possible, choose an area with a southern or southeastern exposure which warms up faster in the spring and receives the maximum amount of sunlight throughout the growing season. Midsummer vegetables, other than lettuce, should not be located on the north side of a building or on a northern slope of a hillside.

Plant your vegetables away from buildings, trees and other objects which would shade them. Your plants need at least eight hours of direct sunlight each day. You can grow lettuce in the shade if you must locate part of your garden in a partially shaded area.

Your garden needs water from rainfall or other sources. However, too much water can be just as damaging as too little.

- Examine your garden site to see how it drains and avoid areas that stay soggy after a rain. To evaluate how your site drains, dig a small diameter hole to a depth of two feet and look for grey colors in the soil. These grey colors indicate that the soil is poorly drained. Consider moving the garden to a different area or installing raised beds.
- Avoid heavy clay soils in favor of loamy soil.
- Improve sandy soils by adding large amounts of organic matter. Adding organic matter can often solve minor drainage problems; however, if the poor drainage is caused by underlying layers of rock or hard clay (hardpan), correcting the drainage could involve the labor and expense of subsoiling with an excavator, laying tile or of building raised beds.
- Locate your garden away from trees as much as possible. Tree roots can compete with your vegetables for water and nutrients.
- Look for a site which supports lush vegetative growth, even if it is dark green, sturdy weeds. Although you can improve poor soil over a period of years, you can save much time and work if you begin with naturally rich soil.
- Make sure to use contour rows or terraces for hillside gardens.
- Avoid windy locations.

Finally, the closer the vegetable garden is to your back door, the more you will use it. You can see when your crops are at their peaks and can take maximum advantage of their freshness. Also, keeping up with planting, weeding, watering and pest control will be easier.

Organic Gardening

In 1990 Congress passed the Organic Foods Production Act, which mandated the creation of the National Organic Program (NOP) and the passage of uniform organic standards. This action was followed by over a decade of public input and discussion, which resulted in a National Organic Program final rule implemented in October 2002. These national standards set out the methods, practices and substances used in producing and handling all certified organic crops and livestock. The standards include a national list of approved non-synthetic and prohibited synthetic substances for organic production.

Organic production is based on a system of farming that maintains and replenishes soil fertility without the use of toxic and persistent pesticides and fertilizers. Organically produced foods also must be produced without the use of antibiotics, synthetic hormones, genetic engineering and other excluded practices, sewage sludge, or irradiation. National organic standards require that organic growers and handlers be certified by third-party state or private agencies or other organizations that are accredited by USDA.

Home gardeners will have no need to concern themselves with the many rules and requirements that go along with organic certification. However gardening organically in your home garden in Kentucky is just as easy as gardening using "conventional" techniques and inputs once you master some simple management practices like scouting your garden often to watch for pest or disease problems, choosing plant varieties that will thrive under organic management, and paying close attention to soil management by adding organic matter to your garden, using compost, practicing crop rotation, and utilizing cover crops. Throughout this guide, organic alternatives to certain conventional practices or inputs are included to give gardeners a choice in how they raise vegetables.

Preparing the Soil

An ideal garden soil has a 10- to 12-inch loamy surface layer overlying a well-drained subsoil. This type of soil can retain large amounts of water but still drains well after a rain. After spring preparation, it stays crumbly and workable without becoming hard and crusted. It should have enough minerals for optimum growth, and the pH should be between 6.2 and 6.8.

Few sites available for the home vegetable garden will match the ideal in all respects. However, most soils can be modified to provide more favorable growing conditions. Soil improvement is really a long-term process, often taking several years. The poorer the soil, the longer it will take to get optimum production from it. However, vegetable crops will tolerate variable soil conditions and still produce fairly well.

After a fertile garden is established, continue amending the soil so that it will stay fertile and workable. Since most gardens must be in the same location year after year, building up a rich soil is essential.

The Soil Test

After deciding on your garden site, take a soil sample and have it tested, preferably in October or November. Use the soil test as a guide as you try to establish a satisfactory fertility level. The standard test measures soil acidity (pH), available phosphorus, potassium and, if requested, calcium, magnesium and zinc. The test results help determine fertilizer and lime requirements.

To take a soil sample, push a spade 7 inches into the soil and throw the soil aside. Take another 1-inch slice of soil from the back of the hole the full depth of the hole. Remove all the soil but the center 1- to 2-inch-wide core. Place this core of soil in a clean bucket (Figure 20.1).

Repeat the procedure in different spots to get a representative sample of the whole garden and to get about 1 pint of soil. Mix the composite sample well and put it on some paper to dry for about two days at room temperature. Then take it to your county Extension office to submit for analysis. The cost of the soil test, which varies with the number of elements tested, will be returned to you many times over in savings of fertilizer and in the production of high yields and quality produce.

Figure 20.1. Taking a soil sample.

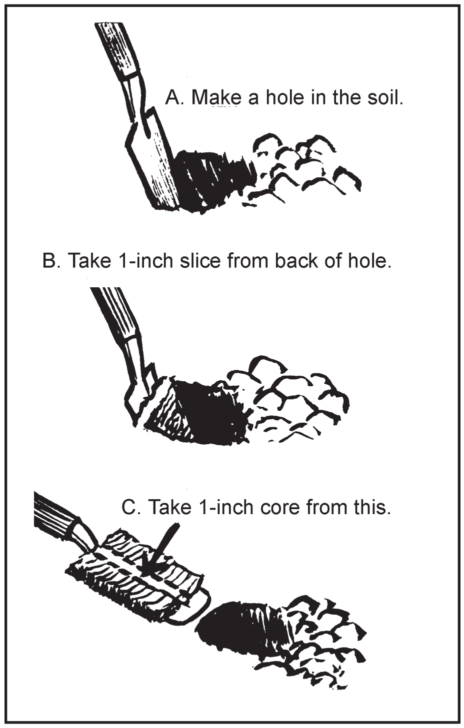


Figure 20.2. Effect of change in pH on the availability of plant nutrients.

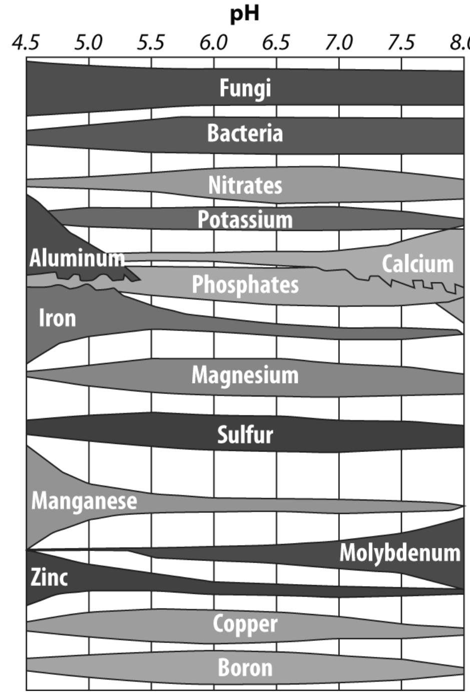


Table 20.2. Rate (lb/1000 sq ft)[1] of agricultural limestone needed to raise soil pH to 6.4.

Water pH of Sample	Buffer pH of Sample								If Buffer pH is Unknown
	5.5	5.7	5.9	6.1	6.3	6.5	6.7	6.9	
4.5	320	300	280	250	220	180	150	130	180
4.7	320	300	280	240	200	170	140	120	170
4.9	310	290	260	230	190	150	130	110	160
5.1	310	290	260	220	180	130	100	80	150
5.3	300	280	240	210	160	120	90	70	130
5.5	290	270	230	190	140	100	70	60	120
5.7	280	260	220	170	120	90	60	50	100
5.9	---	240	200	150	100	80	50	40	80
6.1	---	---	180	120	80	60	40	40	60
6.3	---	---	---	90	60	40	40	30	40

1 See AGR-1 for limestone rates needed expressed in Tons/Acre.

Soil pH—Why Is It Important?

The term pH stands for the relationship of hydrogen ions (H+) to hydroxyl ions (OH-). A soil pH reading indicates on a logarithmic scale the concentration of ions held to soil particles and organic matter. A pH scale ranges from 0 to 14, with pH 7.0 being neutral. Readings below 7.0 indicate a soil is "acid," and readings above 7.0 indicate "alkaline" soil conditions. Most of the plants we grow in our home gardens require a soil which is slightly acid.

The soil's pH is very important because it directly affects soil nutrient availability (Figure 20.2). Plant roots can only absorb nutrients after they have been broken down into certain ion forms. Only at certain pH ranges can sufficient amounts of these nutrients be broken into these ion forms. When the soil's pH is out of this range, the nutrients are "tied up in the soil." By adjusting the pH, we make sure that the plants we grow can use the fertilizers and available nutrients in the soil to their fullest potential. Most vegetables in a garden prefer growing in soil with a pH between 6.2 and 6.8.

Autumn is an excellent time to have your soil tested. You can then make any adjustments of pH needed with limestone or sulfur applications. Also, getting test results in the fall helps you plan your fertilizing needs for the coming year's garden. Contact your Cooperative Extension office about soil testing.

Adjusting pH

If soil test results indicate that your soil's pH falls out of the ideal range of 6.2 to 6.8, you may need to add lime or sulfur, depending on your soil's pH value. If the pH is too low, then your soil is too acid and you should either add calcitic or dolomitic limestone (Table 20.2). If the pH value is too high, your soil is too alkaline and you need to add sulfur (Table 20.3). Applying lime or sulfur in the fall before planting is best because you have a longer soil reaction time. Lime rates shown in Table 20.2 are in terms of agricultural limestone. By regulation in Kentucky, aglime must have a purity equivalent to 80% or higher pure calcium carbonate. It must be ground finely enough so that 90% will pass through a 10-mesh screen and 35% will pass through a screen size of 50-mesh. The purity (% calcium carbonate equivalent) is an index of the amount

Table 20.3. Suggested application of ordinary powdered sulfur to reduce the pH of an 8-inch layer of soil, as indicated in pt/100 sq ft.[1]

Original pHof Soil[2]	Pints of sulfur for 100 sq ft to reach pH of:									
	4.5		5.0		5.5		6.0		6.5	
	Sand	Loam	Sand	Loam	Sand	Loam	Sand	Loam	Sand	Loam
5.0	⅔	2	---	---	---	---	---	---	---	---
5.5	1 ⅓	4	⅔	2	---	---	---	---	---	---
6.0	2	5 ½	1 ⅓	4	⅔	2	---	---	---	---
6.5	2 ½	8	2	5 ½	1 ⅓	4	⅔	2	---	---
7.0	3	10	2 ½	8	2	5 ½	1 ⅓	4	⅔	2

1 Although aluminum sulfate often is recommended to gardeners for increasing the acidity of the soil, it has a toxic salt effect on plants if it is used in large amounts. Small amounts are not very effective. About seven pounds of aluminum sulfate are required to accomplish the same effects as one pound of sulfur.
2 Based on water pH value.

Table 20.4. Phosphate, potash, and nitrogen.

Soil Test Level	Fertilizer (lb/1000 sq ft)	
	P_2O_5	K_2O
High (above 60 P, 300 K)	0	0 - 1
Medium (60 - 30 P, 300 - 200 K)	1 - 2	1 - 2
Low (below 30 P, 200 K)	3 - 5	3 - 5
Nitrogen: For a continuously cropped garden where little or no organic matter has been added, apply 2 lb of actual N/1000 sq ft before planting. Following heavy grass sod, apply 3 lb of actual N/1000 sq ft before plowing. Where heavy applications of barnyard manure or compost have been added, apply no nitrogen.		

of active ingredient per unit weight, while particle size of the liming material is an index of how rapidly the material will dissolve when mixed with soil. The more finely ground the liming material, the faster it dissolves.

Use of Wood Ashes

Wood ashes have some use as a liming material, although they are relatively scarce. Their rather low neutralizing value ranges from 30% to 70%, expressed as calcium carbonate. The ash of hardwoods, such as maple, elm, oak and beech, contains about one-third more calcium mainly as the oxide, but, on exposure to moisture, they are largely in the carbonate form by the time they are applied to soil.

Coal ash has little or no liming value. Do not use it on garden soils because it contains a fairly high concentration of heavy metals and other toxic compounds which may be taken up by the plants.

For organic gardeners, only powdered or prilled elemental sulfur can be used for lowering pH, while aluminum sulfate, a synthetic product, is not allowed. Powdered sulfur should take at least one year to oxidize and reduce soil pH, and prilled sulfur will take slightly longer. Organic growers should be conservative in the application of soil sulfur by splitting the total application between the fall and spring as sulfur has both fungicidal and insecticidal action and can detrimentally affect soil biology if overused. Organic gardeners can use any type of agricultural limestone to increase pH.

Preparing a New Garden Site

As soon as the soil is workable in the spring, turn over the sod of a new garden site by plowing, rototilling or hand spading. Prepare the soil at least 8 inches deep. Increase this depth each year until you reach 10 to 12 inches. Do not work the soil when it is very wet because you can damage its structure by compacting it. If the soil crumbles readily rather than sticking together, you can proceed safely.

Continue to work the plot until the coarse, lumpy texture is replaced with a fine, granular one suitable for a seedbed. Do not overwork the soil to a powdery fine condition which will cause surface crusting. After you have appropriately tilled the soil, add organic material and fertilizer as recommended.

If you want raised beds, throw the soil from the paths into 3- to 4-foot-wide beds after adding organic matter and the recommended fertilizer. This extra soil plus the added organic matter will raise the beds a few inches higher. If you like, boards or stones can hold the soil in place. For the last preparation step, rake the soil surface smooth and lay off rows. Now you are ready to plant seeds or set transplants.

Organic Matter

Add organic matter to the soil each spring and fall. You can also add it as mulch during the growing season and as a green manure or cover crop during or after the growing season. Adding organic matter is the most beneficial treatment for improving and maintaining your garden soil. It loosens and improves the drainage and aeration of heavy clay soils while increasing the moisture-holding ability of very light, sandy soils.

Besides helping the soil structurally, organic matter favors a buildup of organisms which in turn helps make available nutrients that were previously held in the soil in unusable forms. The organic matter itself provides nitrogen and other nutrients as it decays.

The type of organic matter you should add will depend on what materials are most available. Some sources are manure, composted leaf mold, grass clippings and pine bark humus. Caution: Do not apply fresh manure with a high nitrogen content in the spring. Rabbit, chicken and sheep manure should be applied in the fall or composted before they are used on the garden. Fresh manure may also contain bacteria that are harmful to humans.

Use of manure in organic systems is allowed with major limitations. Raw manure must always be incorporated into the soil immediately following application and it must be applied 120 days before harvest for all crops. Though the use of raw manure is allowed in organic systems, it is far preferable to properly compost the manure before using it as a soil amendment or fertilizer source.

Conventional Fertilizers

A continuous supply of nutrients is important for producing high yields of quality vegetables. Conventional fertilizers are a convenient and economical way of supplying these nutrients. However, they must be used properly since plants can be damaged by their improper application or excessive use.

Example 1:
The size of your garden is 800 sq ft, and you intend to use 5-10-10 fertilizer:

Step 1: Determine the **amount of nitrogen** needed for an 800 sq ft garden.
Desired rate: 2 lb of nitrogen per 1,000 sq ft.

formula:

		desired rate:				
garden size (sq ft)	÷	1,000 sq ft	x	2 lb	=	**actual N** needed (lb)
800	÷	1,000	x	2	=	**1.6 lb**

Step 2: Determine the **amount of 5-10-10 fertilizer** needed to supply the nitrogen calculated above (1.6 lb). 5-10-10 fertilizer contains 5% actual N. Convert 5% to 0.05, and solve:

formula:

actual N needed (lb)	÷	N available in chosen fertilizer (%)	=	**chosen fertilizer** needed (lb)
1.6	÷	0.05	=	**32 lb**

Example 2:
The size of your garden is 1,475 sq ft, and you intend to use 12-12-12 fertilizer:

Step 1: Determine the **amount of nitrogen** needed for an 1,475 sq ft garden.
Desired rate: 2 lb of nitrogen per 1,000 sq ft.

formula:

		desired rate:				
garden size (sq ft)	÷	1,000 sq ft	x	2 lb	=	**actual N** needed (lb)
1,475	÷	1,000	x	2	=	**2.95 lb**

Step 2: Determine the **amount of 12-12-12 fertilizer** needed to supply the nitrogen calculated above (2.95 lb). 12-12-12 fertilizer contains 12% actual N. Convert 12% to 0.12, and solve:

formula:

actual N needed (lb)	÷	N available in chosen fertilizer (%)	=	**chosen fertilizer** needed (lb)
2.95	÷	0.12	=	**24.5 lb**

Any fertilizer's value can be determined by its analysis in percentage of nitrogen, phosphorus and potassium. Applying fertilizer according to soil test results allows less chance of under- or over-fertilization (Table 20.4).

Sometimes simple calculations must be made to determine how much fertilizer to add to a garden. These examples use complete fertilizers. If your soil test indicates only a need for nitrogen, use a high nitrogen fertilizer such as 44-0-0 or 33-0-0 instead of a complete fertilizer such as 5-10-10 or 12-12-12 which will supply more nutrients that you actually need in the garden. Follow the steps in the examples on page 251, Examples 1 and 2.

Apply the recommended amounts of fertilizer in the spring. Spread the fertilizer evenly over the garden area before plowing or spading, or after plowing and before rototilling or hoeing in preparation for planting.

If you did not have your soil tested (i.e., if you have a very limited garden area), the following amounts may be applied:

- small garden: 4 lb 33-0-0 or 3 lb 44-0-0/1,000 sq ft
- smaller garden: 0.4 lbs (~1/2 cup) 33-0-0 or 3 lb (1/4 cup) 44-0-0/100 sq ft

For container gardens use a complete fertilizer (5-10-10 or 10-10-10) at a rate of 1 oz/bushel (or 2 Tbs/bushel).

This is a modest recommendation and assumes the presence of some available nitrogen in the soil for plant growth. If you use the same soil or area the next year, you should have the soil tested to prevent under- or over-fertilization.

Organic Fertilizers

Organic fertilizers are just as effective as conventional fertilizers in supplying necessary plant nutrients though they are often more expensive, harder to find and often act more slowly than conventional fertilizers. The preferred manner for certified organic growers to address plant nutrition is to start with a soil management plan that includes the extensive use of compost, crop rotation and cover cropping (see pages 267-270). Once the nutrient contributions of applied compost and turned in cover crops are calculated, then commercial organic fertilizers, preferably from a local source, could be used to "fill the gap" between what has been provided and what a future crop may need.

There are many classes of organic fertilizers ranging from concentrated plant material (alfalfa meal, soybean meal), animal slaughter by-products (blood meal, bone meal), fish by-products (liquid fish emulsion), concentrated animal manures (bird guano), rock minerals, and many micro-nutrient sources. The majority of organic fertilizers are not as soluble in water as conventional fertilizers, and thus are not as immediately available for plant uptake. Instead, microorganisms found in the soil must break down or decompose the organic fertilizer before it becomes completely available to plants. The use of the word "organic" on a fertilizer label does not always mean the fertilizer is allowed for certified organic growing purposes due to differing state and federal regulations relating to the use of the word "organic." Only fertilizer labels that include the words "certified organic" or those fertilizers tested and labeled by the *Organic Materials Review Institute* (OMRI) are truly allowed for use on a certified organic farm or garden.

Crop Rotation

As you continue your vegetable garden from year to year, try to avoid planting the same or closely related crops in exactly the same spot more than once every three years. Rotation helps prevent insect and disease buildups. The vegetables listed together below are subject to the same disease and insect problems.

- chives, garlic, leeks, onions, shallots
- beets, Swiss chard, spinach
- cabbage, cauliflower, kale, collards, Brussels sprouts, broccoli, kohlrabi, turnips, rutabaga, Chinese cabbage, mustard
- peas, broad beans, snap beans, lima beans
- carrots, parsley, celery, celeriac, parsnip

- potatoes, eggplant, tomatoes, peppers
- pumpkins, squash, watermelons, cucumbers, muskmelons
- endive, salsify, lettuce

In addition, root and bulb crops are susceptible to many of the same soil pests so try to rotate these every year.

Pest Control

The goal of many home gardeners is to apply few or no pesticides. This philosophy often results in unacceptable harvests because the gardener is often faced with a dilemma of either applying pesticides or experiencing a significant or total crop loss. While it is difficult to achieve consistent harvests from your garden without some strategy for pest control, the following principles may help you use pesticides more sparingly and still achieve acceptable results.

Pest-resistant crops—Cultivars of some vegetable crops are genetically resistant to certain pests. By choosing these cultivars, the gardener increases their chances of avoiding problems with specific pests. An extensive list of vegetable cultivars, including information regarding their genetic resistance to specific pests, can be found in ID-133, *Vegetable Cultivars for Kentucky Gardens* (http://www2.ca.uky.edu/agc/pubs/id/id133/id133.pdf). The gardener should be aware that there are no "super" cultivars able to resist all known pests and that some pest control may still be needed to ensure a harvest. But using resistant cultivars should lessen the need for pesticides.

Spacing and sun exposure—Avoid crowding plants together in the garden. Crowded plants grow poorly and may become more susceptible to pests. There is also less air movement through crowded plants that may result in increased problems with disease. Garden plants are generally adapted to growth in full sun. Trying to garden in a shady backyard may result in weak, unproductive plants that are more susceptible to pests. Try to ensure that your garden receives at least six hours of direct sunlight each day.

Cultural practices—Make sure plants have adequate water and nutrition. Both over- and under-watering or fertilizing plants may enhance pest problems. Proper watering and fertilizing techniques were covered in the first part of this publication. Also ensure that you clean up the garden once a crop has finished or the season had ended. Many pests overwinter or continue their lifecycles on residue from the previous crop. Destroy or thoroughly compost (better to destroy if a pest infestation is evident) crop residue once harvest is complete. Also consider rotating crops that may be susceptible to soil-borne pests—see "Crop Rotation" on page 251.

Scout for problems—Spy before you spray! Most home gardeners are keenly aware of what's going on in their gardens. As you check germination of newly planted seeds, monitor development of vegetables, and harvest ripe fruit, look for problems. If you do see problems, are you confident in your ability to diagnose them correctly? For help with diagnosis, consult other parts of this publication, gardening books, or your local county extension office (detailed photos or samples of the problem will aid the diagnosis). A correct diagnosis is key to successful pest management or control.

Planting

General Considerations

Buying Seed

Buy fresh, high quality seed from a local seed store, garden center or mail order seed catalog for your vegetable garden. Using seed from the previous year's plants is generally not recommended for the beginning gardener since such seed may not germinate well or may not breed true. You can refrigerate commercial seed in a glass jar with something to dry it (for instance, powdered milk). The seed can then be used later.

Planting

The soil should be moist at planting time but not overly wet. To test for moisture content, squeeze together a handful of soil. If it crumbles readily rather than sticking together, proceed with planting. Drop vegetable seed into furrows in continuous rows. To make straight rows, drive stakes at each end of the garden and pull a string taut between them. Then draw a hoe or rake handle along the string to make a shallow ½-inch furrow for fine seed. Use the corner of the hoe blade to make a deeper 1-inch furrow for larger seed. Measure the distances between rows with a yardstick.

Empty seeds into your hand and drop them from between your fingers. Mix dry, pulverized soil or sand with very small seeds to make even distribution easier. Plant the seed more thickly than needed in case some do not germinate. Cover the seeds and firm the soil lightly over them using the bottom of a hoe blade.

Some seeds, like carrot and parsley, take a long time to germinate—often three to four weeks. If the seeds dry out during germination the seedlings will die, so be sure to keep these rows moistened. You can also put a board or a strip of plastic or burlap over the row to give the seedlings a warm, moist greenhouse environment. Remove this cover just after the seedlings emerge.

Thinning

After germination, you'll need to thin the seedlings to correct their spacing. When your plants have two or three leaves, pull up the weakest ones or pinch off the tops, leaving the rest of the plants spaced correctly (Table 20.5).

The soil should be moist when you thin so you do not injure the remaining plants in the process. Do not wait for the plants to become overcrowded before thinning. With some vegetables, thinning can be at harvest. Beet and turnip thinnings make excellent greens. Radishes, onions and lettuce can be left to thin until some are big enough to eat.

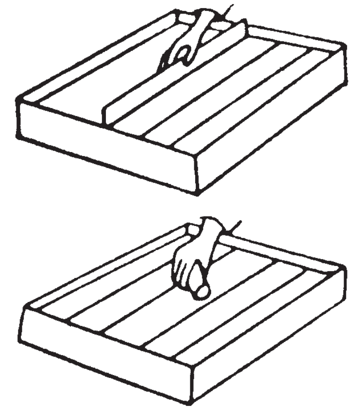


Figure 20.3. A large tray can be sectioned into rows using a ruler or similar sharp-edged instrument. Once seeds are sown in the "furrows," cover the seeds with a growing medium using a blunt instrument or your hand.

Transplants

Why Grow Your Own Transplants?

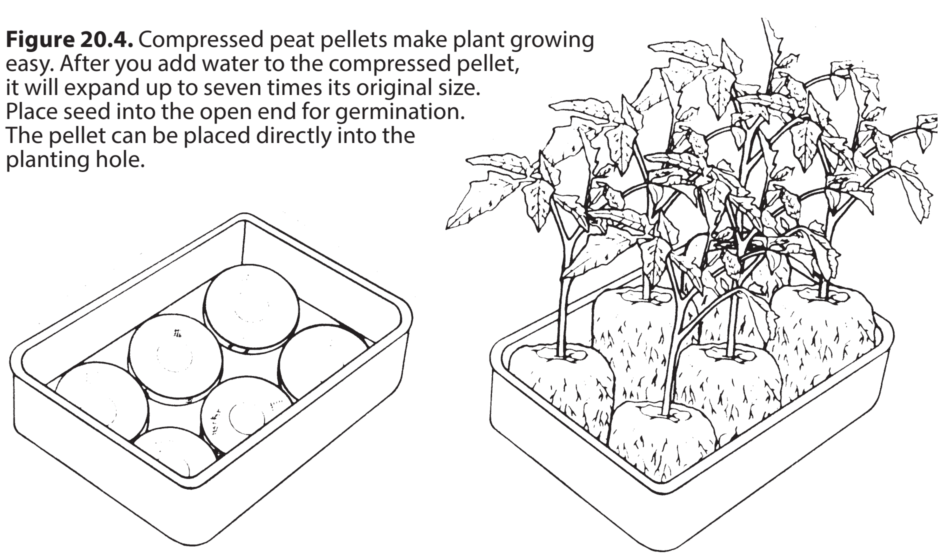
Having the varieties you want when you want to plant them—that's the great advantage of growing your own transplants.

The flip side of that coin is quality. If you can't provide good growing conditions, particularly plenty of bright light for growing seedlings, the quality of your homegrown plants may not be all you desire.

The big advantage of growing transplants yourself is the wide choice of varieties available in seed. People who produce transplants commercially tend to concentrate on a few popular varieties of each crop. Seed catalogs offer a much wider selection.

If you plant the seeds at the appropriate time and the seedlings grow well for you, you can have transplants that are just the right size for planting in the garden at just the right time (Table 20.6). You can have cool-weather crops like broccoli and kohlrabi to plant early in the spring and again in midsummer for a fall crop. And you can have warm-weather crops like tomatoes for planting after the danger of frost is past.

Figure 20.4. Compressed peat pellets make plant growing easy. After you add water to the compressed pellet, it will expand up to seven times its original size. Place seed into the open end for germination. The pellet can be placed directly into the planting hole.



Materials

You can successfully grow vegetable transplants indoors or outdoors if you use a suitable growing structure. While a greenhouse is not essential, being able to control temperature, light, moisture and ventilation is crucial. Day temperatures should be between 60° to 65°F for warm-season crops. Keep the soil moist but not soggy.

You can buy all the materials you need for starting transplants under different brand names from local garden supply centers or through seed and garden supply catalogs. Plant starting kits containing all the necessary equipment are also available. Some have the seed already planted; you only need to add water and put them in a suitable growing area.

Fertilize the plants when the second true leaves appear. Use a liquid fertilizer, such as 20-20-20 or liquid fish emulsion, at rates recommended on the package. Fertilize again in another week or two.

Pots made of peat are good for growing transplants, because plant roots can easily grow through the sides. Do not remove the peat pot when you transplant, and it will gradually decompose. Keeping the plants in the same container reduces transplant shock and helps produce crops a few days earlier than scheduled. You can use egg cartons and paper cups, but be sure to punch holes in the bottoms for good water drainage. Also, cut away these containers before transplanting. Put individual pots in plastic, metal or wooden trays for growing and for convenience when you water and handle them.

Growing Transplants Indoors

For indoor growing, sow seeds in a plant tray containing an artificial growing medium of peat moss and perlite available at garden centers. Adding compost to the potting media at up to 25% of total volume can reduce the need for fertilizers later and potentially encourage seed germination. Enclose the seeded trays in a plastic bag and keep them at room temperature until seedlings begin to emerge. Then, remove the plastic and transfer the trays to suitable growing areas.

The average windowsill is one location for growing plants, but it usually does not get enough light. So, you have to use artificial light to supplement. Use cool white fluorescent lamps alone, a mixture of cool white and warm white fluorescent lamps, or a mixture of cool white and plant growth fluorescent lamps. Locate the lamps 5 to 10 inches from the foliage and operate them 12 to 18 hours/day. Be sure to keep seedlings cool enough (60° to 65°F) for strong, sturdy growth after they germinate.

Plants should be "hardened off" about two weeks before planting them in the garden. That is, you toughen

Table 20.5. Use this vegetable planting guide to plant vegetables the right way.

Vegetable	Number of Transplants or Seeds per ft	Distance Between: Plants When Thinned or Transplanted (in)	Distance Between: Rows (in)	Planting Depth (in)
Asparagus	1 crown	18	30	6-8
Beans, bush, lima	6-8 seeds	4-5	30	1-1 ½
Beans, bush, snap	8 seeds	2-3	30	1-1 ½
Beets	10 seeds	2-3	18	¼-½
Broccoli	1 transplant	14-18	30	
Brussels sprouts	1 transplant per 2 ft	24	36	
Cabbage	1 transplant	9-18	30	
Carrots	15-20 seeds	2-3	18	¼
Cauliflower	1 transplant	16-18	30	
Celery	2 transplants	6-8	30	
Chard	8-10 seeds	6-8	30	¼-½
Chinese cabbage	4-6 seeds	12-15	24-30	¼-½
Collards	8-10 seeds	2-4	24	¼-½
Cucumbers	4-5 seeds	24-36	30	½-1
Eggplant	1 transplant	18	30	
Endive	4-6 seeds	9-12	18-30	½
Garlic, from cloves	1 clove	6	12-18	1 ½
Horseradish	1 root	18	30	2
Kale	4-6 seeds	8-12	24-30	¼-½
Kohlrabi	6-8 seeds	3-6	18-30	¼-½
Leeks	10-15 seeds	3-4	20	½
Lettuce, head	1 transplant	12-18	20	¼
Lettuce, leaf	20-30 seeds	½	8-12	¼
Muskmelons	2-3 seeds	24-36	60	½-¾
Mustard	20 seeds	3	18	¼
New Zealand spinach	4-6 seeds	12	30	½
Okra	3 seeds	12	30	1
Onions, from seed	10-15 seeds	4	12-18	¼-½
Onions	3-6 sets	4	12-18	1-2
Parsley	10-15 seeds	4-6	12-18	¼-½
Parsnips	12 seeds	2-3	18	½-¾
Peas	15 seeds	Do not thin	30-48	1
Peppers	1 transplant	14-18	30-36	
Potatoes	1 seed piece	10-12	36	3-5
Pumpkins	1-2 seeds	4 ft	8-12 ft	1
Radishes, spring	10-15 seeds	2-3	12	¼
Radishes, winter	10-15 seeds	2-4	12	¼
Rhubarb	1 crown per 2 ft	36	4-5 ft	
Rutabaga	4-6 seeds	6-8	18-30	½
Southern pea	3-4 seeds	2-3	30	
Spinach	6 seeds	4-6	12-18	¼
Squash, summer	2-3 seeds in hill	24	48	1
Squash, winter	1-2 seeds	48	6-8 ft	1
Sweet corn	2 seeds	8-10	30	1-2
Sweet potatoes	1 slip	15	36	
Tomatoes	1 transplant per 2 ft	24	36	
Turnips (roots)	6-8 seeds	3-4	12-15	½
Turnips (greens)	10-12 seeds	2-3	12-15	½
Watermelons	2-3 seeds in hill	6-8 ft	72	1

Table 20.6. Transplant production data.

Crop	Weeks from Seeding to Transplanting[4]	Average Seedling Date	Seed Depth (in)	Seed Spacing		Soil Temp. (°F) Needed for Seeds to Germinate	Average Days to Emerge	Satisfactory Growth Temp.	
				Seeds/ in	Rows Apart (in)			Day (°F)	Night (°F)
Cool Season[1]									
Broccoli[2]	5-7	Feb 5, July 1	¼	8	2	80	4-6	65	60
Brussels Sprouts	5-7	Feb. 5, July 1	¼	8	2	80	4-6	65	60
Cabbage	5-7	Jan. 20, July 1	¼	10	2	85	3-5	55	50
Cauliflower[2]	5-7	Jan. 25, July 1	¼	8	2	80	4-6	65	60
Lettuce	5-7		¼	--	2	75	2-3	60	50
Onion	10-12		¼	--	2	75	4-5	65	55
Warm Season									
Cucumber[3]	3-4	April 1	1	2 seeds per 4" x 4" pot, thinned to 1		95	3-6	75	70
Muskmelon[3]	3-4	April 1	1			90	4-6	75	70
Squash[3]	3-4	April 1	1			95	5-7	75	70
Watermelon[3] (seeded)	4-6	Mar. 25	1			85	4-6	75	70
Watermelon[3] (seedless)	4-6	Mar. 25	1			90	4-6	75	70
Tomato	4-7	Mar. 15	½	10	2	80	7-9	70	60
Eggplant	6-8	Mar. 10	¼	10	3	80	7-9	75	70
Pepper	6-8	Mar. 10	¼	10	2	80	8-10	70	65

1 Cool-season crops are frost tolerant and can be set in the garden before the last frost. Warm-season crops are susceptible to frost and should not be set until the danger of the last frost is past.
2 Do not allow broccoli or cauliflower to become deficient in nitrogen or water or exposed to cold temperatures when they are small.
3 Seed into individual containers (peat) that may be placed directly into the soil, because these crops will not tolerate root disturbance.
4 Allow an extra two weeks growing time if grown in plant beds.

the plants so that they can withstand the outside environment. To do so, begin exposing them to lower temperatures. One way is to take your transplants outside in the daytime and bring them in at night. However, don't let them get caught in a frost. Reduce your watering and fertilizing of transplants to help "hardening off" about one week before transplanting. Do not let them dry out and wilt, however.

Growing Transplants Outdoors

Structures used for growing transplants outdoors may or may not be artificially heated.

The cold frame for housing transplants receives no artificial heat. Use the sun to its greatest advantage by locating these structures on the south side of a building (Figure 20.5). Cold frames are used for holding or "hardening off" transplants.

The hotbed is a cold frame structure which includes an additional source of heat. Heat may be supplied from fermenting horse manure, electric cable or light bulbs. Transplants are usually grown in pots set over a 2- to 4-inch layer of composted soil or sand. If horse manure is used or if plants are grown in the bed rather than in pots, use a 4-inch layer of compost as a base. If electricity is the heat source, only a few inches of sand are required for a base, and transplants like cabbage, cauliflower, broccoli and lettuce may be sown directly in the composted soil base.

Buying Healthy Transplants— A Good Investment

Sometimes what appears to be a good buy because it's inexpensive may turn out to be a poor investment in transplants. Transplants which were seeded at the right time and were grown at the right temperature, in abundant light and adequate moisture, will be compact, with the distance between leaves very small. The stems will be pencil thick and rigid. Leaves will be dark green, large and upright with no tendency to droop. Transplants that are trying to produce flowers or fruit are not as desirable as those which are strictly vegetative. Plants trying to produce fruit are slow to develop good root systems to support later fruit production.

Bare root plants will be slower to establish than transplants grown in cell packs or containers. Sometimes, plants are packed in large bundles and shipped great distances. To save space, these plants are clipped before shipping to reduce the amount of top growth. This is a poor practice since it not only induces transplant shock and delays fruiting but spreads disease as well.

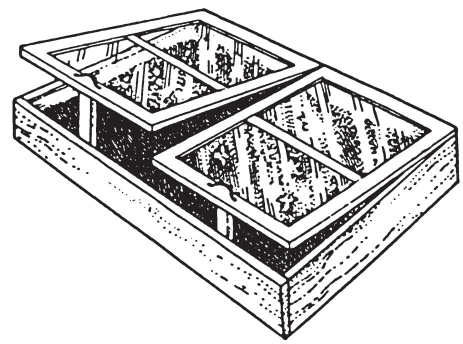


Figure 20.5. Cold frame. Scrap lumber can be used to build the basic frame. The hinged top can be made from old windows or a frame covered with clear plastic.

When purchasing transplants, be sure to ask whether the plants have been hardened off. If not, it is important to place them in a cool spot and reduce water for a couple of days to acclimate the plants to outside conditions.

Moving Transplants to the Garden

Whether you buy plants or grow your own, the time comes to plant them outside.

Transplanting gives a plant more space to develop, but it will temporarily check growth, not stimulate it. Therefore, for successful transplanting, try to interrupt plant growth as little as possible. In doing so, peat pots give you an advantage, even though they are expensive, because they do not have to be removed. Follow these eight steps when transplanting:

1. Transplant on a shady day in late afternoon or in early evening to prevent wilting.
2. Soak transplants' roots thoroughly an hour or two before setting them in the garden.
3. Handle the plants carefully. Avoid disturbing the roots.
4. Dig a hole large enough to hold the roots. Set the plants to the lowest leaf at recommended spacings. Press soil firmly around the roots.
5. Pour 1 cup of starter solution in the hole around the plant. Starter solutions are high analysis fertilizer solutions for rapid transplant root development. To prepare, mix plant food with 15-30-15, 10-53-17 or 20-20-20 analysis at the rate of 2 Tbs/gallon of water. Any liquid organic fertilizer, like fish emulsion, can also be used as a started solution by following the recommendations on the package.
6. Put more soil around each plant, but leave a slight depression for water to collect. Break off any exposed parts of peat pots so that they will not act as wicks and pull water out of the soil.
7. Shade the plants for a few days after transplanting on a very hot day by putting newspapers or cardboard on their south sides.
8. Water the plants once or twice during the next week.

Growing More with Less Space

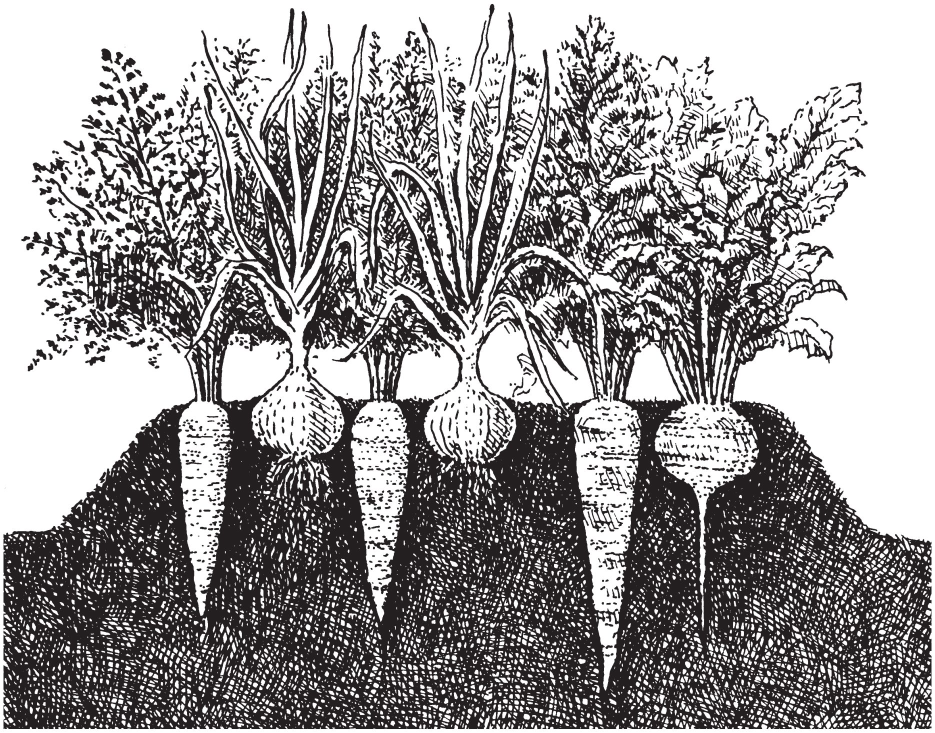


Figure 20.6. Raised bed.

Intensive Gardening

Conventional gardens, planted in rows about 3 feet apart, have been popular for many years because they can be planted and easily cultivated with a farm tractor or a rototiller. However, because of the wide spaces between rows, such gardens are not very space efficient. Gardeners with limited land area may want to plan an intensive garden.

Intensive gardens employ space-saving techniques such as wide-row planting, raised beds, intercropping, succession planting, vertical training and planting in stairstep arrangements. Extending the growing season using plant protectors is another technique of intensive gardening. Lettuce, radishes and other cool-season crops can be grown early in the spring or late in the fall with such protection.

Keep in mind that some intensive techniques may require more time, labor and money than conventional techniques. Also, closely spaced plants use more water than widely spaced plants, and competition for water may reduce yields during times of drought.

In wide-row planting, vegetables are planted in wide rows between narrow pathways as opposed to single rows with wide spaces between the rows. The vegetables are spaced so that they will just touch one another at maturity. This method of gardening may reduce weed problems, although hand weeding will be more difficult. Since less soil remains bare than in conventional gardens, usually less erosion occurs.

Be aware that vegetables prone to certain diseases should not be planted too intensively. Tomatoes, for example, will suffer less from disease if moving air dries their leaves. When placed too closely, plant leaves retain moisture longer, and disease organisms thrive and are easily spread from plant to plant.

Raised Beds

Raised beds increase production by conditioning the soil for excellent root development (Figure 20.6). In an area 3 to 4 feet wide, you loosen the soil and mix it with organic matter and fertilizer (see "Preparing the Soil"). Then, once you've constructed the raised beds and permanent paths between the beds, you no longer disturb the soil. Combining raised beds with other intensive practices such as wide-row planting, intercropping or succession planting gives the greatest yields in a garden. In addition, the excellent drainage in raised beds often permits early planting, though raised beds also will dry out faster than level ground later in the season. Use mulches to retain moisture in your raised beds.

Intercropping

Intercropping involves planting different vegetables side by side to take advantage of the different times of maturity, heights, spreads or rooting depths.

- A classic example of intercropping involves corn, beans and squash. A few weeks after sowing corn seeds, you plant pole beans close to the corn rows to use the corn stalks for support.
- As another example, you can set tomato transplants between lettuce plants; the lettuce matures and is harvested before the tomato plants grow very large.
- Also, try sowing radish seeds with carrot seeds. The radishes germinate quickly, marking the row of slowly sprouting carrots. Radishes are harvested within a few weeks, long before they interfere with the carrots.

Many other intercropping ideas will develop from your own gardening experience. Remember, however, that yields of certain vegetables may be reduced when crowded.

Succession Planting

In succession planting, another seed or transplant immediately takes the place of a harvested plant. For example, when you harvest a lettuce plant in early summer, a Swiss chard or New Zealand spinach transplant can replace it. After harvesting an early crop of sweet corn, you might follow with a fall crop of broccoli, spinach or snow peas.

Vertical Training

Vertical training involves growing plants upright rather than horizontally. You can vertically grow vine crops, tomatoes, peas and beans on wood, wire or string trellises, or in cages. Besides having more plants per square foot, you will also have cleaner fruit that will be easier to harvest.

Stairstep

The stairstep arrangement is a form of vertical planting that lends itself especially well to small plants, such as lettuce, spinach and onions. Basically, stairsteps change a two-dimensional space into a three-dimensional one, usually with wooden bins in pyramid shapes. You can also use metal strips, small stone walls, bricks or concrete blocks to hold the soil in place. As with raised beds, you will need to pay careful attention to watering of plants grown in such arrangements.

Container Gardening

Even if you live in an apartment or condominium with only a balcony, patio or walkway available for gardening, you can still enjoy many of the rewards of vegetable gardening.

Container gardening can provide you with fresh vegetables as well as recreation and exercise. Many container-grown vegetables also have ornamental value and can enhance your home. Using containers allows you to take advantage of the various microclimates in your vicinity. For example, lettuce can be grown in a cool, shaded area while heat-loving plants, such as eggplant, can be located in full sun where reflections from buildings or patio surfaces add to the heat.

Feeding and watering plants is easier if you use big containers, since small ones need more frequent attention. Choose the container size to match the plant's growth requirements.

Choosing Vegetables for Containers

As a rule nearly all leafy vegetables will do well in containers. Plant breeders have developed many dwarf or miniature varieties for container production.

Crops with many fruits per plant such as tomatoes are good choices. Table 20.10 lists some of the vegetables and their requirements for container production.

A 12" x 48" x 8" box makes an excellent patio herb garden. Chives, garden thyme, basil, marjoram and summer savory will all do well in such a planter box. The sprawling growth habit of the various mints, oregano and rosemary make them attractive in hanging baskets. Typical container sizes are listed in Table 20.7.

Containers

Material—You can use containers made of clay, wood (redwood or cedar), plastic or metal for growing vegetables. Also consider using barrels, flower pots or window boxes. Unusual containers will add interest to your garden.

Holes—Each container must have drainage holes in the bottom so the plant roots will not stand in water. If the container does not already have holes, make at least four small nail holes in its sides, ½ inch from the bottom.

Size—The container should be the proper size for the plant growing in it (see Table 20.9 for types and sizes of growing containers).

Planting in Containers

Some vegetable seeds are planted directly in the containers where they will be growing. Others are set in as transplants.

Use a commercially prepared greenhouse soil mix, available at local garden centers or greenhouses, to grow plants in containers. If you're going to have several large containers, you may want to mix your own soil. The soil mix (Table 20.8) is good for container gardening because it is lightweight and sterile.

Planting Procedure

Moisten the soil mix the day before you intend to plant for best results. Many mixes contain a high percentage of peat, which requires time to soak up water. Peat moistens faster with hot water than with cold water. A drop of dishwashing soap will help wet dry potting mixes.

- Fill a clean container to within ½ inch of the top with the mixture.
- Follow the seed package's instructions for planting.
- Sow the seed more thickly than needed in case some do not germinate.
- Put a label with the name and variety of the vegetable and the date of planting in each container.
- Water the seed gently with a watering can after sowing, being careful not to wash out the seed. Or, put a burlap bag over the container to reduce water impact.
- Thin the plants for proper spacing when they have two or three leaves.

Care

Pay particular attention to watering container vegetables. Container soils can dry out very quickly, especially on a concrete patio in full sun. Daily watering may be necessary. Water when the soil feels dry. However, do not go to extremes. The soil should not be soggy or have water standing on top of it. Apply water until it runs out the drainage holes.

Protect plants from very high heat caused by light reflection from pavement or a building. If necessary, move them to a cooler spot or shade them during the hottest part of the day. Plants may also need to be taken to a more sheltered location during severe rain or wind storms.

Table 20.7. Typical container dimensions, and their corresponding size in gallons.

Inches	Gallons
7 ¼" x 6 ¼"	1
8" x 8"	2
10" x 10"	3
12" x 11"	4
12" x 12"	5
13" x 13"	6

Table 20.8. Soil mix for container plants.

1 part composted or sterilized[1] garden soil
1 part sphagnum peat moss (Canadian)
1 part perlite
½ cup dolomitic limestone/bushel
¼ cup superphosphate/bushel

[1] To sterilize, put moistened soil in a cake pan and heat at 200°F for 46 - 60 minutes, or put in a glass pan in a microwave oven for 15 - 20 seconds.

Table 20.9. Types and sizes of growing containers.

Type	Dia.	Hgt.	Vol.
2 inch pot	2"	3 ½"	1 pt
6 inch pot	6"	5 ½"	3 pt
No. 10 can	6"	7"	3 qt
8 inch planter	8"	8"	1 ½ gal
10 inch planter	10"	9"	2 ½ gal
½ bushel basket	13"	9 ½"	4 gal
5 gal can	11"	12 ½"	5 gal
1 bushel basket	17 ½"	11 ½"	8 gal

Table 20.10. Container vegetable recommendations.

Season/ Light Req.	Spacing/ Container Size	Varieties	Days to Harvest
Bean (green, bush type)			
Warm Full sun	5 - 6″ apart 8 - 10″ deep	Romano Bush	50
		Blue Lake Bush	58
		Tendercrop	54
Beets			
Cool Tolerates partial shade	2 - 3″ apart 24″ x 36″ x 8″	Kestrel	53
		Red Ace	53
		Merlin	55
		Detroit Supreme	59
Broccoli			
Cool Full sun	15″ apart 12″ x 48″ x 8″	Green Comet	55
		Emperor	60
Cabbage			
Cool Full sun	12 - 24″ apart 10″ deep	Fast Vantage	65
		Stonehead	70
		Market Prize	76
		Super Red 80	82
Carrots			
Spring, Fall Partial shade	1½ - 3″ apart 24″ x 36″ x 10″	Ya Ya	56
		Sugarsnax	68
		Little Fingers	65
Collards			
Cool, Fall Full sun	6″ apart 8 - 10″ deep	Champion	60
		Georgia/Southern	80
		Vates	80
Cucumbers			
Warm Full sun	12 - 16″ apart 12″ x 48″ x 8″	Sweet Success	55
		Sweet Burpless Hybrid	55
Eggplant			
Warm Full sun	1 per 4 - 5 gal container	Orient Express (Japanese type)	58
		Dusky	61
		Blackbell	70
	12″ apart 10 - 12″ deep	Fairy Tale	50
Kale			
Cool, Fall Partial shade	6″ apart 12″ x 48″ x 8″	Dwarf Blue Curled	55
		Vates	57
Lettuce			
Early spring, Fall Partial shade	4 - 6″ apart, leaf; 10″ apart, head 12″ x 48″ x 8″	Kentucky Bibb	54
		Buttercrunch	75
		Royal Oakleaf	50
		Red Sails	45
		Burpee's Iceburg	85
Onions (bulb)[1]			
Early spring Partial shade	2″ apart 6″ deep	Walla Walla Sweet	
		Candy	
Onions (green)			
Early spring or September Full sun	2″ apart 6″ deep	White Spanish Bunching (early)	

continued

Table 20.10. (continued)

Season/ Light Req.	Spacing/ Container Size	Varieties	Days to Harvest
Peas			
Cool Full sun	4 - 6″ apart 8 - 10″ deep	Little Marvel	62
		Sugar Ann	55
		Cascadia	58
Peppers			
Warm Full sun	14 - 18″ apart ½ - 4 gal	Carmen	75
		King Arthur	59
		Gypsy Hybrid	65
		Hot Anaheim	77
		Hungarian Wax	65
		Jalapeno	65
Radishes			
Early spring, Fall Full sun to light shade	1″ apart Any size, 6″ deep	Cherriette	26
		Cherry Belle	30
		Icicle	28
		Cherry Bomb	25
Spinach			
Spring, Fall Full sun to light shade	5″ apart Any size, 6″ deep	Tyee	42
		Melody	43
		Bloomsdale Long-Standing	48
Summer Squash			
Warm Full Sun	1 per 5 gal container	Black Magic (green zucchini)	44
		Gold Rush (yellow zucchini)	50
		Burpee Hybrid (green zucchini)	50
		Sunburst (yellow scallop)	52
Swiss Chard			
Spring, Summer, Fall Partial shade	4 - 5″ apart Any size, 6 - 8″ deep	Bright Lights	55
		Rhubarb Chard	60
		Fordhook Giant	60
Tomatoes[2]			
Warm Full sun, at least 6 hrs/day	1 per 4 - 5 gal container	Lizzano	65
		Terenzo	56
		Tumbler	49
		Superb Super Bush	75
Turnips			
Cool Partial shade	3 - 4″ apart 24″ x 36″ x 8″	Hakurei	38
		Purpletop Globe	55
		Seven Top	42
Zucchini			
Warm Full sun	1 per 5 gal container	Spineless Perfection (green)	45
		Golden Glory (yellow)	50
		Ambassador (green)	47

[1] In spring, plant long day variety; in fall, plant short day variety.
[2] Two plantings, one in mid to late April and the other in mid to late June, will extend the tomato harvest over a longer season. Transplants should be started four to seven weeks before planting time. Containers may be moved inside to protect plants from early or late season frosts.

Vegetables grown in containers should be fertilized regularly. Make the first application three weeks after the plants have two sets of leaves. Repeat once a week, using a soluble plant food at one-half strength (according to label directions).

Keep a close watch for insects and diseases which may attack vegetables. Identify any problems and take appropriate control measures.

After you harvest spring and early summer crops, replant the containers with vegetables for the summer or fall garden.

Mini-Gardens

Another solution to working with limited space is to plant several mini-gardens in vacant spots around your yard instead of putting all your vegetables in one plot. Some possible sites are near the kitchen door, along the sunny side of the house or garage, around the outdoor grill, along a walk in a flower bed or along a fence. Placed this way, vegetables serve a dual purpose as both food and landscape plants.

One Garden Plot: Three Garden Seasons

The Spring Garden

The spring garden contains cool-season crops that are planted and harvested from late winter to late spring. The seed of some of these crops can be planted directly in the garden soil, while others will need to be started in a greenhouse or other suitable growing area and then transplanted to the garden (Table 20.11).

Spring garden plants grow best with relatively cool air temperatures (50° to 65°F) and are raised either for their leaves, stems or flower buds. Peas are grown for their immature fruits. These crops produce their vegetative growth during spring's short, cool days. If they are planted too late in the spring, summer heat reduces their quality by forcing some to flower and form seeds (bolt), and others to develop off flavors, bitterness, poor texture and low yields.

Avoid these problems by planting spring vegetables as soon as the soil can be worked in the spring since light frost will not injure them. Plant either seeds or transplants, allowing the vegetables to reach edible maturity before hot summer days arrive.

Plant as soon as the soil is workable and dry enough so it does not form wet clods. Do not work the soil when it is wet. Doing so can ruin the texture for several years. Wait for the best conditions no matter how much the planting bug is nibbling at your fingers.

Do not use organic mulches in early spring. Rather, let as much sunlight as possible reach the soil to warm it. After May 1, you can use mulches to conserve soil moisture and help prevent weeds.

Plant spring garden crops together so that you can plant fall vegetables in the same area later. When "double cropping," do not plant closely related vegetables in the same rows because of possible disease and insect carryover from the spring crop.

Table 20.11. Crops for the spring garden.

Vegetable	Seeds	Transplants	Days to Maturity[1]
Beets	x		55-60
Bibb lettuce	x	x	60-80
Broccoli		x	40-90
Brussels sprouts		x	80-90
Cabbage		x	60-100
Carrots	x		60-80
Cauliflower		x	50-100
Celery		x	100-130
Chinese cabbage	x	x	43-75
Collards	x		75-90
Endive	x	x	60-90
Kale	x	x	50-60
Kohlrabi	x		50-70
Leaf lettuce	x	x	40-50
Mustard greens	x		35-60
Onions[2]	x	x	40-120
Peas	x		60-80
Potatoes[3]			90-140
Radishes	x		20-30
Spinach	x		40-70
Swiss chard	x	x	55-60
Turnips	x		40-60
Turnip greens	x		30-50

[1] Days given are for the early to late varieties.
[2] Onions are also available in sets.
[3] Potatoes are available as seed pieces.

The Summer Garden

As the harvest from your spring garden ends, the summer garden's crops should begin to produce. With careful planning you should have a continuous harvest of fresh garden vegetables.

Your summer garden should have a variety of crops, some harvested during the summer months, and others continuing to bear into fall (Table 20.12). Generally, summer crops are planted during the cool days of late spring through the warmer days when the danger of frost is past. Summer garden vegetables consist of:

1. Cool-season crops seeded or transplanted before the danger of frost is past, but able to endure hot weather at harvest times.

Table 20.12. Crops for the summer garden.

Vegetable	Frost-resistant	Seeds	Transplants	Days to Maturity[1]
Beets	x	x		55-60
Cabbage	x		x	60-100
Carrots	x	x		60-80
Collards	x	x		75-90
Cucumbers		x	x	45-65
Eggplant			x	60-75
Endive	x	x	x	50-60
Green beans, bush		x		50-60
Green beans, pole		x		60-90
Irish potatoes[2]				90-140
Kale	x	x		50-60
Leaf lettuce	x	x		40-502
Lima beans, bush		x		65-80
Lima beans, pole		x		65-90
Muskmelons		x	x	75-90
New Zealand spinach		x		70-80
Okra		x		50-80
Onions[3]	x	x	x	40-120
Parsley	x	x		70-90
Parsnips	x	x		90-110
Peppers			x	65-75
Pumpkins		x		90-120
Southern peas		x		60-70
Summer squash		x		50-55
Sweet corn		x		60-100
Sweet potatoes[4]			x	120-140
Swiss chard	x	x		55-60
Tomatoes			x	60-90
Watermelons		x	x	70-90
Winter squash		x		80-120

[1] Days given are for the early to late varieties.
[2] Irish potatoes are available as seed pieces.
[3] Onions are also available in sets.
[4] Sweet potatoes are available as rooted slips.
Note: Varieties which endure summer heat are available. Most of these crops can be seeded or transplanted during July and August and will develop quite well during midsummer's warm growing conditions, if you give them extra water and practice good insect pest control. As the crop develops, the cool, short days enable plants to accumulate sugar and flavor compounds providing the taste that makes many fall-grown crops so good.

2. Warm-season crops seeded or transplanted after the frost-free date. This later planting prevents both slow germination from cool conditions and frost injury to emerging plants. Warm-season crops require warm soil and air temperatures for vegetative growth and fruiting. Their quality is enhanced by long, warm days and mild nights.

Since crops vary in how much time they need to reach edible maturity, the summer garden should include short-, mid- and long-season crops.

The Fall Garden

Gardening doesn't have to end with your summer-grown crops since some vegetables are suitable for late summer planting. Plan to follow your spring and summer gardens with a fall garden so that you can have fresh produce well into the winter.

Plant crops according to your planting plan, grouping plants to be sure short ones are not shaded by tall ones. To encourage good germination, fill each seed furrow with water and let it soak in. Keep the soil moist until seeds have germinated.

Fall vegetables are harvested after early September. They consist of two types:

1. the last succession plantings of warm-season crops, such as corn and bush beans,
2. cool-season crops which grow well during the cool fall days and withstand frost.

Note that cool nights slow growth, so crops take longer to mature in the fall (and spring) than in the summer. Keep this slower pace in mind when you check seed catalogs for the average days to maturity. Some of the best quality vegetables are produced during fall's warm days and cool nights. These environmental conditions add sugar to sweet corn and cole crops, and crispness to carrots.

The vegetables in Table 20.13 can be successfully seeded or transplanted for fall harvest. Often, you will want several seeding dates to extend the harvest over a longer time. This table gives the latest dates for either seeding or transplanting as indicated.

Table 20.13. Crops for the fall garden.

Vegetable	Date of Planting	Seeds	Transplants	Days to Maturity[1]	Date of Harvest
Beets	Jul - mid-Aug	x		70 - 75	Oct
Bibb lettuce	Jul - Aug	x	x	50 - 60	Sep - Oct
Broccoli	Jul - Aug		x	60 - 80	Sep - Nov
Brussels sprouts	Jun - Jul		x	70 - 80	Oct - Nov
Cabbage	late Jun - early Aug		x	60 - 70	Sep - Nov
Carrots	Jul - Aug	x		80 - 90	Nov
Cauliflower	late Jun - early Aug		x	70 - 80	Sep - Nov
Chinese cabbage	Jul - Aug	x	x	50 - 70	Sep - Nov
Collards	Jul - Aug	x		80 - 90	Oct - Nov
Endive	Jul - Aug	x	x	70 - 80	Sep - Nov
Green beans, bush	Jul - mid-Aug	x		60 - 65	Sep
Kale	Jul - Aug	x	x	70 - 80	Sep - Nov
Kohlrabi	Jul - Aug	x		60 - 70	Sep - Nov
Leaf lettuce	Jul - Aug - Sep	x	x	40 - 60	Sep - Oct
Mustard greens	Jul - Aug	x		50 - 60	Sep - Oct
Parsnips	June	x		90 - 100	Nov
Potatoes	mid-Jun	x		90 - 100	Oct
Radishes	Sep	x		30 - 40	Oct
Rutabaga	July - mid-Aug	x		80 - 90	Oct - Nov
Snow Peas	Aug	x		50 - 70	Oct
Spinach	Aug - Sep	x		50 - 60	Aug - Sep
Sweet corn	Jul	x		70 - 80	Sep
Turnips	Jul - Aug	x		50 - 60	Sep - Nov
Turnip greens	Jul - Aug	x		50 - 60	Sep - Nov

[1] Due to cool temperatures in the fall, a long time will be needed for certain crops to mature.

Extending the Growing Season

Typical planting dates for vegetables in Kentucky (Table 20.14) as well as season production times (earliest and latest planting dates, Table 20.15) provide a guide for conventional production, however there are methods for extending production beyond the traditional season. Polyethylene row covers have been used for a long time to help vegetables grow and ripen early in the spring. However, Kentucky's springs are often too warm to benefit much from early season row covers. During the fall, on the other hand, these covers might prove useful to gardeners wishing to extend the harvest of frost-sensitive crops (tomatoes, peppers, cucumbers). The objective of using a row cover is to trap heat from the soil and protect the crop from cold night temperatures which might deform fruit or kill the plant. Many times in Kentucky, a period of mild weather will follow the first killing frost. If you protect frost-sensitive vegetables at critical times in the fall you could extend the harvest season by several weeks. However, the tall stature of some of these crops (tomatoes) makes it more difficult to protect them using row covers. A second use of season extension might be to grow certain frost tolerant vegetables during the winter months. Vegetables like carrots, turnips, leeks, cabbage, lettuce, spinach, kale, and other leafy greens, are generally planted in the spring garden where they tolerate frost and freezing conditions. These vegetable are fairly low growing which would allow them to mature under row covers and their proximity to the ground helps protect them during extremely cold weather. Using solid plastic covering (low tunnels, see below),

Table 20.14. Vegetable gardener's calendar with planting dates for Western, Central, and Eastern Kentucky[1]

Western Ky	Central Ky	Eastern Ky	Planting Method[2]	Crop
Jan. 15	Jan. 22	Jan. 29	I	Onions
Feb. 1	Feb. 8	Feb. 15	I	Brussels sprouts
Feb. 15	Feb. 22	Mar. 1	I	Cole crops (Broccoli, cabbage, cauliflower, kohlrabi), lettuce, Chinese cabbage
Mar. 1	Mar. 8	Mar. 15	O	Spinach, mustard, beets, peas, edible podded peas
Mar. 15	Mar. 15	Mar. 22	M	Cabbage, kohlrabi
			O	Asparagus and rhubarb (crowns), beets, carrots, collards, kale, mustard, spinach, peas, edible pod-ded peas, early potato seed pieces, radishes, turnips, green onions, onion sets, endive
			I	Peppers, tomatoes, eggplant, sweet potato slips. Dig and divide any 4 year old rhubarb plants. Fertilize asparagus and rhubarb with 1 lb 5 10 10 per 100 sq ft.
Apr. 1	Apr. 8	Apr. 15	M	Broccoli, cauliflower, collards, lettuce, Chinese cabbage, Swiss chard, onions from seeds
			O	Mustard, spinach, radishes, lettuce, Swiss chard
Apr. 5	Apr. 12	Apr. 19	I	Muskmelons, watermelons, squash
			O	Sweet corn, beets, carrots, mustard, spinach, radishes, lettuce
May 1	May 8	May 15	O	Sweet corn, mustard, radishes, lettuce
May 7	May 15	May 22	O	Green beans, lima beans
			M	Tomatoes, muskmelons, watermelons, squash
June 1	June 8	June 15	O	Sweet corn
			M	Sweet potatoes
June 15	June 22	June 29	O	Sweet corn, late potatoes, summer squash, bush beans, lettuce, parsnips, beets, carrots
July 1	July 8	July 15	O	Sweet corn (early maturing variety), carrots, beets
July 10	July 18	July 25	O	Sow seeds of fall cole crops in a nursery area
July 15	July 22	July 29	O	Sweet corn (early maturing variety), kale, mustard, turnips, summer squash
Aug. 1	Aug. 8	Aug. 15	M	Transplant fall cole crops to permanent location between now and Aug. 15
			O	Peas, edible podded peas, bush beans, radishes, beets, mustard. Divide old rhubarb or plant crowns if not done in spring.
Aug. 15	Aug. 22	Aug. 29	O	Radishes, spinach, turnips, turnip greens, beets, mustard, lettuce, endive
Sept. 1	Sept. 8	Sept. 15	O	Radishes, spinach, mustard
Sept. 15	Sept. 22	Sept. 29	O	Radishes, mustard, turnips, turnip greens
Oct. 1	Oct. 8	Oct. 15	O	Radishes
Oct. 15	Oct. 22	Oct. 29	O	Sow sets of Egyptian tree or multiplier onions. Harvest carrots before heavy freeze.
Nov. 1	Nov. 8	Nov. 15	O	Dig parsnips and store at 32 40°F, or mulch parsnips heavily in the ground

[1] Planting dates are approximate, consult you local weather conditions and adjust planting dates accordingly.
[2] **I:** Start seeds indoors; **M:** Move transplants to garden; **O:** Start seeds outdoors

these greens may grow well into winter or even all winter long when temperature are not extreme (subzero F). But the nature of the low tunnel will require the growing beds to be ventilated during sunny conditions.

Gardeners have a choice of self-ventilating covers (slitted or perforated), low tunnel covers, or floating row covers. The slitted and perforated types as well as the plastic used for low tunnels are available in clear and opaque polyethylene and require wire hoops or PVC pipe for support. To construct such tunnels after planting, push hoops (made from no. 9 galvanized wire or PVC pipe) into the ground, and spaced 5 feet apart over the row (Figure 20.7). Then when frost or freeze is predicted, cover them with clear polyethylene. Bury the edges of the plastic in the ground. For floating row covers, simply place the fabric directly over the crop and secure at the edges. The slitted sides of perforated covers and the loose nature of floating row

Figure 20.7. Slitted row cover.

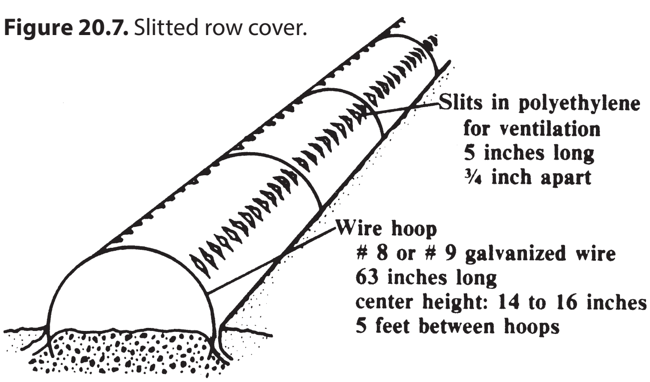
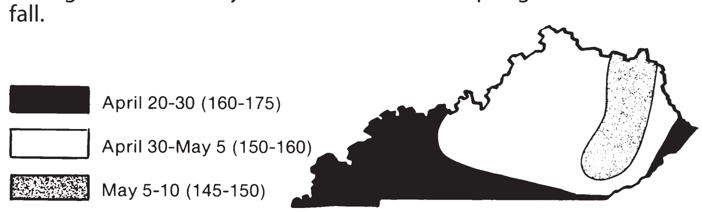


Figure 20.8. Average date of last killing frost (36°F) in spring, plus average number of days between last frost in spring and first frost in fall.



covers allow needed ventilation on sunny days to prevent overheating. However these season extension devises provide less protection from cold at night. Low tunnels made with solid plastic offers the best protection at night but must be ventilated by loosening the sides or ends during sunny days. Without ventilation, temperatures under the cover may quickly reach crop-damaging levels on sunny days. Raised bed gardens are generally easily adapted to low tunnel culture.

Table 20.15. Earliest and latest planting dates in the garden in Kentucky. (If producing your own transplants, begin two to 12 weeks earlier than these listed dates. See Table 6.)

	Earliest Safe Planting Date			Latest Safe Planting Date[1]		
Crops	**Western**	**Central**	**Eastern**	**Eastern**	**Central**	**Western**
Asparagus (crowns)	Mar 10	Mar 15	Mar 20		(Spring only)	
Beans (snap)	Apr 10	Apr 25	May 1	July 15	July 25	Aug 1
Beans (lima)	Apr 15	May 1	May 10	June 15	June 20	July 1
Beets	Mar 10	Mar 15	Mar 20	Aug 1	Aug 10	Aug 15
Broccoli (plants)	Mar 30	Apr 5	Apr 10	July 15	Aug 1	Aug 15
B. Sprouts (plants)	Mar 30	Apr 5	Apr 10	July 1	July 15	Aug 1
Cabbage	Mar 15	Mar 25	Apr 1	July 1	July 15	Aug 1
Carrots	Mar 10	Mar 20	Apr 1	July 1	July 15	Aug 1
Cauliflower (plants)	Mar 30	Apr 5	Apr 10	July 15	July 20	Aug 5
Celery	Apr 1	Apr 5	Apr 10	June 15	July 1	July 15
Chard	Mar 15	Mar 20	Apr 1	June 15	July 15	Aug 1
Collards	Mar 1	Mar 10	Mar 15	Aug 15	Aug 20	Aug 30
Sweet Corn	Apr 10	Apr 20	May 1	June 15	July 10	July 20
Cucumbers	Apr 20	May 1	May 10	June 15	July 1	July 15
Eggplant (plants)	May 1	May 10	May 15	June 1	June 15	July 1
Garlic	-	-	-	Nov 1	Nov 7	Nov 15
Kale	Mar 10	Mar 20	Apr 1	July 15	Aug 1	Aug 15
Kohlrabi	Mar 15	Mar 20	Mar 25	July 15	Aug 1	Aug 15
Lettuce (leaf)	Mar 15	Mar 25	Apr 1	Aug 1	Aug 15	Sept 1
Lettuce (bibb plants)	Mar 15	Mar 25	Apr 1	July 15	Aug 1	Aug 15
Lettuce (head plants)	Mar 15	Mar 25	Apr 1	July 1	July 15	Aug 1
Muskmelons	Apr 20	May 10	May 15	June 15	July 1	July 15
Okra	Apr 20	May 10	May 15	July 1	July 15	Aug 1
Onions (sets)	Mar 1	Mar 10	Mar 15		(Spring only)	
Onions (plants)	Mar 15	Mar 25	Apr 1	June 15	July 1	July 15
Onions (seed)	Mar 10	Mar 20	Apr 1	June 1	June 15	July 1
Parsley	Mar 10	Mar 20	Apr 1	July 15	Aug 1	Aug 15
Parsnips	Mar 10	Mar 20	Apr 1	June 1	June 15	July 1
Peas	Feb 20	Mar 1	Mar 15		(Spring only)	
Peppers (plants)	May 1	May 10	May 20	June 15	July 1	July 15
Irish Potatoes	Mar 15	Mar 15	Mar 20	June 15	July 1	July 15
Sweet Potatoes	May 1	May 10	May 20	June 1	June 10	June 15
Pumpkins	Apr 20	May 5	May 10	June 1	June 15	July 1
Radishes	Mar 1	Mar 10	Mar 15	Sept 1	Sept 15	Oct 1
Rhubarb (crowns)	Mar 1	Mar 10	Mar 15		(Spring only)	
Rutabaga	Mar 1	Mar 10	Mar 15	July 1	July 10	July 15
Southern Peas	Apr 20	May 5	May 10	June 15	July 1	July 15
Snow Peas	Feb 20	Mar 1	Mar 15	July 20	Aug 1	Aug 8
Spinach	Feb 15	Mar 1	Mar 10	Aug 15	Sept 1	Sept 15
Summer Squash	Apr 20	May 10	May 15	July 15	Aug 1	Aug 15
Tomatoes (plants)	Apr 20	May 5	May 15	June 1	June 15	July 1
Turnips	Mar 1	Mar 10	Mar 15	Aug 1	Aug 10	Aug 20
Watermelons	Apr 20	May 5	May 15	June 15	July 1	July 15
Winter Squash	Apr 20	May 10	May 15	June 15	July 1	July 15

[1] Based on average of early maturing varieties. Mid-season and late-maturing varieties need to be planted 15 to 30 days earlier than latest date. Nearly all of the fall-planted garden crops will require irrigation during dry periods. Additional insect controls may be necessary for these tender young plants.

Caring for Your Vegetables during the Growing Season

Once planting is completed, your garden still requires careful attention. You need to see that your plants receive the proper amounts of water and nutrients all season long.

Irrigating

Vegetable crops need about 1 inch of water per week, as rain water, irrigation water or both, from April through September. You should have a rain gauge near your garden or check with the local weather bureau for rainfall amounts; then supplement rainfall with irrigation if needed. An average garden soil will store about 1.5 inches of water/foot of depth.

Irrigation aids seedling emergence, improves percent germination and plant stand, helps maintain uniform growth and permits fruit development. Soils often crust without adequate water, retarding the germination of crops like carrots, onions and beans.

Another use of irrigation is to reduce the wilting of transplanted crops like tomato, pepper, lettuce, cabbage and eggplant. A good supply of soil moisture improves the quality and yields of all crops, increases the fruit size of tomatoes, cucumbers and melons, and prevents premature ripening in crops such as peas, sweet corn and beans. The critical periods of water needs for various vegetables are shown in Table 20.16.

Table 20.16. Critical times to water vegetables.

Vegetable	Critical Period of Water Need
Asparagus	Fern growth
Bean, lima	Pollination and pod development
Bean, snap	Bloom, pollination and pod enlargement
Broccoli	Establishment, crown development
Cabbage	Establishment, head development
Carrot	Establishment, root enlargement
Cauliflower	Establishment, growth, head development
Corn, sweet	Silking, tasseling and ear development
Cucumber	Flowering and fruit development
Eggplant	Uniform supply from flowering through harvest
Melon	Fruit set and early development
Onion, dry	Bulb enlargement
Pea	Flowering and seed enlargement
Pepper	Uniform supply from flowering through harvest
Potato	Tuber set and tuber enlargement
Radish	Root enlargement
Squash, summer	Bud development, flowering and fruit development
Tomato	Uniform supply from flowering through harvest
Turnip	Root enlargement

If overhead irrigation is used, it is a good idea to irrigate during the day so that all the water is evaporated off the plant foliage before dark. This reduces disease problems.

Water Movement in Soil

When water is applied to the soil, it seeps down through the root zone gradually. Each layer of soil must be saturated before water will descend to the next layer. This water movement is referred to as the wetting front. If only one-half the amount of water is applied at a given time, it will penetrate the top half of the root zone; the area below the point where the wetting front stops will remain as dry as if no irrigation had been applied at all (Figure 20.9).

The total water a garden needs is the same as the amount of water lost from the plant plus the amount evaporated from the soil. These two processes are called evapotranspiration. Evapotranspiration rates vary and are influenced by day length, temperature, cloud cover, wind, relative humidity, mulching, and type, size and number of plants growing in a given area.

Watering areas of the garden not occupied by vegetable roots only encourages weed growth.

Watering Equipment

The home gardener has several choices of watering equipment, including the garden hose with a spray or fan nozzle, trickle systems and porous hose systems. Sometimes gardens are located some distance from a water source which may require water to be transported to the garden (Figure 20.10). Other times there are only a few plants that need water and individual water sources (jugs, buckets, etc.) may be placed close to the plants and water directed to their roots. (Figure 20.11). This equipment may or may not be semiautomatic. Many portable lawn sprinklers are adequate for the garden. Adjust the rate of water application to about ½ inch/hour. A faster rate may cause runoff.

Oscillating and rotating sprinklers must be placed on a platform higher than the crop being irrigated to keep the plants from distorting the spray pattern and getting uneven distribution. Rotating sprinklers deliver circular water patterns with more water near the center than on the outer edges. Oscillating sprinklers deliver rectangular patterns, making it easy to water along edges of gardens; these systems, however, deliver more water at the edges than in the center. In any case, sprinklers do not distribute water uniformly like rain, though you can even out the water by overlapping the patterns. However, such overlapping means you must move the sprinkler often, overlapping about half of the area already watered each time you move it.

To check how much water your sprinkler has applied, set several small, straight-sided cans on the ground at varying distances from the operating sprinkler. If the sprinkler is set to apply 1 inch of water, operate it until the can with the most water has about ½ inch in it. Then, shut off or move the sprinkler to another spot. Overlap the measured can and run the sprinkler again until the can has a total of 1 inch of water in it.

An excellent irrigation system for the home garden is the perforated plastic hose or soaker hose. Put the hose, holes down, along one side of the crop row or underneath plastic mulch. Let the water soak or seep slowly into the soil. This method requires less water because the water goes right next to the plant, Also, this way you can water in the evening without encouraging foliage diseases since no water is sprinkled on the plant leaves. You can determine the time required to apply a given volume of water by putting one of the hole openings over a can and measuring the amount of water collected in a given time period.

With trickle irrigation you water vegetables similarly to the way you sidedress fertilizer. Water is applied directly on the row by a special hose or tube at low pressure. Trickle irrigation uses from 30% to 70% of the water required by overhead sprinkle irrigation.

You do not need to be a plumber to construct a trickle irrigation system. For the first year, you may wish to install trickle irrigation on only a few rows of vegetables.

Trickle irrigation equipment is usually available from local garden supply stores and is also listed in many seed and garden catalogs available to home gardeners.

Line Emitters (for Trickle Irrigation)

Three principal types of line emitters are adapted to growing vegetables (Figure 20.13).

1. Twin-wall is essentially a tube within a tube. Water from the feeder line fills the inside tube. When pressure on the inside tube builds up, the water flows through holes spaced about 5 feet apart into the outer tube. Water then trickles through perforations spaced about 12 inches apart in the outer tube and into the soil.

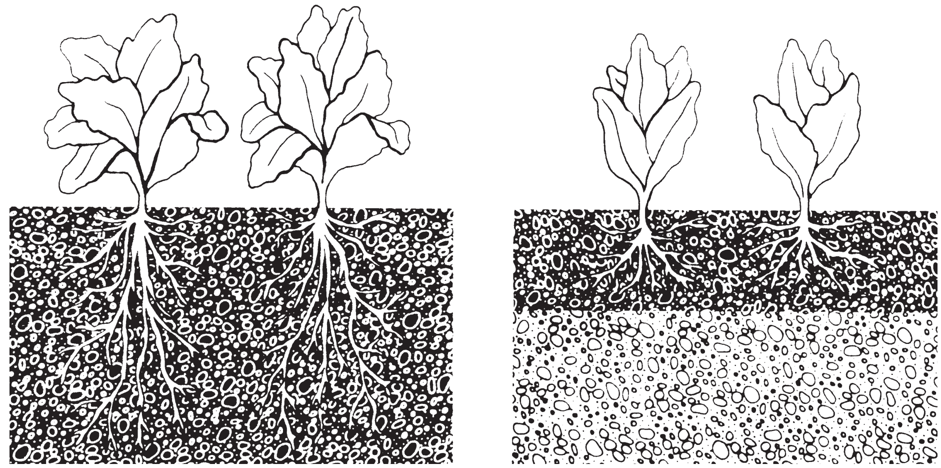


Figure 20.9. To encourage deep rooting, thoroughly water the upper 6 - 8 inches of soil (left). Shallow watering (right) promotes shallow development of roots, resulting in poor growth and increased risk of injury under severe weather conditions.

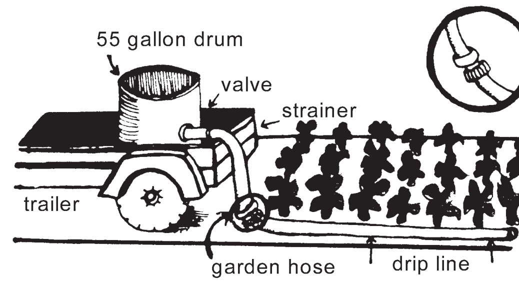


Figure 20.10. Trickle system for a garden that is too far from a water supply.

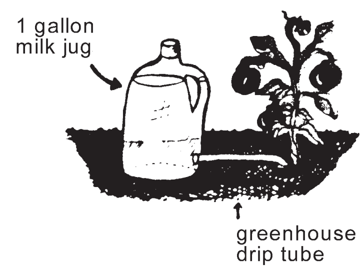


Figure 20.11. Trickle system for favorite plants (i.e., giant pumpkin, early tomatoes, etc.).

2. Bi-wall has a main chamber through which water flows until pressure is the same throughout the trickle line. Water then flows into a secondary chamber on top of the main chamber and is distributed to the plants through holes along the entire secondary chamber.
3. With a plastic soaker hose water seeps through the tube's entire length, not at defined openings. The soaker hose is ideal for closely spaced crops.

Although not used for vegetables, point emitters are available to deliver water to specific locations. They are used to water shrubs and trees.

Trickle Irrigation and Black Plastic Mulch

Black plastic mulch can be put over the line emitter to increase the effectiveness of watering and to control weeds. Further, the black plastic protects the polyethylene emitter tube from sunlight which accelerates material break down. The tubes can be used for several years if cleaned and stored in a cool, dark place. Black plastic mulch, 0.0015 inches (1 ½ mil) thick, may be purchased at garden supply stores. A 4-foot width is ideal for most vegetables.

If you use a trickle system with plastic mulch, you must put the line emitter 8 inches to one side of the center of the row. This precaution assures that the plastic emitter hose will not be punctured when

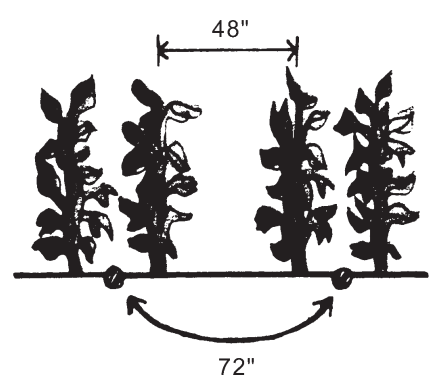


Figure 20.12. One trickle line for every two rows.

plants are set in the middle of the row. Figure 20.14 shows a line emitter installed under black plastic mulch.

Fertilizer—Although a crop could be fertilized if you inject soluble fertilizers into the supply pipe in a home trickle watering system, this method involves a greater risk of applying the wrong amount of fertilizer. Since the black plastic sheet reduces the loss of fertilizer by eliminating downward movement during heavy rain, you can reduce the amount of fertilizer by about 25%.

After lime and fertilizers are applied and raked into the top few inches of soil, the trickle system is installed and the plastic mulch is placed on top. Directions for installing plastic mulch are in the section on mulching.

Mulching

Mulching can make all the difference between a garden that is a joy to work and watch and one that is tedious and untidy.

- Among mulch's greatest attributes is its ability to help control weeds.
- Mulch also helps conserve soil moisture by 50% or more by covering the soil to slow down evaporation. UK soil scientists have found that a mulch on the soil surface can conserve about 6 inches of soil water during the growing season. Most of the water conserved will reduce and/or delay plant water stress.
- Mulch reduces erosion by breaking the impact of rain and wind.
- Nutrients do not leach so readily under plastic and some paper mulches because less rainwater penetrates.
- Vegetables remain cleaner in mulched gardens because they have less contact with the soil.
- Finally, organic mulches can keep soils cool.

Using Plastic Mulch

The most common materials for mulching are either plastic or organic matter. Plastic materials are usually 3 or 4 feet wide and are black, white, brown or clear. The darker plastics are recommended because they do not allow weed growth; clear materials act as greenhouses under which weeds flourish. White-on-black plastic is used for summer planting, because it is cooler.

Plastic mulches tend to warm the soil by about 1 to 5 degrees. This extra warmth can boost plants such as tomatoes in the spring and can promote quite vigorous growth of heat-loving vine crops, such as melons and squashes, in the summer.

- Wait for a calm day to lay plastic mulches.
- Slip a hoe or rake handle through the roll of polyethylene.
- Place the roll at the beginning of the row.
- Hoe furrows about 4 inches deep on either side of the roll.
- Roll out the polyethylene this distance.
- Tuck the edges into the furrows.
- Cover them with soil and proceed another 5 ft until the end of the row.
- Slit the plastic at the end of the row and place the edge into a furrow across the row.
- Insert transplants by cutting holes in the plastic with a knife or bulb planter.
- Plastic weed barrier or landscape fabric mulches, which are more expensive than other plastic mulches, allow water to pass through, can be held down with large wire staples, and can be reused in subsequent years.

Some soil between the rows will remain unmulched. Or, you may wish to use newspapers and organic mulch to control weeds between the plastic strips.

The major disadvantage of most plastic mulches is that you have to remove them and dispose of them. They cannot be tilled under or left on the soil, but must be lifted and discarded. New biodegradable mulches are now available at some garden stores.

Using Organic Mulches

Organic mulches are materials such as lawn clippings or straw. Do not use lawn clippings that come from a lawn recently treated with herbicides. The finer mulches will deter weeds if spread over the garden at least 2 inches deep. One excellent way to spread these materials more thinly is to first lay about six sheets of newspaper on the soil, then cover the paper with organic matter. In this case the newspaper is really the mulch, and the organic matter holds the paper in place and improves appearances.

Figure 20.13. Trickle tubes.

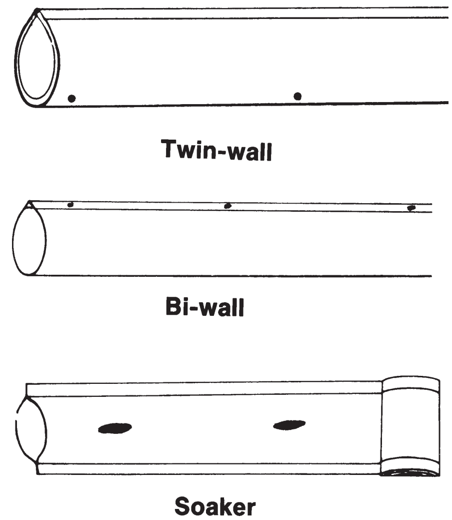
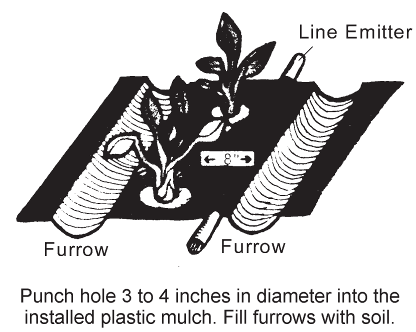


Figure 20.14. Installation of trickle irrigation under black plastic mulch.



Soils will remain cool longer in the spring under organic mulches, because the sun does not strike the soil. If you want your garden to grow rapidly in the spring, do not scatter the mulch until the soil warms. One precaution needed if you use straw is to be sure it is weed- and seed-free. Otherwise, it will be a source of weeds for the growing season.

Most organic mulches will compact and start to decompose by fall. They can be tilled under easily, adding valuable organic matter to the soil. Some gardeners prefer to maintain a permanent mulch, adding organic material as it becomes available. In the spring, they simply pull back the mulch in spots for transplants or in rows for direct-seeded vegetables. This method is a good way to build a rich garden soil.

Figure 20.15. Layers for a compost pile.

Table 20.17. Recommended times for sidedressing vegetables. (General rate for sidedressing is 10 Tbs of nitrogen fertilizer such as 15-0-0/10 ft row for all vegetables except asparagus and onions, which require 20 Tbs/10 ft row, and potatoes, which require 14 Tbs/10 ft row.)

Crop	Time of Application
Asparagus	Before growth starts in spring and again after harvest. Phosphorus and potassium may also be applied at these times if needed. See Asparagus section.
Beans	After heavy blossom and set of pods.
Beets	Additional nitrogen might reduce yield or lower quality.
Broccoli	3 weeks after transplanting.
Cabbage	3 weeks after transplanting.
Cauliflower	3 weeks after transplanting.
Carrots	Additional nitrogen might reduce yield or lower quality.
Cucumbers	Apply 1 week after blossoming begins and same amount 3 weeks later.
Eggplant	After first fruit set.
Kale	When plants are about one-third grown.
Lettuce	Additional nitrogen might reduce yield or lower quality.
Muskmelons	Apply 1 week after blossoming begins and same amount 3 weeks later.
Onions	1 to 2 weeks after bulb formation starts.
Parsnips	Additional nitrogen might reduce yield or lower quality.
Peas	After heavy bloom and set of pods.
Peppers	After first fruit set.
Potatoes	After tuber formation starts (bloom stage), about 6 weeks after planting.
Spinach	When plants are about one-third grown.
Squash	Additional nitrogen might reduce yield or lower quality.
Sweet corn	When plants are 12 inches tall.
Sweet potatoes	Additional nitrogen might reduce yield or lower quality.
Tomatoes	Apply 1 to 2 weeks before first picking and same amount 2 weeks after first picking.
Turnips	Additional nitrogen might reduce yield or lower quality.
Watermelon	Additional nitrogen might reduce yield or lower quality.

Fertilizing

For vegetables to produce lush, continuous growth throughout the season, they need a uniform supply of nutrients. However, many chemical fertilizers are very soluble, so the initial application may leach beyond the root zone before the growing season ends. Thus, many gardeners sidedress their crops with an extra application of fertilizer during the growing season. The usual rate is 10 Tbs of nitrogen fertilizer such as 15-0-0 or 2.5 oz of 10-10-10/10 ft row (Table 20.18).

A combination of chemical fertilizer, organic fertilizer and mulch makes a good sidedressing. The chemical fertilizers give the initial boost required by young plants; organic fertilizers provide nutrients uniformly throughout the season; and mulch keeps the soil more evenly moist and the nutrients more uniformly available.

Compost

Compost is easy to make; all you need is raw organic matter and a little bit of time. This microbial process will take care of itself. Microbes are ubiquitous in the environment and will feed on the organic materials over time provided they are warm enough to grow and reproduce. Leaves, grass clippings, weeds, garden refuse, and manure are excellent organic materials to feed the microbes. Special additives don't help, though nitrogen fertilizer may speed up composting. The finer the material being composted, the faster the decomposition and maturation of the compost. It is best keep limbs and other large woody materials out of the compost bin unless you use a chipper/shredder.

Compost can be started anytime. Choose an area convenient to the garden so that garden residue and kitchen parings can be easily added. The best location is a shady spot; however, do not build directly under a tree, because the tree's roots may grow into the pile. Make two or three open ended bins or boxes to hold the compost. To maintain appropriately warm temperatures, compost piles need to be 3 square feet in size. You can build the boxes of wire fencing supported by posts, or they may be constructed of boards or masonry material. They can be made attractive enough to be part of the landscape or you can hide them among landscaping.

An appropriately-sized pile of organic material will mature to compost in time, but it is quicker to alternate layers of raw organic material, a small amount of N fertilizer or a high N-containing green waste (e.g. grass clippings) and a small amount of top soil (which contains an abundance of microbes, see Figure 20.15). Start with organic matter—6 inches deep if the material is fairly solid, or 12 inches deep if it is loose. If the material is dry, add a small amount of water. The material consistency should feel like a damp, wrung-out sponge. Next, add either an organic or small handful of synthetic fertilizer (e.g. 34-0-0).

After you fertilize, add a small handful of soil. The soil introduces microorganisms which decompose organic matter. Commercial microbial preparations which claim to enhance composting are unnecessary. Continue to alternate layers of organic matter, fertilizer and soil until the pile is 3 to 4 feet high, but slightly lower in the center for easy watering. Complete the pile with a layer of soil on the top.

Keep your compost moist but not soggy. With moisture and a layer of soil on the top, there should be no offensive odors. Turn or mix your compost pile several times during the year. A second bin and a shredder come in handy for this purpose. After mixing your pile into the second bin, you can start a new compost pile in the first one. If you start your compost in the fall and turn it several times, it should be ready for use about June 1.

Note—Fresh animal manures sometimes contain organisms that can make people sick (pathogens), such as the bacteria *Salmonella* sp. and *E. coli* O157:H7, or the parasite *Cryptosporidium parvum*. These pathogens can be present in soil that adheres to roots or low-growing leaves and fruits. The risk is minimized if no fresh manure is used in the garden.

Careful peeling or washing fruits and vegetables with detergent removes most pathogens, but some risk remains. Thorough cooking effectively kills pathogens.

The greatest risk from manure-borne pathogens is for low-growing or underground crops such as carrots, lettuce, and strawberries. The edible part of these crops may become contaminated with soil, the crops are difficult to wash, and they often are eaten raw.

Pathogens in fresh manure typically die over time, especially when the manure dries out or is exposed to freezing and thawing. The rate of die-off depends on the type of pathogen and manure and on environmental conditions such as temperature, moisture, and sunlight. Thorough, high-temperature composting kills pathogens, but it is difficult to maintain these conditions in a back yard compost pile. If any manure is used in the garden (even in compost) the gardener should wait at least 120 days between application to the garden and harvest. You can limit your risk by excluding fresh manure from compost that will be used on fresh gar den crops.

Keep dog, cat, and pig manure out of your compost pile and garden. Some of the parasites found in these manures may survive a long time in compost or

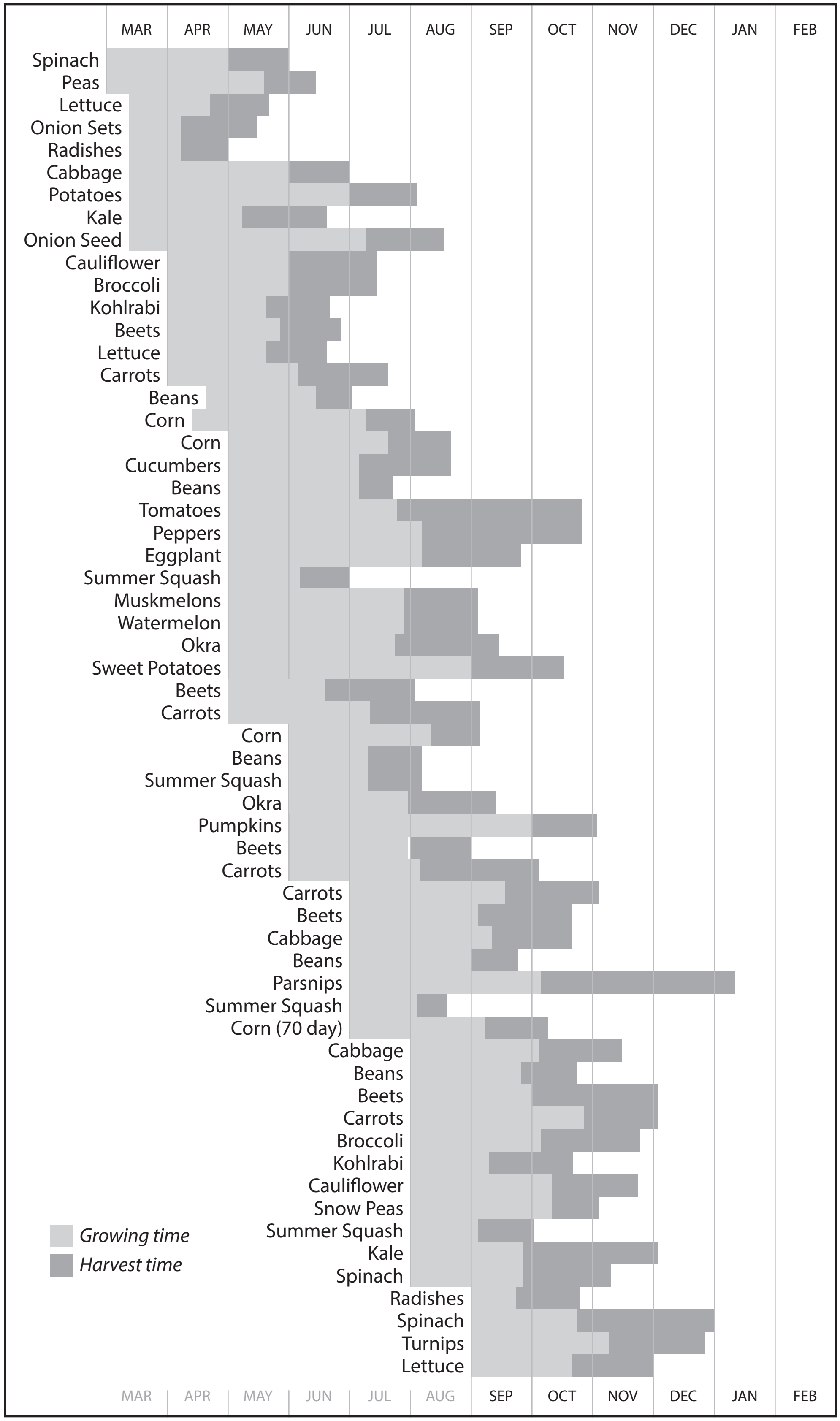


Figure 20.16. Vegetable crop timetable.

in the soil, and remain infectious for people. Beware that some critters enjoy raiding compost bins, such as opossums, raccoons, dogs and cats, and they may defecate in your compost pile, increasing the risk of pathogens in your compost pile.

Cover Crops Protect Garden Plots

The garden plot—that area of tilled ground which offers an abundance of high-quality vegetables—is commonly used for only six to seven months in Kentucky.

What normally happens to the garden in the off-season can be wasteful and destructive. Wind and water may carry away the enriched topsoil. Rains will move minerals down through the soil, leaching them away from the root zone of vegetables. Compaction of soil occurs because of raindrops' impact or footsteps on the bare ground, as well as from loss of granular structure due to tillage and crop production practices. Weeds become established, leaving their seeds or perennial roots to plague the garden in future growing seasons. Some insects and diseases of vegetables overwinter on weeds and are right there on site to infect the next crop.

These problems can be reduced or eliminated with a cover crop to maintain and rejuvenate the garden soil. The benefits of cover crops are reaped in future vegetable harvests. Traditional cover crops are ryegrass, winter rye, winter wheat, oats, white clover, sweet clover, Austrian winter/field peas, hairy vetch, other legumes and buckwheat.

Cover crops can do even more than retain the soil, prevent mineral leaching, reduce compaction and competitively shade out weeds. A lush top growth, termed "green manure," will add organic matter when tilled into the garden soil. But the cover crop's root system is much more valuable than top growth to the soil quality, offering both organic matter and structural granulation as its roots grow through the soil. The roots improve garden soil's aeration and drainage while the tops intercept light energy at times when the garden would not be planted.

Success in growing cover crops requires proper crop selection, correct timing and good management techniques.

Grasses are much easier to establish than legumes, however including a legume in your cover crop mix has many benefits. Legume cover crops have a symbiotic relationship with certain soil microorganisms that allow for nitrogen to be fixed directly from the atmosphere. Nitrogen accumulations by leguminous cover crops range from 40 to 200 lbs. of nitrogen per acre which becomes gradually available throughout the growing season after the cover crop is incorporated. Oats mixed with Austrian winter/field peas and winter rye mixed with hairy vetch have both proven to be excellent cover crop mixes in Kentucky.

Small-seeded crops are slow and more difficult than large-seeded types such as oats. Winter rye and ryegrass grow very densely and are much more effective at shading out weeds than oats or small-seeded legumes. Availability of seed and its cost are other important considerations.

When you plant the cover crop will dictate which crops you can use. By October, only rye and winter wheat can be successfully started. If land is available in August, your choice broadens to include ryegrass, oats and clover. Covers such as annual ryegrass, oats and buckwheat that do not overwinter are easiest to work with the next spring.

Perennial ryegrass and winter rye can give you problems in the spring. They produce a massive amount of top growth and will tangle in a rototiller. Before leaves grow too large, cut them back once with a mower, string trimmer or scythe. Perennial ryegrass makes a tight mass of fibrous roots which can be hard to manage.

Whatever cover crop you use, when the time comes to plant your garden you must remove the cover. You can completely avoid tilling by mowing the plot, broadcasting fertilizer and covering it with black plastic. The absence of light will kill the cover crop within two weeks, and transplants or large-seeded vegetable crops can be planted directly through the plastic. This no-till technique maintains excellent soil conditions, controls weeds and usually gives high yields.

For Kentucky's conditions, consider ryegrass as the best garden cover crop. It is a vigorous grower with an extensive root system occupying the same root zone as the vegetables will. Winter rye is an excellent second choice and best for late planting. It is a biennial, and mowing will stop its growth in spring.

Diseases, Insects and Weeds

Disease Control

Plants in the garden can be attacked and damaged by fungi, bacteria, nematodes and viruses. The symptoms of these attacks are called plant diseases. Plant diseases can be prevented or controlled in a variety of ways. Both urban and rural home gardeners can often use nonchemical methods effectively because they are willing to bear time and labor costs. When chemicals must be used, home gardeners can get by with few chemical applications by spraying only when needed.

Before Planting

- Select a site that is sunny and well-drained.
- Remove or deep-plow under old crop debris well before planting.
- Select disease-resistant varieties.
- Purchase disease-free transplants.
- Practice crop rotation (yes, it can be done in small gardens, but it requires that records be kept).
- Avoid areas with poor air movement.

At Planting Time

- Consider seed commercially treated with fungicides.
- Plant seed into warm soils.
- Space plants to assure air movement between plants.
- Use proper fertility.
- Use raised beds to improve drainage.
- Avoid overlapping plantings to keep diseases from moving from the old crop to the new one.

During the Growing Season

- Regularly inspect plants for disease.
- Remove and destroy diseased plants—do not place them in your compost pile.
- Control weeds, which harbor insects and disease organisms in and near the garden. These weeds include pokeweed, plantain, Johnsongrass, milkweed, wild cucumber, nightshade, ground cherry and clovers.
- Control insects which feed on vegetable plants or vector disease organisms.
- Water and mulch to avoid unnecessary plant stress. Avoid wetting foliage, or irrigate early in the day so foliage can dry before dark.
- Use labeled fungicides only when needed.
- Avoid working in the vegetable garden when leaves are wet to reduce spread of bacterial blights.
- Space plants appropriately to encourage air movement.

Fungicides

The number of chemicals labeled for use in home vegetable gardens is limited compared to the number available to producers of commercial vegetables. Gardeners should rely on preventive practices rather than pesticides to manage diseases. Use fungicides to supplement cultural controls—this will greatly reduce the need for chemicals in the garden.

Seed treatment with fungicides must be applied by commercial seed treaters. Grower application of these products is prohibited to minimize applicator exposure. If you desire to use treated seed, buy seed pre-treated with fungicides.

Fungicides available to home gardeners are *protectants* by nature and will not cure existing infections or symptoms. Protectant fungicides should be applied in a preventive manner to plant parts ideally before pathogens arrive (or no later than development of first symptoms). This is very different from the approach taken with most insecticides. Don't wait until severe damage has occurred before deciding to use a fungicide. The majority of plant diseases tend to develop quickly under favorable environmental conditions, and delaying applications of fungicides in these situations usually has little effect on the disease.

Because fungicides are subject to weathering, they must be reapplied at regular intervals when disease organisms are active to keep plants adequately protected. Growers using certified organic gardening practices can only use certain brands of sulfur or fixed copper from the fungicide options listed on Table 20.18, and they should be used very sparingly. Other organically approved fungicides exist though they may be difficult for the home gardener to find or are only available via mail order. Some of these organic fungicides include naturally occurring soil fungi that are antagonistic to disease-causing pathogenic fungi, and when applied can kill or out compete the pathogenic fungi. Other organic fungicide products include potassium bicarbonate (baking soda), or various horticultural oils, which may have a strong preventative effect against powdery mildew disease.

Chemicals should be applied only in the prescribed manner as recommended by the manufacturer. Read the label carefully and follow directions. Note the number of days required between the last fungicide application and harvest date. The waiting period may vary among crops.

All pesticides listed in Table 20.18 are registered for use in vegetable gardens as of November, 2015. Listing a fungicide is not a recommendation that pesticides are the primary control method suggested. Recent changes in pesticide registrations have significantly reduced the number of chemicals labeled for use in home vegetable gardens. Because labels may change at any time, information listed here may not be accurate. The user must accept responsibility for safe and legal pesticide use.

Measuring Tables for Mixing Small Quantities of Pesticide

Pesticides that are bought in large packages or sizes usually do not include instructions for mixing smaller amounts of a spray. Table 20.20 compares various measurements that are needed to make smaller amounts of a spray.

The powdered pesticide table (Table 20.21) can be used to mix different amounts of spray of the same mixture when using wettable powders. Example: If the label specifies that 3 pounds of a wettable powder pesticide material are to be added to 100 gallons of water, then 3 T of the pesticide material would make 1 gallon of similar spray mixture.

Table 20.18. Fungicides for use in the home vegetable garden.*

Active Ingredient: Trade Name	**Vegetables**[2]	**Remarks**[2]
Chlorothalonil: Bonide Fung-onil Multipurpose, Dragon Daconil, Hi-Yield Home & Garden Fungicide, Monterey Vegetable Fungicide, Ortho Daconil, Ortho Garden Disease Control	Beans, broccoli, Brussels sprouts, cabbage, carrots, cucumbers, cauliflower, corn, melons, onions, potatoes, pumpkins, squash, watermelons	Apply preventively to foliage, stems, fruit to control leaf spots certain fruit rots. Will suppress powdery mildew.
Copper fungicides (fixed coppers): Bonide Copper Spray or Dust, Bonide Liquid Copper,[3] Hi-Yield Copper Fungicide, Southern Ag Neutral Copper, Ortho Elementals Garden Disease Control[3]	Beans, beets, broccoli, Brussels sprouts, cabbage, carrots, cucumbers, eggplant, greens (collard, mustard, turnip) melons, okra, onions, peas, peppers, potatoes, pumpkins, spinach, squash, tomatoes, watermelons	Apply preventively to foliage and fruit to control bacterial diseases, downy mildew, and powdery mildew. May be phytotoxic under certain weather conditions.
Mancozeb: Bonide Mancozeb Flo w/zinc, Southern Ag Dithane M-45	Asparagus, corn, cucumbers, melons, onions, potatoes, squash, tomatoes	Apply to foliage preventively to control a broad range of fungal diseases.
Myclobutanil: Spectracide Immunox	Asparagus, cucurbits, snap bean, tomatoes	Apply to foliage to control powdery mildew, rust, and other fungal diseases.
Neem and horticultural oils: Bonide Bon-Neem II, Bonide Neem Oil Concentrate,[3] Monterey All Natural Disease Control RTU,[3] Monterey Neem Oil RTU	Many—refer to label.	Apply to foliage to suppress powdery mildews. Use caution under conditions of plant stress.
Phosphorous acid: Monterey Agri-Fos	Asparagus, beans, broccoli, Brussels sprouts, cabbage, carrots, cauliflower, collards, cucumbers, eggplant, kale, lettuce, melons, mustard, peas, peppers, potatoes, squash, sweetpotatoes, tomatoes	Systemic product for downy mildew, Pythium damping off, and late blight management. Most effective when applied preventatively, refer to label for specific application instructions.
Sulfur: Bonide Sulfur Plant Fungicide,[3] Ferti-Lome Dusting Sulfur, Ortho Essentials 3-in-1 Rose and Flower Care[3]	Many—refer to label.	Effective against powdery mildew. May cause injury under hot and humid conditions.

*As of February, 2021.
[1] Partial listing of products; see "Homeowner's Guide to Fungicides" (PPFS-GEN-07) at http://plantpathology.ca.uky.edu/files/ppfs-gen-07.pdf.
[2] Product labels differ between manufacturers. Refer to product labels to ensure that the crop and disease to be controlled are listed.
[3] Approved for use in organic gardens.

Different amounts of a similar spray can be made from the liquid pesticide table, when liquid pesticide materials (emulsifiable concentrates or EC) are used. When reducing the amount of a spray mixture, be sure to stay in the right column and line as indicated in Table 20.22. (T = tablespoon, t = teaspoon)

Symptoms of Some General Diseases and Their Management

Root Knot (nematode)—Galls and swellings on roots; plants grow poorly, may be stunted and wilt; tubers and fleshy roots may show lumps and swellings; affects wide variety of garden vegetables. Rotate with tall fescue or other grasses for several years; use resistant tomato varieties.

Southern Blight (Southern Stem Blight) (fungus)—Decay of lower stems near ground line, often with heavy, white fungal growth on stem; top of plant may wilt and die; affects peppers, tomatoes, beans, cucumbers and related crops. Rotate crops; turn under old plant debris early to allow for decomposition. Control defoliating diseases to prevent dropped leaves from serving as a food source for fungus. Consider creating a physical barrier to infec-

All spoons, cups or other measuring utensils used to measure any pesticide or other chemicals must be clearly marked with red paint and kept in the storage cabinet.

Table 20.19. Measuring abbreviations.

WP	wettable powder	C	cup
EC	emulsifiable concentrate	gal	gallon
D	dust	qt	quart
G	granular	pt	pint
Sol	solution	lb	pound
t or tsp	teaspoons	oz	ounce
T or Tbs	tablespoon (level)	fl	fluid

Table 20.20. Measurement comparisons.

3 tsp (level) = 1 Tbs (level)
2 Tbs = 1 fluid oz = 6 tsp
4 Tbs = 12 tsp = ¼ cup = 2 fluid oz
1 cup (level) = 16 Tbs = 8 fluid oz
2 cups = 32 Tbs = 1 pt = 16 fluid oz
2 pt = 64 Tbs = 1 qt = 4 level cups
4 qt = 8 pt = 1 gal = 16 cups
16 oz = 1 lb
6 Tbs = approx. 1 oz of dry weight (WP only)

Table 20.21. Powdered pesticide.

Water	Quantity of Powdered Pesticide Material Needed					
100 gal	1 lb	2 lb	3 lb	4 lb	5 lb	6 lb
25 gal	4 oz	8 oz	12 oz	1 lb	1¼ lb	1½ lb
5 gal	5 T	10 T	15 T (1 C)	20 T (1¼ C)	25 T (1½ C)	1¾ C
1 gal	1 T	2 T	3 T	4 T	5 T	6 T

The above measurements of wettable powder are acceptable for practical purposes.

Table 20.22. Liquid pesticide.

Water	Quantity of Liquid Pesticide Material Needed					
100 gal	½ pt	1 pt	2 pt	3 pt	4 pt	5 pt
25 gal	2 fl oz	4 fl oz	8 fl oz	12 fl oz	1 pt	1¼ pt
5 gal	1 T	2 T (1 fl oz)	4 T (2 fl oz)	6 T (3 fl oz)	8 T (4 fl oz)	10 T (5 fl oz)
1 gal	½ t	1 t	2 t	3 t	4 t	5 t

For amounts of spray not listed, the tables can be halved, doubled or added to get any combination needed.

tion by the southern blight fungus. This can be accomplished by wrapping the lower stems of susceptible plants like pepper and tomato with aluminum foil so that the lower (below-ground) portion of the stem and 2-3 inches of the above-ground portion are covered.

Virus and Virus-Like Diseases (virus)—Symptoms vary—may be mottling, mosaic or yellowing of leaves or fruits; some viruses cause deformed shape of leaves, fruit or growing shoots; can sometimes be confused with nutritional or herbicide injury problems. Use resistant varieties when possible; there are varieties of beans resistant to the bean mosaic viruses and cucumbers resistant to cucumber mosaic; be aware that some plants have resistance to virus strains not present in your garden; many viruses persist in weeds and are carried to the garden by insects, especially aphids and leaf hoppers; control of insects and removal of weeds will decrease the threat of virus infection; use virus-free seeds and transplants; spacing planting dates often helps prevent virus infections. Overlapping of plantings favors virus buildup in later crops.

Insect Control

Insecticidal Soaps

Insect control begins with regular monitoring of plants to recognize the earliest signs of pest infestations. At a minimum, gardeners should inspect plants weekly for insect pests and be able to recognize the common pests. Many pests feed on the undersides of leaves, so gardeners need to flip over leaves when monitoring for pests.

Chemical control of insect and mite pests should be the last tactic and only used when needed. Other techniques to reduce the impact of insect and mite pests include:

- Using recommended planting dates and other horticultural recommendations will help to produce plants that can be more tolerant of pests.
- Do not over-fertilize plants, as this may make them more susceptible to aphids.
- Control weeds in the garden as they can harbor many types of vegetable pests and pathogens they can transmit to vegetable plants.
- If only a few pests are seen, handpick them and toss them in soapy water.
- Consider using row covers over seedlings or small transplants.
- After the final harvest, destroy plants and their residues by turning them under in the soil or through composting.
- Use insecticides only when needed.
- Read, understand and follow label directions with insecticides.
- Make sure the vegetable being treated is on the label.
- Use appropriate personal protective equipment when using pesticides to minimize exposure.
- Check labels for the minimum time between application and when produce can be harvested.
- Avoid spraying plants (or weeds!) in bloom in ways that will harm pollinators.

Insecticidal soaps can be used to control aphids, mealy bugs, scale and mites. The spray must completely coat insects and plants to be effective. Follow directions on the package for dilution and method of use.

Horticultural Oils

These ultra-fine oils are used to control aphids, mites, leafminers, thrips, leafhoppers and whiteflies on certain vegetable crops. These oils may be phytotoxic at high temperatures (> 100°F) and are incompatible with some other pesticides, so read and follow directions on the package before use. Complete coverage is necessary for oils to be effective. Do not confuse these horticultural oils with dormant oils. Dormant oils are usually toxic to foliage.

Botanical Insecticides

Some insecticides come from natural plant materials and are thus allowed for certified organic growers.

Pyrethrum is the generic name given to a plant based insecticide derived from the powdered, dried flower heads of the pyrethrum daisy, *Chrysanthemum cinerariaefolium.* Pyrethrum is a fast acting contact poison that 'knocks down' susceptible insects.

Neem products are derived from the neem tree, *Azadiracta indica*, native to southern Asia, and are usually made by crushing neem tree seeds, then using water or a solvent such as alcohol to extract the pesticidal constituents. Other products are made from cold-pressed neem seed oil or from further processed neem oil. Neem is a broad-spectrum insecticide, which works by contact or ingestion, and acts mainly as an insect growth regulator, but also has anti-feedant and oviposition (egg-laying) deterrent properties.

Floating Row Covers

The floating row cover material mentioned on page 262 is useful for season extension also can play a major role in protecting plants against insect attack. Use the thinnest row cover fabric available and seal the edges after transplanting to ensure insects cannot get to their target plant. Many crops, like turnip greens, cabbage, broccoli, and eggplant, can be grown all the way to harvest without ever removing the fabric except to control weeds or apply side dress fertilizers. The fabric is reusable over multiple growing seasons and when used properly can eliminate all insecticidal sprays that might be necessary for certain crops.

Soil Insects

Cutworms—Cutworms are dull-colored, smooth caterpillars that cut off plants above, at or below ground level. Some climb plants and feed on leaves, buds or fruit. Underground types are particularly destructive to young pepper, tomato, cabbage, pea, bean and squash plants.

Figure 20.17.
Cutworm.

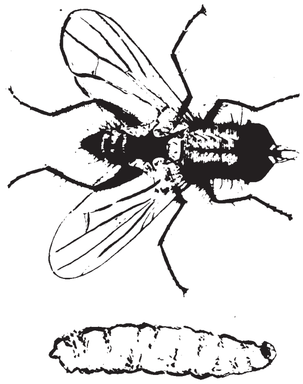


Figure 20.18. Root maggot.

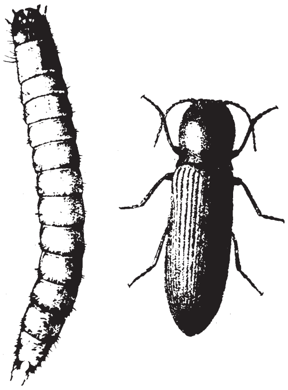


Figure 20.19. Wireworm.

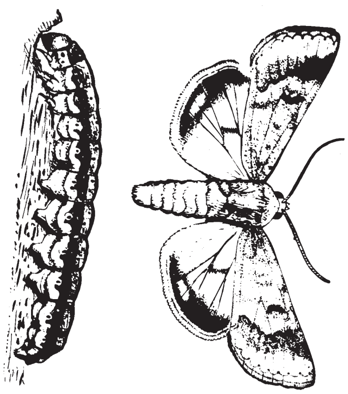


Figure 20.20. Corn earworm.

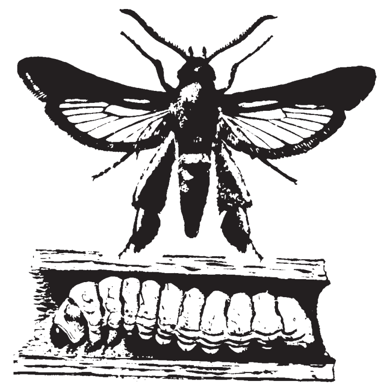


Figure 20.21. Squash vine borer.

Use a 6 inch diameter cardboard collar 3 inches high, pushed into the soil 1 inch after planting transplants. Thorough weed control around the garden and preparing soil at least 2 weeks before planting can reduce cutworms. You can also broadcast insecticide baits or esfenvalerate over cutworm-infested areas. Bait formulations—sometimes using bran or applying rolled oats with molasses containing *Bacillus thuringiensis* var. *kurstaki*—have been known to effectively control cutworm species when applied to the soil.

Root Maggots—There are several kinds of root maggots, including seed-corn maggot, cabbage maggot and onion maggot. They are whitish, legless, somewhat peg-shaped and without a distinct head. They tunnel roots, stems, bulbs or seeds and cause rot in the injured parts. Adults resemble house flies in appearance.

For onion maggots, spray foliage with malathion when flies are present. You can buy insecticide-treated bean, pea, and corn seeds that will give protection against seed maggots. Delay planting until soil conditions favor rapid germination of seeds, and avoid sowing seed too deeply to minimize losses to seed corn maggots. Tilling soil at least 2 weeks before planting can reduce root maggots. Apply diatomaceous earth around the base of the seedlings at planting and following each rain early in the season. Thin floating row covers can prevent infestation by root maggot populations when placed over transplants or seedlings.

Sowbugs—Sowbugs are insect relatives that roll into a ball when disturbed. They feed mostly on decaying organic matter, but also damage root hairs, or ripe tomatoes resting on the ground. Heavily mulched gardens and areas near compost heaps usually have more problems with this pest.

Clean up ground litter under which sowbugs hide during the day. Don't compost next to the garden.

White Grubs—White grubs are C-shaped larvae, ½ to 1 ½ inches long, whitish with hard, brown heads. They are found most often in high humus soil or gardens previously in sod. They feed on roots and tubers. The adults are May beetles or Japanese bettles.

Wireworms—Wireworms are yellowish to whitish, hard-bodied worms resembling a jointed wire. They puncture and tunnel roots or tubers of beans, carrots, beets, celery, lettuce, onions, potatoes, sweet potatoes and turnips. The adults are click beetles.

Avoid planting into ground that was previously in weedy grasses, pasture, sod, or small grains in the past 3 years. Use shorter-maturity root crops, or harvest early to reduce damage.

Borers

Corn Earworm—Corn earworms are also called tomato fruitworms. They are green, brown or pink caterpillars with light stripes along the sides and back and are up to 1 ¼ inches long. They eat holes in the fruit of tomatoes, peppers, okra and beans, and they burrow through silk to feed on kernels of sweet corn. Early in the season they feed on the central shoot of corn. They may also attack other crops. Losses to corn earworm can be minimized by avoiding late planting of sweet corn (after June 1). Generally, corn needs to be protected from this pest while fresh silks are present.

Resistant varieties with long, tight husk leaves will limit penetration and damage to just the tip of the ear. Avoid plantings after end of May. For earworm control on sweet corn, apply 20 drops of vegetable or mineral oil mixed with the recommended rate of *Bacillus thuringiensis* (Bt) with a medicine dropper to silks inside tip of ear after silks have wilted (3 to 7 days after silks first appear).

Squash Vine Borer—Squash vine borers attack the vines and fruit of squash and related plants. The adult moth resembles a wasp and is a daytime flier.

Select an insecticide from those listed on page 292. Two to three insecticide applications are needed 7 to 10 days apart beginning after the vines begin to run. Row covers can be used until female flowers open, remove for 2 weeks then recover. Plant destruction immediately after final harvest helps to reduce the problem the following year. A curative method for the squash vine borer is to split the vine lengthwise, remove the borer, bind the split stem together again and keep the plant watered. Destroy crop residues shortly after harvest.

Sucking Insects and Mites

Aphids—Aphids are black, red or green, soft-bodied insects grouped in colonies on leaves and stems. Most individuals in a colony are wingless. By sucking the sap, they cause leaves to wilt, curl, pucker, stunt or yellow. Aphids produce "honeydew" which falls on leaves, making them sticky. Sooty mold may develop on hon-

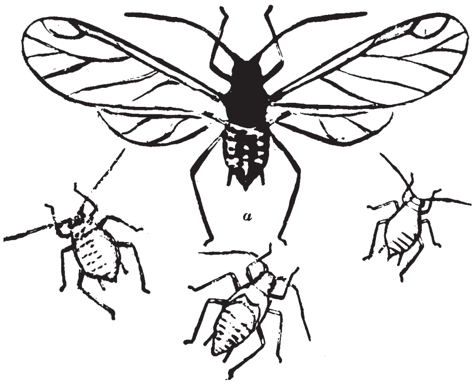


Figure 20.22. Aphids.

eydew deposits. Some aphids transmit viruses. Some whitish or bluish aphids also feed on beet roots but do not seem to be a serious problem.

Early season sprays of malathion—or even a hard stream of water—can reduce aphid numbers. Organic gardeners can use insecticidal soap, neem-based products, or horticultural oil for aphid control. Yellow-colored card traps covered with a sticky glue substance are useful against aphids, as they are attracted to the color yellow. Reflective silver mulches reduce colonization of aphids while plants are small. Keep infestations on tomato colonies of 5 or more aphids to less than half the plants.

Greenhouse Whitefly—Whiteflies are tiny, powdery white insects that flutter from foliage when infested plants are disturbed. The immature stages resemble tiny green scales on leaf undersides. Infested plants lack vigor. Leaves wilt, turn yellow, and are often covered with sooty mold growing on whitefly honeydew. Tomato, eggplant, squash, and certain weeds are common hosts in the garden. The whitefly cannot overwinter outdoors at our latitude, so garden infestations begin from infested transplants or escapees from greenhouses. Keep whitefly numbers to less than 5 nymphs per 10 leaflets.

Control garden weeds and buy only clean transplant material. Doubtful transplants should be watched closely and treated with imidacloprid spray at the first sign of infestation. If the infestation is well-established, additional sprays at weekly intervals may be needed. Heavy infestations late in the season are almost impossible to control. Yellow-colored card traps covered with a sticky glue substance are useful against whitefly, as they are strongly attracted to the color yellow. Sprays of insecticidal soap or horticultural oil are also effective.

Stink bugs, including the harlequin bugs, are shield-shaped. The harlequin bug is orange and black. Most of the other stink bug pests are solid green or brown. The color patterns of young stink bugs differ from that of the adult. Harlequin bugs wilt cabbage and turnips; leaves turn brown as if scalded. Other stink bugs cause warts on bean and okra pods, and tomato and pepper fruit may show yellowish hard spots under the skin. Squash bugs are oblong and brown, but the young are gray. They attack only squash, pumpkins, gourds and melons in that order of preference. Keep stink bug numbers to less than one per 40 plants on tomatoes and peppers.

There is a new stink bug—the brown marmorated stink bug—that is both a winter home invader and a very serious summer garden pest, attacking beans, tomatoes, peppers, sweet corn, eggplant, okra, and other vegetables. This insect can build to very high numbers in some years. As this is primarily a pest attacking the fruit part of the plant, netting or row covers can be used to protect after bloom. Malathion or pyrethroids are used to reduce numbers of this pest. Regular weed control around the garden, hand removal, and trap cropping can help to reduce numbers attacking vegetables.

Plant bugs are usually oval and somewhat flattened. The plant bug group includes lygus bugs, the tarnished plant bug and the four-lined plant bug as well as many others. This group feeds on pods, stems, blossoms and leaves. Attacked pods often drop, or the seeds are pitted and undesirable for food. Leaf feeding may cause dead spots that resemble leaf spot disease symptoms.

Control weeds that are alternate hosts. Apply an appropriate insecticide from the table following this general discussion when bugs are present. Destroy crop residues immediately after harvest.

Figure 20.23. Mite.

Mites—Mites are tiny, eight-legged relatives of insects found on leaf undersides and are barely visible to the naked eye. Infested leaves are very finely speckled or "bronzed," giving them a dusty look. If badly infested, the leaves are covered with very fine cobwebs. Beans, cucumbers, melons and tomatoes are most often attacked. Mite outbreaks are more common during hot, dry periods.

Spray with malathion when injury first appears, and repeat as needed. The webbing may be broken up by strong hosing of infested plants with water. This may provide some reduction of the problem. Insecticidal soaps provide effective mite control when used properly and complete coverage is obtained. Weed control around the garden can help delay the onset of problems. Keep mite numbers to less than 20 per leaflet on tomato and less than 50% infested runners on watermelon.

Thrips—There are several important species of thrips, but only the onion thrip is apt to be a problem. It is yellowish or brown, tiny (only 1⁄25 inch long), and winged. Young onion thrips are tinier, white and wingless. Thrips take sap from onion foliage, causing white blotches. Tips of foliage wither and turn brown. Maintain fewer than 10 per plant at early bulb stage.

Control with esfenvalerate or malathion. Insecticidal soap mixed with horticultural oil and botanical insecticides that include neem oil have been somewhat effective. Properly compost vegetable residues—particularly onion residues—to prevent infestations. Regular weed control around the garden will help.

Leafhoppers—Leafhoppers are tiny, pale green, wedge-shaped, active insects that are mostly pests of potatoes, beans and lettuce. Immature leafhoppers resemble the adults and move sideways when disturbed. By sucking the sap, they cause bean leaves to curl downward and turn yellow. Plants may be stunted or killed. On potatoes, the tips and sides of leaves curl upward, turn yellow to brown and get brittle. Aster yellows virus is spread to lettuce by leafhoppers.

Plant lettuce near hedges or other sheltered areas. Apply malathion or pyrethroid sprays weekly as needed. Control weeds that may host leafhoppers and harbor viruses, or treat weeds along with the crops for leafhoppers. Botanical insecticides based on pyrethrum and neem have shown fair control of this pest.

Chewing Insects

Asparagus Beetle—The asparagus beetle is ¼ inch long and black with yellow markings. The larva is olive green and ⅓ inch long. The eggs look like tiny black pegs on spears and stems. Adults and larvae eat asparagus foliage and disfigure spears. The threshold for control is 10% of spears with beetles and to keep defoliation below 10%.

Mexican Bean Beetle—The Mexican bean beetle is coppery to yellow with 16 black spots on its back and is ¼ inch long. Larvae are yellowish, spiny, up to ⅓ inch long and are found on the undersides of leaves. Adults and larvae skeletonize bean foliage and feed on pods. While most lady beetles feed on other insects, the Mexican bean beetle is only a plant feeder. Use a pyrethroid as necessary for control. Mexican bean beetles can be excluded from small bean plantings using thin floating row cover material. Handpicking of beetles is also useful for small plantings. Neem-based botanical insecticides have some effect. Use sanitation of debris around the garden at end of year to reduce overwinter survival. Keep defoliation below 30% prior to bloom and 15% after bloom.

Cucumber Beetle—There are two species of cucumber beetles. They are yellowish-green, with one species having black stripes and the other black spots. Besides cucumbers, the flowers and leaves of many other vegetables and flowers may be attacked. Cucumber beetles spread the pathogen that causes bacterial wilt in cucumbers. The larva of the spotted species is also a rootworm of corn and other plants. Early control of cucumber beetles on cucumbers and melons beginning at plant emergence is necessary to reduce bacterial wilt transmission. Cucumber beetles can be excluded from melon/squash/cucumber plantings using thin floating row cover material to cover the plants until harvest. Row covers may have to be opened when the plants are flowering to ensure pollination. Imidacloprid used at planting or the day of transplanting will provide a month of control. Keep cucumber beetle numbers below 1 adult per 4 plants.

Japanese Beetle—The Japanese beetle is metallic green with coppery wing covers. It is ½ inch long. The larvae are white grubs in sod. The adults coarsely skeletonize the foliage of beans and okra, and feed on the foliage and silks of corn. Use a pyrethroid or BeetleGone as necessary for control. Thin floating row cover can exclude Japanese beetles from plants. Botanical insecticides based on Pyrethrum have shown fair control of this pest. Keep defoliation below 30% prior to bloom and 15% after bloom for garden beans.

Colorado Potato Beetle—The Colorado potato beetle is a yellow, black-striped, robust beetle, ½ inch long. Larvae are brick red, humpbacked and up to ⅗ inch long. Adults and larvae defoliate eggplant, potato and tomato. There are two generations per year. Hand-picking of the adults in the spring or effective control of the first generation with sprays helps to reduce the more troublesome summer generation. Adding mulch around potato plants before adult beetles arrive has shown to limit infestation. Neem-based botanical insecticides have some effect. Keep insect numbers below 1 per 4 plants when plants are less than 6 inches in height, and to 1 to 2 per plant afterwards

Bean Leaf Beetle—The bean leaf beetle is reddish to yellow, ¼ inch long, with black spots on its back. Adults eat regularly-shaped holes in pea, bean, and cow-

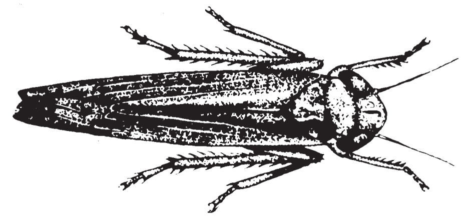


Figure 20.24. Leafhopper.

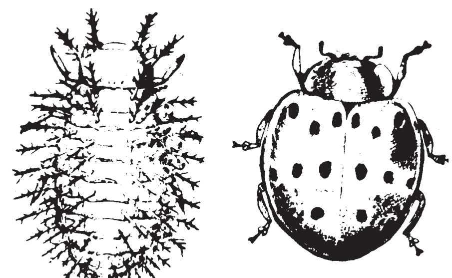


Figure 20.25. Mexican bean beetle.

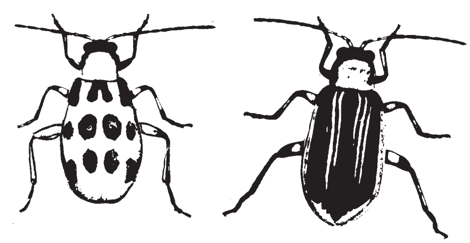


Figure 20.26. Cucumber beetle.

Figure 20.27. Japanese beetle.

Figure 20.28. Colorado potato beetle.

pea leaves, while larvae feed on the plant's root system. Use a pyrethroid as necessary for control. Bean leaf beetles can be excluded from small bean plantings using thin floating row cover material. Handpicking of beetles is also useful for small plantings. Neem-based botanical insecticides have some effect.

Blister Beetle—There are several species of blister beetles. They are black or gray, sometimes with yellow stripes, soft-winged and ¼ to ½ inch long. They eat foliage of various vegetable crops, including potato, tomato and beets. Hand picking and removal can be very effective.

Flea Beetles—Flea beetles are tiny jumping beetles about 1⁄10 inch long. There are many species. They eat shot holes in potato, tomato, eggplant, pepper, beet, spinach, turnip, radish, cabbage, and other crops. Young transplants are often damaged severely. Use a pyrethroid as needed for control. Thin floating row cover can exclude flea beetles from plants and can be left in place until harvest on most crops. Other botanically-based insecticides that include pyrethrum or neem allow only fair control. Keep defoliation below 20% on potato, below 10% with tomatoes, fewer than 2 per plant on eggplant, and below 3 to 5 per plant on cole crops.

Grasshoppers—There are a number of species of grasshoppers, and when they are a problem, a pyrethroid insecticide can be used for control.

Imported Cabbageworm—Imported cabbageworm is a velvety green caterpillar up to 1 ¼ inch long. The adult is a white butterfly with black markings on the wings. The caterpillar eats ragged holes in cabbage leaves and bores into the head. Larvae are commonly found near the developing bud of the plant. Sprays containing *Bacillus thuringiensis* are effective. Keep infestations below 1 worm per 10 plants prior to head development, 1 per 20 heads thereafter.

Cross-Striped Cabbageworm—Cross-striped cabbageworm is a caterpillar up to ½ inch long with many fine, black, transverse lines across a bluish gray back. It has a yellow stripe along each side and a light green, mottled underside. It prefers buds and heads of cabbage, but attacks all cole crops. *Bacillus thuringiensis* sprays are effective. Keep infestations below 1 worm per 10 plants prior to head development, 1 per 20 heads thereafter.

Cabbage Looper—The cabbage looper is a pale-green caterpillar with light stripes down the back. It is up to 1 ½ inch long and humps up or loops when it crawls. It eats ragged holes in many kinds of plants, but particularly cole crops. It also burrows into cabbage heads. This pest is more common with fall plantings. Keep infestations below 1 worm per 10 plants prior to head development, 1 per 20 heads thereafter.

Armyworm—Armyworms are caterpillars similar to cutworms that feed on a wide variety of plants, generally grasses. These may be a problem with early sweet corn plantings. After defoliating a food source, they may move in large masses to new areas.

Hornworm—Hornworms are green caterpillars up to 4 inches long with diagonal white lines on the sides and a prominent horn on the rear end. These large, green caterpillars blend into the foliage and are often overlooked. They defoliate tomato, eggplant, potato, tobacco, and related weeds. Sprays containing *Bacillus thuringiensis* are effective against hornworms. Hand removal is useful when numbers are low, but be careful to leave hornworms that have wasp cocoons attached, as these will do no additional damage and promote biological control. Keep defoliation of tomato below 10%.

Figure 20.29. Flea beetle.

Figure 20.30. Imported cabbageworm.

Figure 20.31. Cabbage looper.

Figure 20.32. Hornworm.

Table 20.23. Spray Dilution Chart.

	Amount per Gallon	Notes
Sevin 50% WP	2 T	See the label for the number of waiting days from the last application of insecticide to harvest.
Malathion 57% EC	2 t	
Captan 50% WP	2 T	If different concentrations (% WP or EC) of any of these fungicides or insecticides are used, be sure to follow label directions for the amount to use per gallon of water.
Zineb 75% WP	2 T	
Maneb 80% WP	2 T	
Mancozeb 80% WP	2 T	
Karathane 25% WP	1 t	
Bravo 75% WP	1 T	
Bravo 500	2-3 T	
Fixed Copper	1 ⅓ T	

Weed Control

Weeds compete with desirable garden plants for water, nutrients, sunlight, and space needed for growth. Weeds also harbor diseases and insect pests that attack vegetable plants. The following measures will help you avoid a weedy garden:

- Prevent garden weeds from going to seed. Some weed seed can remain viable for 20 years or more.
- Keep border areas around the garden free of weeds.
- Clean equipment to prevent weed seeds or plant parts from being transported into clean areas.
- Do not mulch with hay containing grass or weed seeds.
- Avoid using manure unless it has been sterilized or well composted.
- Avoid using soil infested with weeds or weed seeds.
- Avoid buying transplants that are weedy.
- Purchase high-quality vegetable seeds free of weed seeds.

When soil and growing conditions are as ideal as possible and the plants selected are adapted to the soil conditions, garden plants may have a competitive advantage over weeds. No better way of controlling garden weeds exists than having vigorous, desirable plants crowding them out.

Starting Right

Identify your garden site as early as possible and eliminate any perennial weed problems prior to planting. Perennial weeds are those that come back year after year and can reproduce vegetatively through runners, stolons, tubers, etc., as well as by seed. If necessary delay planting one year until you have eliminated those perennial weeds. If you have a site that is suitable and you don't have any perennial weeds, consider solarization. Solarization is using clear plastic over the site prior to planting to warm the soil and cause a rapid flush of weed germination. This is usually done about 3 weeks prior to planting and will give you an opportunity to control many of the annual weed seeds that would germinate and compete with your garden crops.

Controlling Weeds by Hand

Weeding the garden by hand is the oldest form of weed control and is still quite practical in small areas. A major advantage of hand weeding is that no equipment, other than a hoe or hand trowel, is needed. Hand weeding is a good exercise for the heart and a great sense of accomplishment for the soul. However, it is time consuming and only temporarily effective. It must be repeated several times throughout the growing season to assure continuous weed control. Weeding also helps the gardener regularly check plants for early signs of insect and disease problems.

If you decide to weed by hand, a few tips can make it more efficient and possibly even enjoyable. Use high quality, ergonomically designed tools to lessen the strain on your back, wrists, knees. Make sure the hoe blade is clean and sharpened before each use. A sharp hoe will cut the weeds rather than rip them out of the soil and can save a lot of sore arms. Shave off the weeds near the soil surface while they are still small (less than 2 inches) and gently break up the crust. Don't till too deep or you may injure shallow-rooted garden plants and turn up a fresh supply of weed seeds which will germinate. Power equipment such as a rototiller probably cannot be set shallow enough for this type of weed control. For bigger weeds, a rototiller is useful especially in the area between rows.

Mulching for Weed Control

Both organic and inert mulch materials may be used to provide season long control of garden weeds. Advantages and disadvantages of various mulches are discussed in "Caring for Your Vegetables During the Growing Season" under "Mulching."

Chemical Weed Control

Hand weeding and mulching are more preferable than herbicide use in the home garden, because herbicides which can be safely used with some crops may severely damage more sensitive ones. They also may remain in the soil and damage future plantings. Herbicides, however, provide effective weed control where substantial areas of single or related crops are grown. Even so, their use should be complemented with hand weeding and/or mulching.

For any seed, including weed seed, to germinate and grow, three soil factors must be present in the proper ratio: soil moisture, optimum temperature, and oxygen. These factors normally occur in an optimum combination near the soil surface where weed seeds are located. That is, optimum conditions for weed seed germination and subsequent growth occur in the top 1 inch of soil. Because weed seeds are near the soil surface, any hand weeding or tilling after herbicides are used should be as shallow as possible. Follow these points for successful use of herbicides in the home garden:

Plan the garden in advance—Group crops according to their herbicide tolerance, i.e., group in one area all crops for which one herbicide is recommended. This grouping lets you treat larger areas with minimum effort.

Apply at the right time—Understand that most garden herbicides are termed "preemergence." That is, they should be applied to a clean tilled soil surface before weed seeds germinate. They do not have an effect once weeds have already emerged.

Know what weeds you have—Herbicides may control one species of weed and not another. There are good weed identification guides available.

First prepare the soil—Before applying a preemergence herbicide, till the soil to remove existing weeds and work out all clods, leaving the soil surface as smooth and level as possible.

Follow the label directions very carefully—THE LABEL IS A LEGAL DOCUMENT. Apply preemergence herbicide accurately and uniformly. Uneven application may result in poor weed control or may injure present or subsequent crops. Check amounts of the material to be used and read carefully the application techniques on the container label.

Apply the herbicide on moist soil—When using most preemergence herbicides, about ½ inch of rainfall is needed within seven days of application for optimum weed control. If not enough rain has fallen within seven days, apply ½ inch of water by way of overhead irrigation. Do not use furrow irrigation as it will wash out the herbicide and reduce its effectiveness.

Sprayer types—The simplest and most reliable sprayer for application of home garden herbicides is the 1- or 2-gallon compressed air sprayer. These sprayers are simple to operate, inexpensive and provide uniform application of the herbicide. *It is highly recommended that you assign one sprayer for exclusive herbicide use and another for insecticide or fungicide use.*

If the label does not specify the water volume to use, a general rule of thumb for best distribution over the entire area is to use 1 gallon of the herbicide-water mixture per 400 square feet of soil surface. This volume should be sprayed evenly over the 400 square feet. Square footage is figured by multiplying the length of the garden by the width of the garden. For example, a 20 ft x 20 ft garden = 400 square feet; or a 10 ft x 40 ft garden = 400 square feet. Do not guess distances and/or areas to be sprayed. Accurately measure or weigh the amount of herbicide that is to be added to the sprayer. Practice with water only for several times if you have not sprayed pesticides previously.

Granular herbicides—Some garden herbicides are available as granular materials in shaker-type containers. These are the easiest formulations for most home gardeners to apply since they do not need to be mixed with water for application. As with all herbicides, use these exactly as the label directs. After sprinkling the granular material over the treatment area, use a rake to lightly incorporate the herbicide into the soil.

Cleaning equipment—Rinse all spray equipment thoroughly inside and out after each application and run plenty of clean water through the hose and nozzle. Never use growth regulator or phenoxy-type herbicides such as 2,4D in or around the home garden. These herbicides cannot be cleaned out of sprayers thoroughly enough to avoid injury to vegetable crops. Do not use sprayers in the garden which have been used to apply these herbicides to lawns. Be careful of drift onto the garden when spraying your lawn.

Where to purchase—Home garden herbicides can generally be purchased at nurseries, garden centers, or garden supply stores. In smaller communities and in rural areas, the homeowner may be able to purchase these materials from farm supply stores, hardware stores, and drugstores or through mail order nursery and seed catalogs.

Use herbicides with caution—Follow the manufacturer's directions to the letter when measuring, mixing, or applying them. Read the label carefully for the names of plants that product can be safely used. Heed all other warnings and note precautions. If you have any questions, consult your Extension agent for agriculture.

Garden Herbicides

The following section includes the trade name and formulation of one of the readily available garden herbicides. It would be impossible to list all the potentially available home garden products as the list changes on a yearly basis. Since rates and methods of herbicide application vary from one formulation to another, be sure to read the product label for complete application instructions before application.

CHEMICAL NAME: Trifluralin

TRADE NAME: Greenview Preen, 1.47% granules. There are several other formulations that contain trifluralin.

PLANT: Asparagus (established beds), Lima and Snap beans, Broccoli (transplants), Brussels sprouts (transplants), Cabbage (transplants), Cantaloupes, Cucumbers, Carrots, Cauliflower (transplants), Celery, Collards, Okra, English and Snap peas, Southern peas (cowpeas, field peas, blackeyed peas), Peppers (transplants), Potatoes, Tomatoes (transplants), and Watermelons.

REMARKS AND LIMITATIONS: For control of annual grasses such as crabgrass, foxtail, and goosegrass, and broadleaf weeds such as pigweed and lambsquarters. Remove existing weeds prior to application. Mix thoroughly into the top 1 to 2 inches of soil. Read and follow label directions for use on each crop. Other crops not listed here may be easily injured.

Storing Vegetables

Vegetables do not improve in quality after harvest. Therefore, harvesting sound, healthy produce at the proper stage of maturity is important. Produce that will be stored must be harvested carefully to avoid bruising and to maintain quality. Breaks in the skin enable decay organisms to enter the produce and also increase moisture loss.

Vegetables and fruits can be grouped in four basic storage groups:

- The cool- and cold-moist groups may be stored in an old-fashioned outdoor pit or underground root cellar.
- The cold- and cool-dry groups can be stored in a cool area of a basement or garage.

While storage does not require investment in expensive equipment, it does demand an awareness of good food characteristics and periodic examination to remove defective produce.

Generally, late-maturing varieties are better suited for storage. Garden crops held in storage are still living plants that are kept dormant by their environment. If these crops are subjected to adverse conditions like lack of oxygen, freezing, or excessive moisture, they can die or decay. Produce can tolerate less than optimum storage conditions, but storage life is shortened.

You can store some produce in the garden right where it grew. It may be protected from late fall frosts and freezing by insulating materials such as straw, dry leaves, sawdust or soil. Root crops such as carrots, turnips and parsnips will store well this way. When the ground begins to freeze in late fall, cover them with a heavy mulch of straw or dry leaves to make midwinter harvesting easier.

Beets, cabbage, Chinese cabbage, cauliflower, kale, leeks and onions can also withstand light frosts. They can be stored for several weeks under heavy mulch but usually will not keep through the winter.

Be sure to plant crops to be stored under mulch in a spot that is easily accessible for winter removal.

A 20-gallon trash container can be buried in the ground for storage and is more easily opened and closed than a soil mound or trench. Metal cans are more rodent proof than plastic. Drill holes in the bottom for drainage (Figure 20.33). Leave 1 to 2 inches of the can above the soil level and use straw to cover the lid. A foam plastic chest also makes a good small produce storage container and can be kept in an unheated garage or building. Use separate containers for fruits and vegetables. Be sure the storage containers are clean so that they do not impart flavors or odors to the stored produce.

Basement areas near the furnace make an acceptable storage site for winter squash and pumpkins. Use a thermometer to monitor the temperature in various areas of a basement or building to find locations adaptable for good food storage.

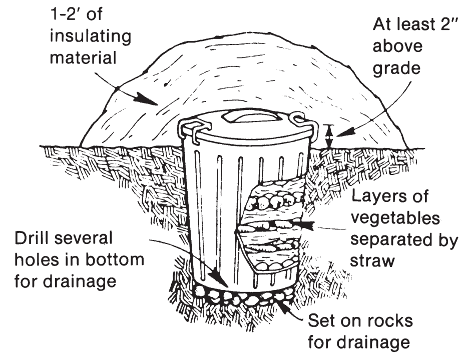


Figure 20.33. Storing vegetables in the ground.

Basement window wells which open inward and have exterior wells can be converted to small storage areas if the well is covered after the weather turns cool and is insulated with bales of hay or straw.

Table 20.24. Produce storage conditions.

Produce Category		Storage Temp. (°F)	Relative Humidity	Storage Period
Cold-Moist	Broccoli	32	95%	3 weeks
	Cabbage (late)	32	95%	3-4 months
Cool-Moist	Irish potato (late)	40	85-90%	4-6 months
	Sweet potato (after curing)	55	85-90%	4-6 months
	Tomato (mature green)	60	85-90%	1-4 weeks
Cold-Dry	Onion	32-35	60-70%	2-8 months
Cool-Dry	Pumpkins	50-55	60-70%	2-4 months
	Winter Squash	50-55	60-70%	2-4 months

Table 20.25. Preservation methods for specific vegetables.

Produce	Store	Can	Pickle/ Preserve	Freeze	Produce	Store	Can	Pickle/ Preserve	Freeze
Asparagus				x	Horseradish	x		x	
Beans, Wax or Green		x		x	Kohlrabi	x			
Beans, Dry[2]	x				Parsley (dried)	x			x
Beets	x[1]	x	x		Parsnips	x	x		
Broccoli		x		x[1]	Peas		x		x
Brussels Sprouts	x			x	Peppers, Hot (dried)	x			
Cabbage	x[1]		x		Peppers, Sweet		x		x
Cauliflower	x			x	Potatoes	x[1]			
Celery	x				Potatoes, Sweet	x	x		
Chard				x	Pumpkins	x[1]	x		
Chinese Cabbage	x				Rutabagas	x			x
Corn		x	x	x	Salsify	x			
Greens, Kale	x				Tomatoes	x	x[1]		
Greens, Swiss Chard		x		x	Winter Radishes	x			
Greens, Spinach				x	Winter Squash	x[1]	x	x	

[1] Preferred method
[2] Kidney, navy, white marrows, turtles

What You Should Know about Asparagus through Watermelons

Asparagus

Asparagus is a perennial vegetable that, once established, may live for 15 to 30 years. Locate asparagus to one side of the garden where it will not be disturbed. It is one of the most valuable early vegetables and is well adapted to freezer storage. The spears develop daily in early spring with the rate of emergence increasing as temperatures increase.

Planting—You can start asparagus from seed, although starting from one- to two-year-old crowns set in early March is recommended. One-year-old crowns or plants are preferred. The crowns are actually a combination of rhizomes, fleshy roots and fibrous roots. The fleshy roots, which may spread laterally under the soil several feet from the rhizomes, store food reserves that help develop the tender shoots the next spring.

Soil type determines the depth to plant crowns. Usually they are planted in a trench 12 to 15 inches wide and 6 to 8 inches deep. Plant at the shallower depth if the soil is heavy. Incorporate rotted manure or compost, plus fertilizer, into the soil before setting the crowns because little organic matter can be added later. Set plants 15 to 18 inches apart in rows 30 inches apart. Place the crown on a small amount of soil in the trench, allowing it to be slightly higher than the roots. Spread the roots out and cover the crown with 2 to 3 inches of soil. Firm down well. As plants begin to grow, continue to put soil around and over the crowns until the trench is filled.

Insect Control, Asparagus:
See insect descriptions, pgs 273-277.

	Insect Treatments
Aphids	8, 9, 10
Asparagus Beetles	2, 12
Cucumber Beetles	2
Cutworms	12

Note: *The treatments listed below were accurate when this publication when to press. Always consult the pesticide label before applying pesticides. Recommendations may change at any time.*

Harvesting—Asparagus shoots or spears should not be harvested the first year after crowns are set. Limit harvests the second year after planting to three to four weeks, then let the ferns grow. This procedure is necessary so that the root system will develop from its limited size and will store food reserves to produce growth the next year. Plants harvested too heavily too early after setting may become weakened and spindly. After the third year, harvests can be continued for eight to ten weeks. Harvest spears daily when they are 5 to 7 inches tall. Break them off at the soil level instead of cutting below the soil surface. Cutting can easily injure the crown buds which produce the next spears. Harvest in early morning and use or refrigerate immediately.

Fertilizing—Each year in the early spring, sidedress asparagus with 1 pound or 2 cups of 5-10-10/50 feet of row. Apply 2 cups of 10-10-10 or similar fertilizer after harvest. Following freezing weather in the fall, remove the asparagus tops to decrease disease problems.

Diseases

Crown Rot, Wilt (fungus)—Plants gradually decline and die. Avoid acid soils and poorly drained sites. Maintain good fertility. Avoid excessive harvest.

Rust (fungus)—Reddish-black pustules on leaves and stems. Grow rust-resistant varieties. Spray with mancozeb (from harvest until August 15) or sulfur fungicides.

Beans

Beans grown for the pod, such as green snap beans, are the most common type of bean growing in the home garden, though some green beans are grown primarily for the bean itself and not the pod. Lima beans and edible soybeans are also popular. Beans are sensitive to cold temperatures and should not be planted until after the danger of frost is past in the spring.

Insect Control, Beans:
See insect descriptions, pgs 273-277.

	Insect Treatments
Aphids	1, 2, 3, 8, 9, 10
Bean Leaf Beetle	9, 12
Corn Earworm	5, 13
Cutworms	11
Flea Beetles	5, 9, 12
Grasshoppers	1, 5
Japanese Beetle	1, 13, 14
Leafhoppers	1, 2, 3, 5, 8, 9, 10
Lygus Bugs	1
Mexican Bean Beetle	2, 5, 9, 14
Mites	1, 10
Seed Maggots	1
Stink Bugs	5
Tarnished Plant Bug	5
Whiteflies	2, 3, 10

The bush type is the most popular of the snap beans because it matures earlier and requires less space. Most varieties of bush snapbeans will have pods ready for harvest 50 to 60 days from seeding.

Pole type snapbeans require stakes, a trellis, a fence or some other type of support. They also require a few more days to mature their pods and they continue to bear over a longer period than the bush type varieties. They require about 65 days from seed to harvest.

Snap beans reach their best stage of edible maturity when the seed within the pod is about one-third developed.

Varieties of shell beans are more suitable for shelling than for use in the pod. Varieties such as "Dwarf Horticultural" and "French Horticultural" are examples of good shell beans. They mature in 65 to 70 days and have a bush habit.

There are both pole and bush type lima beans, which are sometimes called "butterbeans." Several types of pole lima beans

Insect Treatments: 1. Malathion 50% EC (Ortho Max Malathion Insect Spray), **2.** Pyrethrins, **3.** Imidacloprid (Bioadvanced Fruit, Citrus, Vegetalbe Insect Control), **4.** Cyfluthrin (Bioadvanced Vegetable and Garden Insect Spray), **5.** Bifenthrin 0.3% + zeta-cypermethrim 0.075% EC (Ortho Bug-B-Gon Insect Killer for Lawns and Gardens), **6.** *Bacillus thuringiensis* var *kurstaki*, **7.** Carbaryl 5% B (Southern Ag Mole Cricket Bait), **8.** Insecticidal soap, **9.** Neem, **10.** Horticultural Oil, **11.** Bifenthrin, (Bonide Eight Flower and Vegetable Soil Insect 0.115% granules), **12.** Permethrin (Bonide Eight Insect Control Vegetable Fruit and Flower Concentrate), **13.** Spinosad (Captan Jacks Dead Bug Brew), **14.** Acetamiprid 0.5% (Ortho Flower, Fruit & Vegetable Insect Killer)

Insect Control, Beets:
See insect descriptions, pgs 273-277.

	Insect Treatments
Aphids	1, 3, 9, 10
Blister Beetles	2
Cutworms	7
Flea Beetles	3, 9, 13
Harlequin Bug	4
Imported Cabbageworm	4, 6
Leafhoppers	4, 9, 10
Root Maggots, Seed Maggots	1
Sowbugs	7
Stink Bugs	4
Tarnished Plant Bug	4

exist. In general, the pole types take longer for the pods to mature than do bush types. Lima beans often drop their blossoms during excessively hot or rainy weather.

Edible soybeans are grown like bush snap beans. They require a longer growing season, usually 80 to 100 days. Pick them when the pods are nearly full-grown but before they begin to turn yellow. Shelling is easier if you drop the pods in a pot of boiling water for 15 to 20 minutes. The length of time they should be left in the boiling water depends on how tender you like them. After draining the water from the pods, sprinkle them with salt or dip in soy sauce. You can then squeeze the beans from the pods and eat them. Soybeans also can be grown for dry beans.

Plant Spacing—Plant bush snap beans in rows 24 to 30 inches apart. Plant seeds 2 to 3 inches apart in the row and 1 to 1 ½ inches deep in a well-prepared seedbed. It will usually take 1 pound of bush snap bean seed to plant 100 feet of row. Seed lima beans about 4 to 5 inches apart in the row. They do not produce well when they are crowded. Plant soybeans the same as bush snap beans. Plant pole beans 4 to 6 inches apart in rows 36 to 48 inches apart. You can have a continuous supply of beans by planting every two weeks until mid-August.

Diseases (Snap and Lima Beans)

Anthracnose (fungus)—Pod spots are dark, sunken, circular or oval areas with brown borders and salmon-colored ooze in center; disease also occurs on leaves and stems. Do not save seed from diseased beans; use disease-free seed; rotate crops; plow under bean residue. Apply chlorothalonil at seven- to ten-day intervals starting at first sign of disease. Sulfur spray or dust can be used for disease control. Guard against phytotoxicity under certain weather conditions. Do not work wet plants.

Bacterial Blights (bacteria)—Brown or tan dead areas on the leaves as spots or blotches, often with a yellow border; pods may also show brick-red or brown sunken blotches. Use disease-free seed; avoid saving seed from one growing season to the next since bacteria can be carried to the seed; in severe cases, fixed copper fungicides applied at seven-day intervals at first sign of disease will assist in control.

Damping-Off and Seed Decay (fungi)—Failure of seeds to grow; death of young plants; poor stands. Buy seed treated with fungicides; plant seed in warm soil.

Root and Stem Rots (fungi)—Brown, decayed areas on lower stem and decayed roots, resulting in wilting, poor top growth, and death of plants. See "Damping-Off" above; rotate beans to another part of the garden from year to year so that root decay fungi won't build up in the soil.

Rust (fungus)—Small, rusty-brown spots (pustules) on leaves; mainly a late-season or fall garden problem. Use resistant varieties; chlorothalonil spray or sulfur dust will help prevent the disease; do not use chlorothalonil within seven days of harvest.

Bean Mosaic (virus: may include several different aphid-carried viruses)—Yellowing, crinkling, downward cupping of leaves; mosaic yellow and green patterns on leaves; dead areas along veins; on vine and runner types, dieback of the growing tip; disease carried to beans by aphids from clovers. Avoid planting beans near white or red clover or other legumes; plant bush beans or other resistant varieties; destroy legumes and other weeds near the garden; plant successive crops of beans; increased plant seeding density may also help.

Beets

Beets are easy to grow and are rich in iron and vitamins A and C. The tops may be harvested as greens. Beets are sensitive to acid soil, so add lime before planting if a soil test so indicates.

Planting—Sow successively at about three- to four-week intervals from early spring to mid-August for a continuous supply of young, tender beets.

Plant seeds ¼ to ½ inch deep in rows 18 inches apart or wider if you use a mechanical cultivator. Beet seeds are actually fruits containing several seeds. Thin the seedlings when well established to stand 2 to 3 inches apart in the row.

Problems—Boron deficiency in the soil can cause hard or corky black spots scattered throughout the root in light-colored zones. To alleviate this problem in subsequent years, sprinkle ¼ pound of borax/1000 square feet where beets are to be grown. Do not plant beans or soybeans in the same area for a year or two, since these vegetables are sensitive to boron toxicity.

Also, close planting or failure to thin can cause undersized roots to form.

Harvesting—Harvest for greens when the tops are large enough for cooking. For good quality roots, harvest when they are 1 ½ inches or less in diameter. Beets will keep for several months if packed in moist sand and placed in a basement or garage. Do not let them freeze. Before storing, trim off all but ¼ inch of the tops.

Broccoli

There are different types of broccoli—annual green or, more rarely, purple broccoli; "romanesco," which has yellowish green, conical groups of buds arranged in spirals; and sprouting broccoli, an overwintering annual or perennial, rarely grown in this country. Varieties dif-

Insect Treatments: 1. Malathion 50% EC (Ortho Max Malathion Insect Spray), **2.** Pyrethrins, **3.** Imidacloprid (Bioadvanced Fruit, Citrus, Vegetalbe Insect Control), **4.** Cyfluthrin (Bioadvanced Vegetable and Garden Insect Spray), **5.** Bifenthrin 0.3% + zeta-cypermethrim 0.075% EC (Ortho Bug-B-Gon Insect Killer for Lawns and Gardens), **6.** *Bacillus thuringiensis* var *kurstaki*, **7.** Carbaryl 5% B (Southern Ag Mole Cricket Bait), **8.** Insecticidal soap, **9.** Neem, **10.** Horticultural Oil, **11.** Bifenthrin, (Bonide Eight Flower and Vegetable Soil Insect 0.115% granules), **12.** Permethrin (Bonide Eight Insect Control Vegetable Fruit and Flower Concentrate), **13.** Spinosad (Captan Jacks Dead Bug Brew), **14.** Acetamiprid 0.5% (Ortho Flower, Fruit & Vegetable Insect Killer)

Insect Control, Broccoli:
See insect descriptions, pgs 273-277.

	Insect Treatments
Aphids	1, 2, 3, 5, 9, 13, 14
Cabbage Looper	5, 6, 12, 13, 14
Cutworms	5, 7, 11
Diamondback Moth	5, 6, 12, 13, 14
Flea Beetles	2, 5, 9, 13
Harlequin Bug	2, 5, 14
Imported Cabbageworm	1, 2, 5, 6, 12, 13, 14
Sowbugs	7, 11

fer in compactness and number of sprouting lateral heads. Broccoli is an excellent home garden vegetable, if the wormy insects can be controlled.

Planting—Buy transplants locally or produce your own and set out April 1 to 15 or by August 1. Transplants for a fall setting can be produced along with cabbage and cauliflower transplants, taking about four to six weeks from seeding to setting. Broccoli does much better as a fall crop. Set plants 14 to18 inches apart in rows 30 inches apart. Use starter fertilizer for transplants.

Harvesting—The heads of broccoli are a mass of flower buds which must be harvested before the flowers open to show yellow. When mature, the central head measures 6 to 9 inches across. Lateral heads are smaller. When harvesting, cut 5 to 6 inches of the stem and accompanying leaves with the head. Use or freeze broccoli soon after harvesting.

Diseases

Black Rot (bacterium)—Yellow or tan-colored V-shaped areas on leaf edges; leaf veins and vascular ring in stem may be black; head may decay; young plants may be dwarfed or one-sided with yellow or brown shriveled leaves. Select tolerant varieties; use commercially grown, disease-free seed or transplants; rotate broccoli with other crops from year to year.

Damping-Off, Wirestem (fungus)—See "Damping-Off" discussion for beans; wirestem describes condition of seedling stem following stem decay. Use fungicide-treated seed or buy disease-free transplants. Plant shallowly, in warm soils. Avoid transplant shock.

Brussels Sprouts

The Brussels sprout is closely related to cabbage, cauliflower and broccoli. The plant's edible portions are the buds or small heads that grow in the axils of the leaves. The heads, about 1 inch in diameter, can be prepared like cabbage.

Planting—Brussels sprouts do best as an early spring crop or as a fall crop in a cool, moist climate. For an early spring crop, start the seed about eight weeks before the plants are to be transplanted to the garden. Well-grown transplants can be transplanted to the garden by March 15 in most areas of Kentucky, allowing for harvest in mid-June.

For a fall crop, sow seeds in open plant beds from May 15 to early June. Transplants will usually be ready in four to six weeks. Space plants 24 inches apart in the row. Cut off the top of plants in mid-September to firm up sprouts. Harvest after the first frost in October. Fall harvest is the most practical and rewarding.

Harvesting—Sprouts are produced earliest in the axils of the lower leaves of the plant. Harvest the sprouts when they are about 1 to 1 ½ inch in diameter. The plant's lower leaves should be broken away and the sprouts twisted or cut off close to the stem with a sharp knife. Make successive harvests from the base upwards as the sprouts develop.

Diseases: see "Broccoli"

Insect Control, Brussels Sprouts:
See insect descriptions, pgs 273-277.

	Insect Treatments
Aphids	1, 2, 3, 5, 8, 9, 13, 14
Cabbage Looper	1, 2, 5, 6, 12, 13, 14
Cross-Striped Cabbageworm	1, 2, 5, 6, 12, 13, 14
Cutworms	5, 7, 11
Diamondback Moth	1, 2, 5, 6, 12, 13, 14
Flea Beetles	2, 5, 9, 13
Harlequin Bug	2, 5, 14
Imported Cabbageworm	1, 2, 5, 6, 12, 13, 14
Sowbugs	7, 11

Cabbage

Cabbage grows in cool temperatures but is well-adapted for home gardens from March to December. It will withstand temperatures down to 20°F.

Cabbage heads differ in sizes, hardiness, shape, color and leaf type. Cabbage can be used fresh or made into sauerkraut. Red cabbage can be pickled and adds color to slaw, but it is not adapted to cooking or for sauerkraut because it releases its red color to the juices. Generally, late cabbage is made into sauerkraut.

Planting—Buy locally grown transplants or start your own in growing structures four to six weeks before the planting date. A few seeds can be sown in the cold frame or garden every month up to July 15 to have cabbage plants to set at intervals during the season.

Plants take about three weeks from seeding to setting during the summer months. Plant only the earliest-maturing varieties after July 5.

Plant spacing affects head size; close spacing (9 to 12 inches apart in the row) produces small heads. The average spac-

Insect Control, Cabbage:
See insect descriptions, pgs 273-277.

	Insect Treatments
Aphids	1, 2, 3, 5, 8, 9, 12, 14
Cabbage Looper	1, 2, 4, 5, 12, 13, 14
Cutworms	5, 7, 11
Diamondbacked Moth	1, 5, 6, 12, 13, 14
Flea Beetles	2, 5, 9, 13
Harlequin Bug	2, 5, 14
Imported Cabbageworm	1, 2, 5, 6, 12, 13, 14
Root Maggots	1
Sowbugs	7, 11

Insect Treatments: 1. Malathion 50% EC (Ortho Max Malathion Insect Spray), **2.** Pyrethrins, **3.** Imidacloprid (Bioadvanced Fruit, Citrus, Vegetalbe Insect Control), **4.** Cyfluthrin (Bioadvanced Vegetable and Garden Insect Spray), **5.** Bifenthrin 0.3% + zeta-cypermethrim 0.075% EC (Ortho Bug-B-Gon Insect Killer for Lawns and Gardens), **6.** *Bacillus thuringiensis* var *kurstaki*, **7.** Carbaryl 5% B (Southern Ag Mole Cricket Bait), **8.** Insecticidal soap, **9.** Neem, **10.** Horticultural Oil, **11.** Bifenthrin, (Bonide Eight Flower and Vegetable Soil Insect 0.115% granules), **12.** Permethrin (Bonide Eight Insect Control Vegetable Fruit and Flower Concentrate), **13.** Spinosad (Captan Jacks Dead Bug Brew), **14.** Acetamiprid 0.5% (Ortho Flower, Fruit & Vegetable Insect Killer)

ing is 14 to 16 inches apart in rows spaced 30 inches apart. Varieties for sauerkraut are planted at the wider spacing.

Harvesting and Storage—Harvest cabbage when it reaches adequate size, depending on variety and growing conditions. Firm heads are preferred to soft heads, especially for storage. Heads can be left on the plant in the garden for about two weeks in the summer but longer in the fall after they are ready to harvest. Cabbage can be stored in the refrigerator for a month or two.

Long-term Storage—Harvest late fall or winter cabbage once the weather is cool by pulling up the plant with the root still attached. Discard the loose outer leaves and check for possible insect problems. Cabbage has a strong odor which may contaminate other vegetables. Hang plants by roots or wrap them in several sheets of newspaper tied with string. See "Storing Vegetables" on page 280.

Diseases: see "Broccoli"

Carrots

Carrots are rich in vitamin A, thiamine and riboflavin. They may be cooked or eaten raw. Varieties with extremely long roots are not recommended for home gardens.

Planting—You can plant carrots from March 15 until the first of July. Sowing at three-week intervals will assure a continuous supply.

Plant seed ¼ inch deep in rows 18 inches or more apart. Since carrot seed is slow to germinate, radish seed is often mixed with it. The radishes will mark the row and break the soil crust, making it easier for the carrots to emerge. Thin carrots to 2 to 3 inches between plants after the seedlings are 1 to 2 inches tall.

Harvesting and Storage—Carrots may be harvested when they reach the desired size. Harvest fall-planted carrots before freezing weather. Wash the roots, trim tops to ½ inch and store in perforated plastic bags in the refrigerator, a cold, moist cellar or pit. Carrots will keep from two to four months. Do not store carrots in the same room as apples. Apples give off ethylene, which causes carrots to become bitter.

Insect Control, Carrots:
See insect descriptions, pgs 273-277.

Insect	Treatments
Aphids	2, 8, 9
Cutworms	4
Flea Beetles	3, 4, 9, 13
Root Maggots, Seed Maggots	3

Cauliflower

To develop the white center head, or curd, cauliflower plants probably require more exact growing conditions than any other vegetable crop. Cauliflower plants need a cool, humid climate.

Varieties differ in plant size, curd size, color (white, orange, purple), and days to maturity, ranging from 50 to 100 days.

Planting—Buy good quality transplants or start your own about four to six weeks before transplanting. Set plants 16 inches apart in rows 2½ feet apart March 10 to 25 for the spring crop and July 15 for the fall crop. Any interruption in growth (cold, heat, drought) can cause stunting and premature heading or "buttoning." Cauliflower does much better as a fall crop.

Blanching—Exposing the young curd to sunlight discolors the curd and produces off flavors. Gather the long leaves over the small, white curd and tie them together or band them over the heads. This must be done as soon as the curd begins to show.

Harvesting—Curds will mature one or two weeks after tying, reaching about 6 to 9 inches in diameter. Heads will turn from clear white at peak of maturity to yellowish-brown when overly mature. Cool immediately after harvest and keep refrigerated. If storage for several weeks is required, leave a portion of the stalk and leaves to protect the delicate curd.

Diseases: see "Broccoli"

Insect Control, Cauliflower:
See insect descriptions, pgs 273-277.

Insect	Treatments
Aphids	1, 2, 3, 5, 8, 9, 12, 14
Cabbage Looper	1, 2, 5, 6, 12, 13, 14
Cross-Striped Cabbageworms	2, 5, 6, 8, 12, 13, 14
Cutworms	5, 7, 11
Diamondback Moth	1, 2, 4, 5, 12, 13, 14
Flea Beetles	2, 4, 5, 9, 13
Harlequin Bug	2, 5, 14
Imported Cabbageworm	1, 2, 5, 6, 12, 13, 14
Sowbugs	7, 11

Chinese Cabbage

Chinese cabbage is one of the oldest vegetable crops, but it is seldom grown by Kentuckians. It is more closely related to mustard than to cabbage and is sometimes called Crispy Choy, Chihili, Michili and Wong Bok. The leaves are folded together into a conical head more or less open at the top. It is eaten raw or stir-fried.

Planting—Chinese cabbage can be more successfully grown as a fall rather than a spring crop. Plant seeds in 24-inch or wider rows in late July. Irrigation and mulch will aid germination and growth. Plants should be thinned to 12 to 15 inches in the row. Fertilize when half grown.

Harvesting—Harvest heads after the first moderate frost in the fall. Store Chinese cabbage in perforated plastic bags in the refrigerator, cellar or outdoor pit for up to two months.

Collards

Collards are a member of the cabbage family used as greens. They are highly nutritious and rather easy to grow.

Planting—Sow seed in mid-March or start plants indoors three weeks before outdoor planting time. Additional plantings can be made until mid-August. Plants should be set or thinned to 2 to 4 inches apart within the row. Rows should be 24 inches or wider if you use mechanical cul-

Insect Treatments: 1. Malathion 50% EC (Ortho Max Malathion Insect Spray), **2.** Pyrethrins, **3.** Imidacloprid (Bioadvanced Fruit, Citrus, Vegetalbe Insect Control), **4.** Cyfluthrin (Bioadvanced Vegetable and Garden Insect Spray), **5.** Bifenthrin 0.3% + zeta-cypermethrim 0.075% EC (Ortho Bug-B-Gon Insect Killer for Lawns and Gardens), **6.** *Bacillus thuringiensis* var *kurstaki*, **7.** Carbaryl 5% B (Southern Ag Mole Cricket Bait), **8.** Insecticidal soap, **9.** Neem, **10.** Horticultural Oil, **11.** Bifenthrin, (Bonide Eight Flower and Vegetable Soil Insect 0.115% granules), **12.** Permethrin (Bonide Eight Insect Control Vegetable Fruit and Flower Concentrate), **13.** Spinosad (Captan Jacks Dead Bug Brew), **14.** Acetamiprid 0.5% (Ortho Flower, Fruit & Vegetable Insect Killer)

Insect Control, Collards:
See insect descriptions, pgs 273-277.

	Insect Treatments
Aphids	1, 2, 8, 9, 14
Cabbage Looper	1, 2, 6, 14
Corn Earworm	1, 6, 14
Cross-Striped Cabbageworm	1, 6, 14
Cutworms	4
Diamondback Moth	1, 2, 6, 14
Flea Beetles	3, 9
Harlequin Bug	1, 4, 14
Imported Cabbageworm	1, 2, 6, 13, 14
Leafhoppers	3, 8, 9, 14

tivators.

Harvesting—Harvest when the leaves reach a suitable size. The entire plant or the lower, larger leaves may be picked. If the lower leaves are harvested, upper leaves will develop for later use. Collards do not store well, but may be kept in plastic bags in the refrigerator for up to 14 days. The surplus can be frozen.

Diseases: see "Broccoli"

Cucumber

Cucumber is a warm-season vegetable. Varieties differ in fruit types and uses; both the slicer, or fresh salad type, and the pickle type are available. The pickle type can also be used fresh. Varieties differ in flowering habit and amount of fruit set. The newer gynoecious or all-female-flower hybrids are well adapted to home gardens and produce high yields. Cucumbers are multiple-harvest plants, providing fruits for four to eight weeks. A second planting in mid- to late June will provide quality fruit for late summer-early fall harvesting. Only a few plants are needed to provide an adequate supply.

Insect Control, Cucumber:
See insect descriptions, pgs 273-277.

	Insect Treatments
Aphids	1, 2, 3, 5, 8, 9
Cucumber Beetles	1, 3, 5, 12
Cutworms	5, 7, 11
Leafhoppers	3, 5, 8, 9, 12
Mites	1, 8
Sowbugs	7, 11

Planting—Cucumber vines ramble and spread from row to row. Training on a trellis or fence along the edge of the garden will correct this and also lift fruit off soil. If trellised, plant four to five seeds/foot in rows spaced 30 inches apart. Untrellised rows may need to be spaced 4 feet apart. When plants are 4 to 5 inches high, thin them to stand 2 to 3 feet apart in the row. Cucumber plants are shallow rooted and require ample moisture at all growth stages.

Pollination—For the flower to develop into a fruit, bees must carry pollen from male flowers on the same plant or different plants to the female flower, the one with the tiny "pickle" at the base. Poor cucumber set is common during rainy weather when bees are inactive. Spray insecticides late in the day to avoid harming the bee population.

Harvesting—Fruits may be used when 1 ½ to 2 inches long up to any size before they begin to turn yellow. The length of this period is approximately 15 days for any one fruit. The harvesting period for all fruits extends for about six to eight weeks before plants begin to grow old. It is important to remove fruits before they turn yellow so plants continue to produce. If fruits are picked early, small plants can bear 35 to 50 cucumbers, but if fruits are picked at a large size, only five to 12 cucumbers will form on each plant. Old cucumbers prevent plant food from going into the production of new fruit.

Diseases

Anthracnose, Leaf Spots (fungi)—Sunken circular or irregular spots with dark margins and salmon pink centers on fruits and stems; leaves with brown spots ¼-½ inch across; spots may join together and leaves shrivel and die; other leaf spots vary in size and shape of yellow or dead areas on leaves. Spray with chlorothalonil or mancozeb. Start at first sign of disease and continue as needed. Plant disease-free seed.

Bacterial Wilt (bacterium)—Wilting and drying of vines; bacterial ooze can sometimes be drawn out into fine strands from cut ends of stems. Use insecticides or other means to control striped and spotted cucumber beetles, which transmit the disease-causing bacteria. Use wilt-resistant cucumbers. Use a very thin floating row cover over transplants, sealed at the edges until flowering, as a barrier to cucumber beetles.

Fruit Rot (fungus)—Soft, mushy decay at blossom end of squash fruit; gray, moldy growth resembling a pin-cushion on rotted fruit. See Cucumber "Anthracnose;" spray as young fruits develop.

Mosaic (virus)(may include several different aphid-carried viruses)—Mosaic and malformed leaves. Discolored, lumpy, malformed fruits. Use resistant varieties when available. Destroy weeds near the garden. Plant crops early or raise transplants in cold frame or greenhouse and set out as weather allows.

Powdery mildew (fungus)—White, powdery growth on leaves, yellowing and blighting of foliage. Use resistant varieties when available. Spray chlorothalonil, copper fungicides, sulfur spray or dust, horticultural or neem oils at first signs of disease and at weekly intervals. Guard against copper or sulfur phytotoxicity under certain weather conditions.

Seed Rot and Damping-Off (fungi)—Stand failure due to seed rot or seedling death. Plant seed in warm soils or raised beds. Use commercially treated seed.

Eggplant

Eggplant is a subtropical vegetable, very susceptible to cold soils and frost. Hybrid varieties are popular.

Planting—Buy transplants locally or grow your own in pots in growing structures. Transplants require about eight to ten weeks to develop when grown from

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Insect Control, Eggplant:
See insect descriptions, pgs 273-277.

	Insect Treatments
Aphids	1, 2, 3, 5, 8, 9, 14
Colorado Potato Beetle	3, 5, 9, 12
Corn Earworm	5, 14
Cutworms	5, 9, 11
Flea Beetles	2, 3, 5, 9
Grasshoppers	5, 7
Hornworms	5, 7
Leafhoppers	3, 5, 8, 9, 14
Mites	1, 8
Sowbugs	7, 11
Stink Bugs	5, 14

Insect Control, Garlic:
See insect descriptions, pgs 273-277.

	Insect Treatments
Thrips	14

Insect Control, Kale:
See insect descriptions, pgs 273-277.

	Insect Treatments
Aphids	1, 3, 9, 14
Armyworms	1, 14
Cabbage Looper	5, 14
Cutworms	4
Flea Beetles	9, 14
Harlequin Bug	1, 4, 14

seed. Set plants after late frost, about May 15. Maintain as much of the root system as possible at setting and fertilize with a liquid starter solution. Eggplant is more susceptible to cold injury than tomato. Fruit should be available 50 to 80 days after transplanting.

Harvesting—Fruits are edible from the time they are one-third grown until they are ripe and remain edible after achieving full color. Remove mature fruits so new ones can develop.

Cut fruits from the plant so that the branches will not be broken, and handle the easily bruised fruits carefully. Store them in a refrigerator.

Diseases

The only serious disease of eggplant that we see in Kentucky is Verticillium wilt. See "Tomatoes."

Garlic

There is only one species of true garlic. *Allium sativum*, an herbaceous biennial which belongs to the lily family. It is usually divided into two subspecies *ophioscordon* (hardneck or top set garlic) and *sativum* (softneck garlic). Hardneck garlic produces flower stalks called scapes and bulbils at the top of the stalk. Soft-neck garlic usually does not produce bulbils but produces larger bulbs with more cloves per bulb. The cloves which make up the mature garlic bulb are used for propagation. Propagation from bulbils is more difficult and requires two years to produce mature bulbs. Hardneck garlic cultivars usually do better in Kentucky and produce larger cloves that are easier to peel.

Planting—Planting and culture of garlic differ little from onions, but many gardeners believe garlic is more exacting in its requirements. No one cultivar or cultural practice is best suited for every situation. An open, sunny location, with a fertile well drained soil that is high in organic matter is desirable. Fertilizer is usual applied beginning in the spring as sidedressings every two weeks until bulbs begin to form. Garlic is day length sensitive and begins to bulb around the summer solstice. In Kentucky, it is best to plant garlic in October and early November. Plant individual cloves root end down and cover with two to three inches of well-drained soil. Allow six inches between sets. Mulch helps provide winter protection and conserves moisture during the summer. On hardneck garlic remove any flowering stalk that forms to increase bulb size. During the growing season garlic needs 1 in. of water/week. Stop watering about 2 weeks before harvest.

Harvesting—Many gardeners enjoy eating the green shoots and leaves of garlic plants. However, cutting them continuously inhibits bulb formation. By early June, flower stalks may appear and should be cut back and discarded so the plant's energies can be directed toward root and bulb formation. Some people eat the flower stalk. Bulbs begin to mature or ripen in mid-July and early August, and the leaves become yellow and the leaf tips turn brown. When the leaves have yellowed, lift the plants and dry the bulbs in a partly shaded storage area for about 2 weeks. After drying the tops may be removed, braided or tied and then hung in a cool, well-ventilated spot. Dampness invites rotting. Properly dried garlic should last for 6-7 months at 32°F and 70% RH.

Kale

Kale is related to cabbage, collards, cauliflower, broccoli and Brussels sprouts. Kale is especially valuable nutritionally since it supplies important amounts of vitamin A, ascorbic acid and iron. Pound for pound, greens such as kale contain many times more vitamin A than snap beans, sweet corn or green peppers. Varieties are widely diverse, being tall or short, erect or flattened.

Planting—Seeds may be sown in the spring or in late summer where the plants are to stand, or they may be sown in seedbeds in the greenhouse or hotbed and transplanted to the garden. Plant a spring crop as early as the soil can be prepared.

Space plants 8 to 12 inches apart; rows should be 24 to 30 inches apart. Tall-growing types need the wider spacing.

Plant seed for the fall crop in late July and August.

Diseases: see "Broccoli"

Leeks

The leek resembles the onion in adaptability and cultural requirements. Instead of a bulb, leeks produce a thick, fleshy cylinder like a large green onion. The flavor is milder than an onion's. They are used in soups, sauces and as a pot herb.

Insect Treatments: 1. Malathion 50% EC (Ortho Max Malathion Insect Spray), **2.** Pyrethrins, **3.** Imidacloprid (Bioadvanced Fruit, Citrus, Vegetalbe Insect Control), **4.** Cyfluthrin (Bioadvanced Vegetable and Garden Insect Spray), **5.** Bifenthrin 0.3% + zeta-cypermethrim 0.075% EC (Ortho Bug-B-Gon Insect Killer for Lawns and Gardens), **6.** *Bacillus thuringiensis* var *kurstaki*, **7.** Carbaryl 5% B (Southern Ag Mole Cricket Bait), **8.** Insecticidal soap, **9.** Neem, **10.** Horticultural Oil, **11.** Bifenthrin, (Bonide Eight Flower and Vegetable Soil Insect 0.115% granules), **12.** Permethrin (Bonide Eight Insect Control Vegetable Fruit and Flower Concentrate), **13.** Spinosad (Captan Jacks Dead Bug Brew), **14.** Acetamiprid 0.5% (Ortho Flower, Fruit & Vegetable Insect Killer)

Planting—Sow seed in early spring in rows 20 inches or wider apart. Thin plants to 3 to 4 inches apart within the row. Soil should be hilled around leeks as they grow to blanch them once they have the diameter of a pencil.

Harvesting—Leeks are ready to use after they reach a suitable size. Under favorable conditions they grow to 1 ½ inches or more in diameter, with white parts 6 to 8 inches long. They may be dug in autumn and stored like celery.

Lettuce

Lettuce is an important cool-season vegetable crop for salads and one of the easiest to grow. It tolerates light frost, but intense sunlight and high summer temperatures cause seedstalk formation and bitter flavors, especially in bibb types. Slow-bolting or heat-resistant varieties are available.

There are four types of lettuce: crisphead, the most common fresh market type; butterhead or bibb, most commonly grown in forcing structures; romaine or cos, a very nutritious lettuce that forms an upright head; and leaf, the most common home garden lettuce. The color of the leaf varieties differ from shades of green to red.

Planting—Seeds of leaf varieties are generally sown in rows, 20 to 30 seeds/foot, with rows 8 to 12 inches apart. For early and late planting, cos and head types should be started as transplants and spaced 12 to 18 inches apart in rows 20 inches apart.

Insect Control, Lettuce:
See insect descriptions, pgs 273-277.

	Insect Treatments
Aphids	1, 3, 5, 8, 9, 12, 14
Corn Earworm	5, 12, 13, 14
Cutworms	5, 11, 12
Grasshoppers	1, 5
Imported Cabbageworm	1, 5, 13, 14
Leafhoppers	1, 3, 5, 9, 14
Sowbugs	11

Plant lettuce on the shady side of tall-growing crops such as sweet corn, staked tomatoes and pole beans, or in other cool areas of the garden. Interplanting (planting between rows or plants of later-maturing crops like tomatoes, broccoli and Brussels sprouts) can be practiced, especially in the fall garden. Border planting along the edges of the garden or flower bed is excellent. Make succession plantings so that lettuce will be available from May through November. Lettuce, especially leaf and bibb, does well in hotbeds during the winter months and in cold frames in the spring and late fall.

Problems—"Tipburn" is a physiological problem where the tips or edges of the lettuce leaves turn brown during a dry, hot period that has followed moist weather. No disease organism is associated, so chemical sprays will not correct the problem. Plants grown in shady areas are less affected than those grown in full sun and dry areas.

Harvesting—You can pick leaf lettuce as soon as the plants reach a suitable size. The older, outer leaves contain high levels of calcium and can be used first. Also, thinning the rows prevents crowding, so you may wish to harvest every other plant or the very largest plants first.

Bibb lettuce is mature when leaves begin to cup inward to form a loose head. Cos or romaine is ready to use when leaves have elongated and overlapped to form a fairly tight head about 4 inches wide at the base and 6 to 8 inches tall. Crisphead is mature when leaves overlap to form a head similar to that available in the stores.

Crisphead lettuce will store about two weeks in the crisper drawer of the refrigerator before russetting begins. Leaf and bibb will store as long as four weeks if the leaves are dry when bagged. If lettuce is to be stored, harvest when dry. Do not wash; place in a plastic bag, and store in the crisper drawer. Wash before use.

Diseases

Damping-off—Use fungicide-treated seed and plant into well-drained soils.

Bottom rot—Cultural practices, warmed soils, and crop rotation are important tools to manage this disease. Do not plant lettuce after beans, and turn under grass and other crops early to ensure thorough rotting before planting. Avoid wet, poorly drained sites.

Muskmelons

Muskmelons, commonly called cantaloupes, are a warm-season crop. They require a relatively long growing season of 80 to 100 days from seed to marketable fruit. Some cultivars are not well suited to small gardens because of space required for growing the large vines. Cantaloupe grows quite well on black plastic mulch.

Planting and Transplanting—Cantaloupes can be produced from transplants, or they can be direct-seeded. Rows should be 5 feet apart with hills spaced 2 to 3 feet apart in the rows. Plant two or three seeds per hill. The seed should be placed ½ to ¾ inch deep after danger of frost is past.

To produce transplants, plant seed in individual containers three to four weeks before the plants are to be transplanted out-of-doors. Cantaloupes grown from transplants can be harvested as much as two weeks earlier than those grown directly from seed. Be careful not to injure the roots of seedlings when transplanting cantaloupes. Use starter fertilizer for transplants.

Cantaloupes should receive a nitrogen sidedressing when they begin to vine.

Pollination—Male and female flowers

Insect Control, Muskmelons:
See insect descriptions, pgs 273-277.

	Insect Treatments
Aphids	1, 3, 5, 8, 9, 12
Cucumber Beetles	1, 3, 5, 12
Cutworms	5, 7, 11, 12
Leafhoppers	1, 3, 5, 8, 9, 12
Stink Bugs	4, 5

Insect Treatments: 1. Malathion 50% EC (Ortho Max Malathion Insect Spray), **2.** Pyrethrins, **3.** Imidacloprid (Bioadvanced Fruit, Citrus, Vegetalbe Insect Control), **4.** Cyfluthrin (Bioadvanced Vegetable and Garden Insect Spray), **5.** Bifenthrin 0.3% + zeta-cypermethrim 0.075% EC (Ortho Bug-B-Gon Insect Killer for Lawns and Gardens), **6.** *Bacillus thuringiensis* var *kurstaki*, **7.** Carbaryl 5% B (Southern Ag Mole Cricket Bait), **8.** Insecticidal soap, **9.** Neem, **10.** Horticultural Oil, **11.** Bifenthrin, (Bonide Eight Flower and Vegetable Soil Insect 0.115% granules), **12.** Permethrin (Bonide Eight Insect Control Vegetable Fruit and Flower Concentrate), **13.** Spinosad (Captan Jacks Dead Bug Brew), **14.** Acetamiprid 0.5% (Ortho Flower, Fruit & Vegetable Insect Killer)

Insect Control, Okra:
See insect descriptions, pgs 273-277.

	Insect Treatments
Aphids	1, 3, 8, 9
Japanese Beetle	1
Stink Bugs	12

are separate on the same plant. Bees must carry pollen from the male flower to the female flower to ensure good fruit set and development. Delay insecticide applications until late in the day to prevent killing bees.

Harvesting and Handling—Melons should be harvested once they reach the full slip stage for best flavor. The term "full slip" indicates that fruit will pull away from the vine easily. Care should be taken when walking through the garden to avoid injury to plants. Plants can be trained during the early stages of development to grow in rows for easier harvesting. Growing on a trellis allows for closer spacing (3 feet between rows) than is possible when plants lie on the ground. Spraying to control cucumber beetles, aphids and fungal diseases is necessary.

Diseases: see "Cucumber"

Mustard Greens

Mustard greens are easy to grow, and they reach maturity quickly. They can be cooked or used in salads.

Planting—Mustard tends to bolt or go to seed quickly in hot weather. Plant in early March to late May as a spring crop and from late July to early September as a fall crop. Successive plantings during these periods will assure a continuous supply. Seed may be broadcast or sown in rows and thinned to 3 inches apart. Thinned plants may be cooked or eaten fresh. Plant seeds ¼ inch deep in rows 18 inches or farther apart. Remove plants which bolt.

Harvesting—Pick leaves as they become large enough to use. Greens mature quickly and do not store well, so several plantings may be desired. Mustard greens can be stored in plastic bags in the refrigerator for one to two weeks.

Okra

Okra is a warm-season crop. Varieties differ in plant size, pod type and color, and number of spines. Dwarf plants without spines and with smooth, green pods are best for home gardens. Fruits are used as flavoring in soups, such as gumbo, and they can be fried.

Planting—Soak seeds for 6 hours in warm water and sow about 12 inches apart in rows 30 inches apart.

Harvesting—Cut pods off when they are about 2 to 4 inches long. Once harvesting starts, continue to harvest every two to three days until frost. Store pods in plastic bags in the refrigerator for a week, or blanche and freeze them for later use. They pickle nicely also.

Onions

The two main types of onions are American (pungent) and foreign (mild). Each type has three distinct colors: yellow, white and red. In general, the American onion produces bulbs of smaller size, denser texture, stronger flavor and better keeping quality.

For green or bunching onions, use sets, seeds or transplants for spring planting. For fall planting, use Egyptian or perennial tree and the yellow multiplier or potato onion sets.

Onions that keep well in storage are globe types. Globe varieties are yellow, red and white. They should be grown from seeds.

Planting—Spring-planted sets are popular and may be placed 1 to 2 inches apart and 1 to 2 inches deep in the row. Thin them to 4-inch spacing by pulling and using the thinned plants as green onions. Rows should be 12 to 18 inches apart. Avoid large sets in spring plantings. Sets more than 7/8 inch in diameter are likely to produce seed stalks. Divide the onion sets into two sizes before planting. Large

Insect Control, Onions:
See insect descriptions, pgs 273-277.

	Insect Treatments
Root Maggots, Seed Maggots	1
Thrips	1, 5, 9, 13

sets (bigger than a dime) are best used for green onions. The smaller sets produce the best bulbs for large, dry onions. Early planting and/or exposure to cold temperatures may also cause seed stalk development.

Sets of Egyptian tree or multiplier onions should be harvested in late October or early November. Fall-planted sets should be spaced 4 inches apart in rows 1 to 2 feet apart. (Distance between rows is determined by available space and cultivating equipment). Onions are shallow-rooted and compete poorly with weeds and grasses.

Harvesting and Storage—Pull green onions whenever the tops are 6 inches high. Bulb onions should be harvested when about two-thirds of the tops have fallen over. Careful handling to avoid bruising will pay big dividends in controlling storage rots. Onions may be pulled and left to dry. Place them so bulbs are partly covered with tops to avoid sunscald. If space is available, onions may be placed inside a building for curing. Tops may be left on or cut off. When curing inside, spread onions out. Onions may be hung up to dry in small bunches. Before storing, remove most of the top from each onion, leaving about ¾ inch. Put onions in mesh bags, ventilated wooden crates or a well-ventilated storage space after they have thoroughly cured. Curing usually takes three to four weeks. Immature, soft and thick-necked bulbs should not be stored with other onions. The essentials for successful storage are thorough ventilation, uniform temperatures of 35° to 40°F, dry atmosphere, and protection against actual freezing.

Long-term Storage—The best varieties for storage are grown from seeds rather than

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sets. Harvest them when tops have turned brown and died or in late fall before the ground freezes. Remove bruised onions or onions with thick "bull necks" and use them first because they will not store well. Onions must be allowed to dry for several weeks before storage. Spread them no more than two layers deep on newspaper. Put them out of the direct sun in a well-ventilated area until the skins are papery and the roots shrivelled.

When they are dry, hang them in braids or put them in mesh bags. Braid them soon after digging while the stalks are still pliable. Store in a well-ventilated, cool, dry, dark area. See "Storing Vegetables" on page 280.

Parsnips

Parsnips are a hardy, full-season, winter vegetable. Their high food value and eating quality are greatly improved by storing at near-freezing temperatures, which increases the sugar content. This crop stores well and is therefore available for eating from late fall to late winter.

Parsnips require a long growing time, from 100 to 160 days. One 20- to 25-foot row of parsnips is usually ample for a family's needs.

Planting—Parsnip seed retains its vitality for only about one year, so never plant old seed. The seed is slow to germinate, and it may be difficult to get a good stand if soils are heavy and moisture is low. Hasten germination and emergence by (1) sowing a few radish seeds along with the parsnip—they will help break soil crust and allow parsnip seedlings to emerge and also provide a double crop; (2) covering the seed with leaf mold, ashes or sandy soil; (3) firming the covering material over the row and watering with a watering can or spray nozzle.

The seed should be planted ½ to ¾ inch deep from June 15 to July 1 in rows spaced 18 inches apart, with seeds 2 to 3 inches apart in the row. When plants are grown too far apart the roots become large and the edible portion has a woody, fibrous texture.

Insect Control, Peas:
See insect descriptions, pgs 273-277.

	Insect Treatments
Aphids	1, 3, 9
Cutworms	11
Sowbugs	11

Harvesting and Storage—Parsnip roots may be dug in late fall, topped and stored at 32° to 40°F in a root cellar or in an outdoor pit. They may be left in the ground through winter. Parsnips will tolerate alternate freezing and thawing in soil but will be damaged if frozen after harvest. A heavy mulch over the parsnips will delay freezing of the soil; mulch can be pulled aside, and parsnips can be harvested late into the winter. See "Storing Vegetables" on page 280.

Peas

Peas are a cool-season legume crop and should only be planted in early spring or late summer.

Podded peas (snow or snap peas) are usually eaten cooked or raw, pod and all. They possess the tenderness and pod qualities of snap beans and the flavor and sweetness of fresh English peas. Seeds may be shelled and eaten like regular peas if pods develop too fast.

Planting—Plant peas in spring as soon as soil is workable. Early planting normally produces larger yields than later plantings. They will tolerate light freezes. A few successive plantings can be made at one- to two-week intervals. A single planting of early-, midseason- and late-maturing varieties will also extend the supply. Plant a fall crop of snow or snap peas around the first week of August. These plants will require irrigation.

Sow about 15 seeds/foot of row and cover about 1 inch deep. Rows of dwarf varieties should be planted 2 ½ to 3 feet apart, and tall varieties 3 ½ to 4 feet apart. Tall varieties of peas will benefit from some support for the vines. Branches may be placed in the row, or seeds may be planted along a fence or string trellis.

Dwarf pea varieties seldom need support. Many gardeners plant twin rows of dwarf varieties 6 to 10 inches apart and allow them to support themselves. The peas may also be scattered about 4 inches apart in all directions in rows about 2 feet wide.

Harvesting—Harvest peas when pods have filled. For tender peas, harvest a bit immature. Use peas as soon after harvest as possible. They will stay fresh longer if left in the pods until they are to be cooked. They will keep up to a week in plastic bags in the refrigerator. Some varieties are superior to others for freezing.

Peppers

A number of pepper types are available to the home gardener. These include bell or green, banana, pimento, cherry, cayenne or red or green chili peppers, serrano, yellow wax, habanero, and other hot types. All are grown similarly.

Planting—Begin transplants indoors eight to ten weeks before planting time. Set plants after all danger of frost has past. Direct seeding of peppers in the garden may be done, but transplants are generally more satisfactory and will provide heavier yields. Use a starter fertilizer when transplanting. Apply supplemental fertilizer cautiously and only after a good crop of peppers is set. Rows should be 30 to 36 inches apart or wider if mechanical cultivators are used. Set plants 14 to 18 inches apart within the row.

Harvesting—Harvest peppers when they

Insect Control, Peppers:
See insect descriptions, pgs 273-277.

	Insect Treatments
Aphids	1, 3, 5, 9, 10, 14
Cutworms	4, 5, 7, 11
European Corn Borer	4, 5, 12, 14
Flea Beetles	3, 4, 5, 9, 12
Sowbugs	7, 13
Stink Bugs	4, 5, 14

Insect Treatments: 1. Malathion 50% EC (Ortho Max Malathion Insect Spray), **2.** Pyrethrins, **3.** Imidacloprid (Bioadvanced Fruit, Citrus, Vegetalbe Insect Control), **4.** Cyfluthrin (Bioadvanced Vegetable and Garden Insect Spray), **5.** Bifenthrin 0.3% + zeta-cypermethrim 0.075% EC (Ortho Bug-B-Gon Insect Killer for Lawns and Gardens), **6.** *Bacillus thuringiensis* var *kurstaki*, **7.** Carbaryl 5% B (Southern Ag Mole Cricket Bait), **8.** Insecticidal soap, **9.** Neem, **10.** Horticultural Oil, **11.** Bifenthrin, (Bonide Eight Flower and Vegetable Soil Insect 0.115% granules), **12.** Permethrin (Bonide Eight Insect Control Vegetable Fruit and Flower Concentrate), **13.** Spinosad (Captan Jacks Dead Bug Brew), **14.** Acetamiprid 0.5% (Ortho Flower, Fruit & Vegetable Insect Killer)

Insect Control, Potatoes:
See insect descriptions, pgs 273-277.

	Insect Treatments
Aphids	8, 9
Blister Beetles	14
Colorado Potato Beetle	9, 12, 13
Cutworms	7
Leafhoppers	1, 8, 9, 12
Sowbugs	7

are firm. If red fruits are desired, allow the green fruit to remain on the plant until the red color develops. Cut peppers from the plant to prevent injuring the plant and remaining fruit. Leaving a short piece of stem will allow the pepper to store longer. Store peppers in the refrigerator in plastic bags. They will keep two to three weeks. Gather remaining peppers before a hard frost.

Diseases

Bacterial Spot (bacterium)—Dark brown to tan irregular spots on leaves; leaves turn yellow and drop from the plant. Treat seed by washing for 40 minutes in a solution of household bleach (½ cup/pint of water); air dry promptly, then plant. Use disease-free transplants; spray with fixed copper at first sign of disease and thereafter as needed.

Fruit Soft Rot (bacterium)—Smelly, soft decay of fruit. Control fruit-feeding insects and bacterial leaf spot.

Potatoes

In Kentucky, potatoes can be grown as an early crop for fresh use in early summer and as a late crop for table use in winter. White-skinned, red-skinned, and yellow-skinned varieties are excellent for planting. Choose an early-maturing variety and a medium- to late-maturing variety. The planting time for early potatoes is from March 1 to April 10; for the late crop, June 15. The late planting will generally give a lower yield than the spring planting.

Recently turned-under sod may have populations of grub worms and/or wireworms which can cause serious damage to developing potato tubers unless soil insecticides are used. The yield of potato tubers is influenced by season, variety, moisture availability and the amount of nutrient elements available to the plant. Highest yields are obtained in years with cool springs and adequate moisture throughout the season.

Fertilizers—Potatoes require large amounts of fertilizer. A soil pH of 6.0 to 6.5 is considered most desirable; however, scab disease will usually be less when pH is between 5.0 and 5.2.

In addition to the base application of fertilizer worked into the garden soil, add about ¼ pound of 10-20-10 for each 75 feet of row. Work this into the bottom of the furrow and mix with soil before putting down the seed piece.

Seed Selection and Planting—Purchase certified seed stock. The "certified" means that stock has been inspected for diseases which cause low yields. Seed potatoes should be firm and unsprouted. Wilted and sprouted potatoes usually have lost vigor from being too warm in storage.

Cut seed pieces to about 2 ounces for planting. Each seed piece should have two to three eyes. Potatoes weighing about 6 ounces will cut into three pieces nicely. Potatoes planted in early March should be planted in furrows 3 to 5 inches deep, and the late crop should be planted 5 to 6 inches deep. Seed pieces should be spaced 10 to 12 inches apart, and furrows about 36 inches apart.

Cultivation—At planting, pull a ridge of soil over each row. Dragging across the ridges just before the sprouts break through helps eliminate any weeds and grasses and allows the sprouts to break through more easily. Later cultivation should be shallow and far enough from rows to make certain no roots are pruned.

When tops have made sufficient growth that cultivation must stop, a finishing cultivation, sometimes called "laying by," is given. "Laying by" throws soil over the potatoes to help prevent exposure to the sun, which can cause greening and "scalding."

Abiotic Problems—"Hollow heart," a condition where large potatoes have a hollow center, is caused by the potato growing too rapidly or getting too large. Closer spacing of plants will cause tubers to grow slower and be smaller. High temperatures (above 95°F) may cause black discoloration inside potato tubers due to lack of oxygen during rapid respiration.

Knobby tubers are caused when the potato stops growing, due to drought, and then starts growing again when moisture is supplied.

Fine, black strands or necrosis inside the potato's vascular tissue may be due to freeze damage in handling or storage or to heat damage in the garden or storage. Irrigation and mulching will help keep the soil cool.

Harvesting—The early crop of potatoes can be dug before the skins are mature and while they are still somewhat small. For mature potatoes, wait and harvest after vines have been dead for two weeks so skins of potatoes will have toughened. This method minimizes losses due to skinning. Potatoes should be quickly removed from the field or shaded during periods of bright sunlight and high temperature to avoid the danger of sunscald. Be careful to avoid bruising the tubers at all times. Dig late potato crop when first frost has nipped the vines.

Storage—With proper care, potatoes can be stored for four to six months. The most important factor is storage temperature, 40°F being ideal. Sprouting in storage is a serious problem at high temperatures. Other important factors include maintenance of high humidity (80% to 90%), proper ventilation, and having tubers which are free of disease when placed in storage. Clean your storage room thoroughly before storing potatoes.

Long-term Storage—Late maturing potatoes will store better than early ones. Har-

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vest after the vines die completely and when the ground is damp but not wet. Remove the withered vines before digging. Dig carefully to avoid bruising and let tubers surface dry before storing. Potatoes need to be cured for ten to 14 days at 50° to 55°F in the dark with high relative humidity before storing. They will turn green and become bitter if exposed to light. If tubers in the garden are set shallow and are turning green, they should be hilled (covered with soil) for two to three weeks. Most will be normal when dug. Pack them unwashed in baskets, boxes or open mesh bags. Sprouting of potatoes indicates they were stored in too warm a place. Sweet-tasting potatoes indicate that they were stored in too cool a place. See "Storing Vegetables" on page 280.

Diseases: White or Irish Potatoes

Black Leg (bacterium) and other seedborne diseases (fungi, nematodes)—Stems decay and blacken at or below ground line; tops grow poorly, may turn yellow, wilt and die; soft rot on tubers in storage. Seed tubers decay; poor stands or low yields result. Plant only certified disease-free tubers; plant cut seed immediately or allow to cork over before planting; allow tubers to warm up several days before planting; do not plant cold potatoes in cold soil.

Early Blight (fungus)—See Tomato "Early Blight" for description and management suggestions. Maintain adequate nitrogen and potassium fertility to reduce early blight susceptibility.

Late Blight (fungus)—Nationally, the potential for late blight has increased greatly, but this disease is relatively rare in Kentucky. Dead areas on leaves, brown or dark purple color, variable in size with white or gray moldy growth on leaf undersides during cool, moist weather; whole plant can become blighted; tuber infection causes discoloration under skin and decay in field or storage. Use varieties with partial resistance; plant disease-free tubers. Use chlorothalonil, copper fungicides, phosphorous acid, or mancozeb as needed.

Rhizoctonia "scurf" appears on mature tubers as small, black specks, known as "the dirt that can't be washed off." Using clean seed and rotation will help prevent occurrence of this disease.

Scab (bacterium)—Rough, scabby lesions on tubers. Plant resistant varieties; do not apply manure within 2 months of planting; maintain acid soil for potato culture and practice crop rotation.

Virus diseases such as mosaic and leaf roll can be carried in the seed piece and transmitted from one plant to another by insects. Use certified seed, which is relatively free of viruses. Good insect control will also help prevent infection.

Pumpkins

Pumpkins should only be grown if a great deal of space is available. Many people plant pumpkins among early corn. Pumpkins are one of the few vegetables which thrive under partial shade, and sweet corn will be harvested before they require a great deal of room. For extra large pumpkins, remove all but one or two fruits from a vine.

Planting—Plant pumpkins for Halloween around mid-June. If pumpkins are planted too early they may rot before Halloween. Seed pumpkins in hills spaced 8 to 12 feet apart in each direction. Do not plant until all danger of frost is past.

Harvesting—Harvest pumpkins whenever they are a deep, solid color and the rind has hardened but before they are injured by hard frost. When cutting pumpkins from the vine, leave a portion of the stem attached. Pumpkins keep best in a well-ventilated place where the temperature is 55° to 60°F.

Long-term Storage—Winter squash and pumpkins must stay on the plants until fully mature. Fruit maturity can be roughly estimated by pressure from the thumbnail on the fruit skin. If the skin is hard and impervious to scratching, then it is mature.

Insect Control, Pumpkins:
See insect descriptions, pgs 273-277.

	Insect Treatments
Aphids	1, 3, 5, 8, 9, 12, 14
Cucumber Beetles	1, 3, 5, 12, 14
Squash Bugs	5, 12, 14
Stink Bugs	4, 5, 14

Harvest before a hard frost with a sharp knife, leaving at least 1 inch of stem attached. Fruit picked without a stem will soon decay around the stem scar. Handle pumpkins and squash carefully to avoid bruising. All winter pumpkins and squashes should be cured in a warm, dry place for ten days at 75° to 85°F before storage at 50° to 55°F in a dry area. Examine the fruit every few weeks for mold and discard any contaminated produce. See "Storing Vegetables" on page 280.

Diseases: see "Cucumber"

Radishes

Radishes are easy and quick to grow. Cool weather is essential for highest radish quality since they become "hot" and woody in hot weather. Small, round varieties mature more quickly than long types.

Planting—Sow seed ¼ inch deep in rows 12 inches or wider. Radishes should be thinned to allow 2 to 3 inches between plants. Make several small plantings at seven- to ten-day intervals since radishes are in prime condition for only a few days. Plant in early spring or as a fall crop around the first of August.

Harvesting—Harvest radishes when roots are ½ to 1 inch in diameter. Radish-

Insect Control, Radishes:
See insect descriptions, pgs 273-277.

	Insect Treatments
Cutworms	4, 7
Flea Beetles	1, 3, 4, 13
Root Maggots, Seed Maggots	1
Sowbugs	7

Insect Treatments: 1. Malathion 50% EC (Ortho Max Malathion Insect Spray), **2.** Pyrethrins, **3.** Imidacloprid (Bioadvanced Fruit, Citrus, Vegetalbe Insect Control), **4.** Cyfluthrin (Bioadvanced Vegetable and Garden Insect Spray), **5.** Bifenthrin 0.3% + zeta-cypermethrim 0.075% EC (Ortho Bug-B-Gon Insect Killer for Lawns and Gardens), **6.** *Bacillus thuringiensis* var *kurstaki*, **7.** Carbaryl 5% B (Southern Ag Mole Cricket Bait), **8.** Insecticidal soap, **9.** Neem, **10.** Horticultural Oil, **11.** Bifenthrin, (Bonide Eight Flower and Vegetable Soil Insect 0.115% granules), **12.** Permethrin (Bonide Eight Insect Control Vegetable Fruit and Flower Concentrate), **13.** Spinosad (Captan Jacks Dead Bug Brew), **14.** Acetamiprid 0.5% (Ortho Flower, Fruit & Vegetable Insect Killer)

es remain in edible condition for only a short time before they become pithy and hot. Wash roots, trim both tap root and tops and store in plastic bags in refrigerator. They will keep up to a month.

Diseases

Damping off—Use fungicide-treated seed and plant into well-drained, warmed soils.

Rhubarb

Rhubarb is propagated by planting pieces of rhubarb crown. These pieces can be purchased commercially or obtained from old plants. If you have an old plant, cut through the crown between the buds, leaving as large a piece of storage root as possible with each large bud. Plant crown in early spring (March). If you must hold the crown for a week or longer before planting, store it in a cool, dark place.

Divide crowns and make new plantings when plants have borne for about four years, or whenever the production of numerous small stalks indicates that crowns are becoming crowded.

Propagation by seed is not recommended because rhubarb seedlings do not "come true to type" from parent plants.

Crown pieces are usually transplanted in rows 4 to 5 feet apart, with plants spaced along the row 3 feet apart. Crown pieces should be planted with 2 to 3 inches of soil above the pieces. Since this planting is intended to stay in place for more than one season, it should be at the edge of the garden or along a fence in a well-drained area.

Each year, soon after the ground is frozen, cover the rows with straw or similar mulch material. Rake it off the row in early spring so new growth can get started.

Harvesting—Rhubarb may be harvested for a short period during the second year and for full harvest (eight to ten weeks) during the third growing season and thereafter. Pull stalks from the base instead of cutting them.

Special Note—To promote and maintain vigorous growth, rhubarb should not be allowed to flower. Remove flower stalks as soon as they appear by cutting or pinching them off near the crown of the plant.

Diseases

Crown Rot (bacterium or fungus)—Brown, soft, decayed areas at base of leaf stalk; decay spreads to crown and other stalks; leaves wilt and plant dies. Carefully remove and destroy decayed plants; spray crowns of nearby healthy plants with fixed copper fungicide; start a planting in a new location using disease-free plants on raised or well-drained beds.

Insects

Eliminate curly doc weeds that may serve as host for rhubarb curculio.

Southern Peas

The southern pea, a warm-season crop, is sometimes referred to as cow pea, crowder pea, field pea and black-eyed pea. It is not a true pea but a bean with high protein content that is commonly grown in the South. This crop should be included in every Kentucky home garden.

Planting—Sow seeds 2 to 3 inches apart in rows 30 inches apart.

Harvesting—Vegetable can be used fresh, canned, frozen or as dry shelled beans.

Both seeds and pods are eaten in the green, immature stage like snap beans, or they can be left to further mature the seed. Shell before pods turn yellow. For dry use, let pods turn brown or yellow and then shell.

Diseases and Insects: see "Beans"

Spinach

Spinach is a quick-maturing, cool-season crop of high nutritional value. It can be grown early in spring and from late fall into winter. Hot summer days cause it to bolt. Some varieties will mature as early as 20 to 40 days after sowing under favorable weather conditions. Spinach is well-adapted to winter production in cold frames.

Insect Control, Spinach:
See insect descriptions, pgs 273-277.

	Insect Treatments
Aphids	1, 2, 9, 12, 14
Armyworms	6, 12, 13, 14
Cabbage Looper	6, 12, 13, 14
Cutworms	7, 12

Varieties differ in seed type (smooth or round vs. prickly seeded) and in leaf type (smooth vs. savoy-leaves). The round-seeded types are most popular.

Planting—Sow seeds around March 1 in rows spaced 12 to 18 inches apart. Start fall seeding between August 15 and September 1. Thin plants to stand 4 to 6 inches apart in rows. It is important to firm soil over the rows so there is good contact with seed for high germination. Spinach grows best with ample moisture and fertile, well-drained soil.

Harvesting—Cut whole plants at soil surface when they reach 4 to 6 inches in diameter. Making successive plantings is better than removing only outer leaves, allowing inner leaves to make additional growth. Use or place in refrigerator immediately after harvest.

Diseases

Damping-off may be biggest problem for home garden. Use fungicide-treated seed and plant into well-drained, warmed soils.

Squash

Squash may be divided into two classes—summer and winter.

Summer squash are bush-type plants and are well suited for small gardens. Fruits are eaten in immature stages, when the rind can be easily penetrated by the thumbnail. Under favorable conditions, most summer varieties produce their first usable fruits seven to eight weeks after planting and continue to bear several weeks afterward.

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Insect Control, Squash:
See insect descriptions, pgs 273-277.

	Insect Treatments
Aphids	1, 3, 5, 9, 10, 14
Cucumber Beetles	1, 3, 4, 5, 7, 12, 14
Cutworms	5, 7, 12
Sowbugs	11
Squash Bugs	5, 12, 14
Squash Vine Borer	4, 5, 14
Stink Bugs	4, 5, 14

Winter squash include varieties such as butternut, hubbard and acorn and require more room than summer types. Bush type winter squash such as 'Table King' and 'Gold Nugget' are available, so this vegetable could be part of smaller gardens. The division between winter squash and pumpkins is not absolute. Winter squash have flesh that is dark orange, sweeter, less fibrous, and higher in dry matter than pumpkins and summer squash. Winter squash have hard rinds and are well adapted for storage. Harvest for storage only when the rind is hard enough to resist denting by a thumbnail.

Planting—Seed summer squash in the garden after danger of frost is past, in hills 4 feet apart with two to three seeds/hill. Bush types of winter squash use the same spacing, but separate vining types by at least 6 to 8 feet between hills.

For extra early fruit, plant seeds in peat pots in greenhouses or hotbeds and transplant them to the garden about three weeks later. Squashes are warm-season plants and do not do well until soil and air temperatures are above 60°F. Soil pH can be between 5.5 and 7.5.

Black plastic can be put on soil, and seed or transplants can be planted through the plastic. Seed should be covered 1 inch deep with soil.

Storage—Summer squash will store up to a week if kept in a perforated plastic bag in the refrigerator. Take care in harvesting not to bruise or injure fruits.

Harvest winter squash for storage when the rind is quite hard. Do not leave them exposed to frost, which reduces their keeping quality. Leave a portion of stems and handle carefully to avoid bruising. Keep in a well-ventilated place for several weeks and examine frequently for decay. Remaining sound fruit should be placed in a clean area with a temperature of around 55°F and with 60% relative humidity. Acorn squash do not store longer than a month or so. See "Storing Vegetables" on page 280.

Long-term Storage—see "Pumpkins"

Diseases: see "Cucumber"

Sweet Corn

Sweet corn varieties differ a great deal in quality and time of maturity. Weather is also an important influence on the number of days required to reach maturity from seeding date. Maturation may be increased under high temperature conditions or delayed under cool ones.

To keep sugar content high in super-sweet cultivars and to avoid mixtures of white and yellow kernels, prevent cross pollination by providing a certain amount of isolation. When planting at different times, a minimum of 14 days difference in maturity dates of cultivars is required. For example, 'Vision' is a super-sweet cultivar with 75 days to maturity. It could be planted at the same time as 'Silver Queen,' which is a standard cultivar and matures in 95 days.

An example of preventing a mix of yellow and white kernels would be the planting of 'Silver Queen' and 'Golden Queen.' If both these cultivars are desired in the same growing season and you do not want mixed kernels, stagger the planting of one of them by two weeks. No cross pollination should occur if planting times are scheduled accordingly.

Fertilization—An additional sidedressing of ammonium nitrate when corn is knee-high, using about ¼ pound per 25 feet of row, should adequately supplement the regular garden fertilization program.

Insect Control, Sweet Corn:
See insect descriptions, pgs 273-277.

	Insect Treatments
Aphids	2, 5, 8, 9, 10
Armyworms	4, 5, 6, 12, 13
Corn Earworm	4, 5, 6, 12, 13
Cucumber Beetles	4, 5
Cutworms	4, 5, 7
European Corn Borer	4, 5, 6, 12, 13
Flea Beetles	4, 5, 9
Grasshoppers	4, 5, 12
Japanese Beetle	4, 5, 12
Stink Bugs	4, 5

Planting—Gardeners interested in having sweet corn early may plant just a few days before the average date of the last killing frost. The harvest period for sweet corn can be extended by planting early-, midseason- and late-maturing varieties or by making successive plantings. Make successive plantings every two weeks throughout the season until July 15. Use only earliest maturing varieties for July plantings. The fall-maturing sweet corn will give high quality because of cool nights in September, but is also much more prone to worm damage.

For early-maturing varieties that produce small plants, plant at row spacings of 30 inches with plants 8 to 9 inches apart in the row. For medium to large plant varieties, use a 36-inch to 40-inch row spacing with plants 12 inches apart in the row. Plant at least three or four rows of the same variety in a block for good pollination and ear fill.

Harvesting and Handling—The harvest season for sweet corn is brief because of texture changes and enzymatic conversion of starch to sugar. Harvesting should be done in early morning while air temperature is still cool. If temperature is high when corn is harvested, the field heat should be removed from corn by either plunging ears in cold water or placing them in the refrigerator. This will help maintain fresh-from-the-garden quality of corn. Normally, sweet corn is ready

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for harvest about 20 days after the first silk appears on the ear.

Diseases

Bacterial Wilt (bacterium)—Leaves show long, pale green or tan dead streaks; symptoms can be confused with other leaf blight diseases; early infection may result in stunting, wilting and death of plants. Use resistant varieties; use approved insecticides on corn seedlings to control corn flea beetles that carry the disease-causing bacteria.

Smut (fungus)—Swellings or galls on leaves, stems, ears or tassels that are shiny, greenish-white color at first; galls continue to enlarge, turn black and break open, exposing a black, dusty spore mass. Rotate corn in garden; take care to prevent injuries to plants; remove and destroy galls as they occur and before they break open.

Corn Stunting Diseases (viruses)—Yellowing, mosaic on leaves; stunting of plants; often no ears produced; plant may show purple color; disease carried to corn by aphids and leafhoppers from nearby Johnson grass. Destroy Johnson grass; use resistant corn varieties.

Sweet Potatoes

Sweet potatoes need a long growing time and medium to light sandy soils which are well-drained and relatively low in nitrogen. Excess nitrogen and heavy applications of fresh animal manures cause long, spindly roots of low quality. Heavy, tight soils cause misshaped roots.

There are two types of sweet potatoes—moist- and dry-flesh types. Moist-flesh or "yam" type is most popular. Root skin color varies from yellow to white for dry- or firm-flesh varieties, to bronze, red, pink and orange for moist types.

Insect Control, Sweet Potatoes:
See insect descriptions, pgs 273-277.

	Insect Treatments
Flea Beetles	2, 8, 9

Plant Source—Most home gardeners buy transplants or "slips" from a local plant grower. If you are producing transplants, the potatoes should be bedded in a greenhouse or hotbed (75° to 80°F preferred) about five to six weeks before field setting date. Use only disease-free potatoes.

Ordinarily, ½ bushel will cover 8 to 10 square feet of bed surface and produce about 1000 transplants. The roots should be covered with 3 to 4 inches of sand and then watered down.

Planting—Shape rows into ridges about 10 inches high before planting. Space rows about 3 feet apart, and place plants in the row every 12 inches. Soil pH should be 5.2 to 6.7. Temperatures below 55°F can be detrimental.

A starter solution is recommended after plants are set. Add ¼ pound of 20% nitrogen fertilizer to 5 gallons of water and use about 1 cup of this solution per plant.

Harvesting—Sweet potatoes can be harvested any time they reach a usable size. Sweet potatoes continue to grow until vines are killed by frost. You should harvest the crop when the greatest number of 6- to 8-ounce potatoes are found in the hill. Sample digging will provide this information. A good practice is to clip vines before frost occurs. The crop can then be harvested easily with less damage to potatoes. Plow or spade one row at a time and pick up potatoes. To reduce rotting in storage, be sure potatoes are clean, dry and free of injury.

Curing/Storage—Stack crates or baskets in storage space. Place them 6 to 8 inches off the floor and 12 to 15 inches from the walls to allow for adequate ventilation. Curing requires 7 to 10 days if temperature can be maintained at 80° to 85°F with 70% to 90% relative humidity. Extend the curing period to two or three weeks if the temperature is under 75°F. After curing is complete, keep potatoes in a place as near 55°F as possible with relative humidity of 85%.

Insect Control, Swiss Chard:
See insect descriptions, pgs 273-277.

	Insect Treatments
Aphids	1, 2, 3, 8, 9
Blister Beetles	2, 14
Cutworms	7
Flea Beetles	3, 9, 13

Diseases

Scurf (fungus)—Irregular purple-brown discolored areas on roots; color only skin deep but affects keeping quality of stored roots. Use only disease-free potato roots for bedding; cut plants above soil line and reroot plant cuttings into new soil. Dip transplants in a dilute bleach (1:5) solution before planting.

Swiss Chard

Swiss chard can be grown either for greens or its large, fleshy leaf stalks. A hardy plant, Swiss chard will withstand hot weather from spring to late fall better than most greens.

Planting and Care—Plants may be started in the greenhouse or hotbed and transplanted in the open after danger of hard frost is past, or seed may be sown in the garden where plants are to grow.

Space rows about 18 inches apart for hand cultivation and 30 to 36 inches apart for mechanical cultivators. Sow seeds ¾ inch deep and thin plants eventually to 10 to 12 inches apart in the row.

Harvesting—Several harvests can be made from the same plants through the growing season. Outer leaves should be removed near ground level with a sharp knife, leaving smaller leaves near the center of the plant. It is important not to cut into the growing point or bud in the center of the plant so new leaves can continue to develop.

Tomatoes

Tomatoes grow under a wide range of conditions with minimum effort. They require relatively little space for large pro-

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Insect Control, Tomatoes:
See insect descriptions, pgs 273-277.

	Insect Treatments
Aphids	1, 2, 3, 5, 8, 9, 10, 14
Blister Beetles	5, 14
Cabbage Looper	4, 5, 6, 12, 13, 14
Colorado Potato Beetle	3, 4, 5, 9, 12, 13, 14
Corn Earworm (tomato fruitworm)	4, 5, 6, 12, 14
Cutworms	4, 5, 7, 12
Flea Beetles	3, 4, 5, 9, 13
Hornworms	4, 5, 6, 12, 13, 14
Mites	1, 8
Sowbugs	9, 13
Stink Bugs	4, 5, 14
Whiteflies	1, 3, 5, 8, 10, 14

duction. Each tomato plant, if properly cared for, can be expected to yield 10 to 15 pounds of fruit.

The tomato is a warm-season plant and should not be set outside until danger of frost is past. This date varies from April 20 in western Kentucky to May 15 in northern Kentucky.

Fruits vary from small cherry sizes to large baseball sizes. Shapes range from plum to round to pear, and colors vary from greenish white through yellow, orange, pink and red. Growth habits also vary, but those which have indeterminate growth habit and produce fruit over a long period of time are most desirable for the home garden. Select a variety with resistance to plant diseases, especially to fusarium wilt.

Planting—Select stocky transplants about 6 to 10 inches tall. Set tomato transplants in the garden a little deeper than the pot in which they were grown. Starter fertilizer should be used around transplants.

Since plants should be pruned and staked, space them 24 inches apart in rows 3 feet apart.

Fertilization—Tomato plants benefit from additional fertilizer after fruit has set. When first fruits reach golf ball size, scatter 1 Tbs ammonium nitrate in a 6- to 10-inch circle around each plant. Water thoroughly and repeat about every two weeks.

Staking—Staking makes the job of caring for tomatoes easier and aids in reducing fruit rots. Drive stakes in soil about 4 to 6 inches from plant, 1 foot deep, soon after transplants are set in the garden. Use wooden stakes 6 feet long and 1 ½ to 2 inches wide. Attach heavy twine at 10-inch intervals to stakes. As tomatoes grow, pull them up alongside stakes and tie loosely. Tomatoes may also be set along a fence or trellis and tied there.

Pruning—If tomatoes are staked, they need to be pruned to either one or two main stems. At the junction of each leaf and first main stem, a new shoot will develop. If plants are trained to two stems, choose one of these shoots, normally at the first or second leaf stem junction, for your second main stem. Once each week, remove all other shoots to hold the plant to these two stems. Remove shoots by pinching them off with your fingers.

Caging—Large-vined tomatoes benefit from being grown in wire cages, show fewer cracks and sunburn, ripen more uniformly, show fewer green shoulders and produce fewer cull fruits than tomatoes which are pruned and tied to stakes or allowed to sprawl on the ground.

Erect cages soon after plants have been set out. Otherwise, breakage often occurs when you try to train stems which have grown too long.

One material suggested for cage use is concrete reinforcing wire (6-inch mesh) which gives good support and allows you to reach through to pick tomatoes. However, this wire will rust, so after making cages, it's a good idea to paint them with rust-resistant paint.

Galvanized fence wire lasts many seasons without painting. Be sure to get 4- to 6-inch mesh so your hand will fit through for harvesting. Galvanized fence wire comes either welded or woven. Since welded joints occasionally break, woven is the best type to use.

Long-term Storage—Mature green or slightly pink tomatoes can be stored for one to two months. Spread them on a rack covered with newspaper and sort them according to ripeness. Then store them in the dark, covered with paper to retain moisture. Tomatoes put in sunlight become bitter. Check them every week and remove ripe or damaged ones.

Matured green tomatoes will be ripe enough to eat in about two weeks if kept at 65° to 70°F. The ripening period can be slowed to three or four weeks if the temperature is 55°F. (Don't let it get below 50°F.) The immature ones will take longer at either temperature.

Another way to ripen tomatoes is to pull the vines just before a freeze and hang them upside down in your garage or basement. The fruits will ripen gradually and may be picked as needed. See "Storing Vegetables" on page 280.

Diseases

Early Blight (fungus)—Leaves have dark brown spots with concentric rings or target board pattern in the spots; disease begins on lower foliage and works up with severely affected leaves shriveling and dying; similar spots can occur on stems and fruits; can be confused with other leaf spots, but this is most common. Maintain proper fertility. Spray foliage with fungicide at first sign of disease and as needed (weekly during hot, humid weather) thereafter; use chlorothalonil, mancozeb or fixed copper. (Good coverage is needed.) Make second planting in midsummer for fall crop. A few early blight tolerant varieties are now available.

Fusarium and Verticillium Wilt (fungi)—Leaves wilt, turn yellow and fall, often on one side of plant before the other; plants may be stunted or killed; inner "bark" or vascular tissue may be yellow, brown or have dark discoloration that can be seen when lower stem is cut open; Verticillium more likely under cool growing conditions, Fusarium when soils are warm. Use resistant tomato varieties; varieties la-

Insect Treatments: 1. Malathion 50% EC (Ortho Max Malathion Insect Spray), **2.** Pyrethrins, **3.** Imidacloprid (Bioadvanced Fruit, Citrus, Vegetalbe Insect Control), **4.** Cyfluthrin (Bioadvanced Vegetable and Garden Insect Spray), **5.** Bifenthrin 0.3% + zeta-cypermethrim 0.075% EC (Ortho Bug-B-Gon Insect Killer for Lawns and Gardens), **6.** *Bacillus thuringiensis* var *kurstaki*, **7.** Carbaryl 5% B (Southern Ag Mole Cricket Bait), **8.** Insecticidal soap, **9.** Neem, **10.** Horticultural Oil, **11.** Bifenthrin, (Bonide Eight Flower and Vegetable Soil Insect 0.115% granules), **12.** Permethrin (Bonide Eight Insect Control Vegetable Fruit and Flower Concentrate), **13.** Spinosad (Captan Jacks Dead Bug Brew), **14.** Acetamiprid 0.5% (Ortho Flower, Fruit & Vegetable Insect Killer)

beled "V," "F" or "N" are resistant to Verticillium, Fusarium or root knot nematodes; "VFN" varieties are resistant to all three; use recommended varieties; rotate with other garden crops.

Late Blight (fungus)—See "Potato" for description of foliar symptoms; fruits may develop dark brown or greenish blemishes, usually on stem and during cool, moist weather. See "Tomato Early Blight" for fungicides. Use disease-free transplants and control late blight in potatoes.

Septoria Leaf Spot (fungus)—Small, brown, circular spots on leaves. Similar to early blight, but often develops earlier in the season. See "Early Blight."

Southern Stem Blight—See "Symptoms of Some General Diseases and Their Management" on page 272.

Virus Diseases—See "Symptoms of Some General Diseases and Their Management" on page 272.

Other Problems

Blossom End Rot (environmental)—Black or brown leathery decay on blossom end of fruit; dark area often sunken and fruits practically worthless. Irrigate to maintain uniform soil moisture levels; mulch plants to conserve moisture; avoid deep cultivation and root pruning; lime soil as needed according to soil test results.

Walnut Wilt (environmental)—Grown plants which set fruit suddenly wilt and die; internal vascular browning in lower stem; strictly associated with plants growing near walnut trees or in soil with decaying walnut roots. Do not plant tomatoes, eggplant or peppers near walnut (*Juglans* spp.) trees.

Insect Control, Turnips:
See insect descriptions, pgs 273-277.

	Insect Treatments
Aphids	1, 3, 9
Cabbage Looper	6
Cutworms	7
Flea Beetles	3, 4
Garden Webworm	1
Root Maggots, Seed Maggots	1
Sowbugs	7 (not for turnip greens)

Turnips

Turnips are a rapidly maturing, cool-season crop which can be planted for late spring or late fall harvest in Kentucky. Some cultivars are grown only for their leaves or "greens," while others are grown for their fleshy roots. Turnip greens are rich in calcium, iron and vitamin A. The white-fleshed group of turnips is recommended for roots.

Planting—For spring turnips, seed should be planted around March 15 or as soon as ground can be worked in spring. For a late fall turnip crop, seed should be sown the latter part of July or first of August.

It is a common practice to broadcast turnip seed. However, drilling seed ½ inch deep in rows 12 to 15 inches apart results in more uniform growth.

When plants have become established, thin them to 3 to 4 inches apart in the row.

Harvesting and Storage—Harvest turnips when they reach 2 to 3 inches in diameter. Large turnips tend to become woody. After growth stops in the fall, turnips can be left in the garden, if protected from freezing. They may also be kept in the refrigerator for several months.

Watermelons

Watermelons are a warm-season, frost-sensitive vine crop and require a lot of garden area for growing because of large vines. Therefore, they are generally not grown in small gardens. Types range from large, 30-pound fruits to small, round, "icebox types" weighing between 5 and 10 pounds. There are also yellow-fleshed types, but red-fleshed types are most popular.

Seedless watermelons are a triploid type. They require a diploid (regular seeded) watermelon for pollination.

Insect Control, Watermelons:
See insect descriptions, pgs 273-277.

	Insect Treatments
Aphids	1, 2, 3, 5, 9, 14
Cucumber Beetles	3, 5, 12, 14
Cutworms	5, 7, 11
Leafhoppers	3, 5, 9, 12, 14
Mites	8

Planting or Transplanting—For early harvest, grow seed in peat pots or similar containers in a greenhouse or hotbed three to four weeks before the last frost, then transplant to the garden. Watermelons grow well on black plastic mulch.

Watermelons may also be direct-seeded. Plant two to three seeds per hill about 1 inch deep after danger of frost is past. Space hills 6 to 8 feet apart in the row with rows 6 feet apart. If spaced too closely, bees cannot get into plants to pollinate them properly and weed control is nearly impossible.

Pollination—Since male and female flowers are separate on the same plant, bees must carry pollen from flower to flower to ensure good fruit set and development. Apply insecticides late in the day to avoid killing bees.

Harvesting—Watermelons should be harvested when fully ripe. This stage is difficult to determine. "Thumping" the fruit is not a reliable indicator of fruit maturity. The presence of a dead tendril at the point where the fruit is attached to the vine helps in determining when to harvest. Also, checking for a change in color on the belly or ground spot of the watermelon is a good way to check for maturity. At maturity, the spot will appear creamy white to yellow.

Diseases: see "Cucumber"

Insect Treatments: 1. Malathion 50% EC (Ortho Max Malathion Insect Spray), **2.** Pyrethrins, **3.** Imidacloprid (Bioadvanced Fruit, Citrus, Vegetalbe Insect Control), **4.** Cyfluthrin (Bioadvanced Vegetable and Garden Insect Spray), **5.** Bifenthrin 0.3% + zeta-cypermethrim 0.075% EC (Ortho Bug-B-Gon Insect Killer for Lawns and Gardens), **6.** *Bacillus thuringiensis* var *kurstaki*, **7.** Carbaryl 5% B (Southern Ag Mole Cricket Bait), **8.** Insecticidal soap, **9.** Neem, **10.** Horticultural Oil, **11.** Bifenthrin, (Bonide Eight Flower and Vegetable Soil Insect 0.115% granules), **12.** Permethrin (Bonide Eight Insect Control Vegetable Fruit and Flower Concentrate), **13.** Spinosad (Captan Jacks Dead Bug Brew), **14.** Acetamiprid 0.5% (Ortho Flower, Fruit & Vegetable Insect Killer)

Gardening Resources

Insects, diseases and other disorders of vegetable crops

IPM Scouting Guides:

Solanaceous Crops in Kentucky, ID-172
http://www2.ca.uky.edu/agcomm/pubs/id/id172/id172.pdf

Sweet Corn in Kentucky, ID-184
http://www2.ca.uky.edu/agcomm/pubs/id/id184/id184.pdf

Cole Crops in Kentucky, ID-216
http://www2.ca.uky.edu/agcomm/pubs/ID/ID216/ID216.pdf

Cucurbit Crops in Kentucky, ID-91
http://www2.ca.uky.edu/agcomm/pubs/id/id91/id91.pdf

High Tunnel and Greenhouse Vegetable Crops In Kentucky, ID-235
http://www2.ca.uky.edu/agcomm/pubs/ID/ID235/ID235.pdf

Legume Vegetables in Kentucky, ID-227
http://www2.ca.uky.edu/agcomm/pubs/ID/ID227/ID227.pdf

Natural Enemies of Vegetable Pests in Kentucky, ENT-67
http://www2.ca.uky.edu/agcomm/pubs/ent/ent67/ent67.pdf

Sustainable Disease Management:

Cole Crops in the Home Garden, PPFS-VG-23
https://plantpathology.ca.uky.edu/files/ppfs-vg-23.pdf

Cucurbit Crops in the Home Garden, PPFS-VG-19
https://plantpathology.ca.uky.edu/files/ppfs-vg-19.pdf

Leafy Green Crops in the Home Garden, PPFS-VG-20
https://plantpathology.ca.uky.edu/files/ppfs-vg-20.pdf

Legume Vegetable Crops in the Home Garden, PPFS-VG-22
https://plantpathology.ca.uky.edu/files/ppfs-vg-22.pdf

Solanaceous Crops in the Home Garden, PPFS-VG-21
https://plantpathology.ca.uky.edu/files/ppfs-vg-21.pdf

Insects Affecting Vegetables
https://entomology.ca.uky.edu/vegetable

Other publications related to gardening

Gardening in Small Spaces, ID-248
http://www2.ca.uky.edu/agcomm/pubs/ID/ID248/ID248.pdf

Home Composting, HO-75
http://www2.ca.uky.edu/agcomm/pubs/ho/ho75/ho75.pdf

Vegetable Cultivars, ID-133
http://www2.ca.uky.edu/agcomm/pubs/id/id133/id133.pdf

Organic Manures and Fertilizers
https://www.uky.edu/hort/sites/www.uky.edu.hort/files/documents/organicmanures.pdf

Starting Seeds at Home, HO-56
http://www2.ca.uky.edu/agcomm/pubs/ho/ho56/ho56.htm

Plan, Eat, Move: Gardening Information
(includes a gardening calendar and other information for home gardeners)
https://www.planeatmove.com/get-moving/growing-your-own-garden/

Vegetable Production Guide, ID 36
(geared toward commercial producers)
http://www2.ca.uky.edu/agcomm/pubs/ID/ID36/ID36.pdf

Chapter 21

Organic Gardening

By Krista Jacobsen, assistant professor, Horticulture, University of Kentucky.

In this chapter:

Organic farming and gardening have grown in popularity in recent years as consumers and producers have sought alternatives to synthetic fertilizers and pesticides in favor of biologically based management. A 2008 survey by the National Gardening Association found that 12 percent of American household gardens (12 million households) used all-natural management techniques, an increase of 7 percent from 2004.

The U.S. Department of Agriculture (USDA) National Organic Program (NOP) defines the rules for USDA Certified Organic production practices. (The label used to designate certified organic products is shown in Figure 21.1. See the USDA-NOP website at http://www.ams.usda.gov/AMSv1.0/nop for additional details). This publication provides an overview of the principles and practices of organic agriculture for the home gardener, whether he or she wants to grow a completely organic garden or adopt select practices to lower input costs and build soil fertility. The fertilizer and pest control strategies in this publication are consistent with spirit of the USDA-NOP guidelines. However, gardeners who want to meet the "letter" of those guidelines should explore the Organic Materials Review Institute (OMRI) list of NOP-approved materials at www.omri.org. or look for the OMRI label when purchasing garden supplies (Figure 21.2).

Figure 21.1. USDA Certified Organic label.

Figure 21.2. OMRI label.

Organic gardening offers the gardener many benefits—a safe, low-chemical gardening environment; produce free from synthetic pesticide residues; and gardens that can increase in fertility and natural pest control over time. However, reaping the benefits of organic management requires planning, observation, and thinking about the garden as an interconnected system of soils, plants, pests, and beneficial organisms. Principles and practices include:

- Building long-term soil fertility with composts, manures, and mulches
- Rotating crops
- Using good planning practices to avoid insect, disease, and weed pests, and using biological or mechanical controls when necessary

Planning Your Organic Garden

Crop Rotation

Crop rotation is alternating crops grown in a particular bed or field between growing seasons. By rotating crops, you can avoid buildup of certain pests and also enable nutrients in the soil to be used more efficiently.

The most popular type of rotation is alternating crops by botanical family. For example, diseases that affect tomatoes can also affect other members of the Solanaceae family, including peppers, potatoes, and eggplants.

Rotating crops in the Solanaceae family with crops in other families can minimize losses from these diseases. Similarly, rotating among crops that have different growth habits can help deter pests. For example, if root crops such as sweet potatoes or carrots are planted in the same location year after year, soil-dwelling insect pests, such as white grubs, wireworms, and some nematodes, may proliferate. Rotating among plants with different root architecture may prevent proliferation or help break these pest cycles.

One common rotation method is based on the fertility requirements for each crop. With this method, you categorize crops by whether they "feed" on nutrients or "give" nutrients to the soil over the course of the growing season. Crops with high fertility (primarily nitrogen) requirements have been described as heavy feeders, those with moderate fertility requirements as medium or light feeders, and crops that contribute nutrients are "givers." (See Jeavons' book in "Additional Resources" section.) Crops are rotated in a cycle from heavy givers to light feeders to heavy feeders and back to heavy givers. Examples of crops in these categories are:

- **Heavy givers:** Beans (snap, pole, bush), peas, green manure crops such as clovers, and field peas

- **Light feeders:** Beets, carrots, garlic, onions, sweet potatoes, turnips
- **Heavy feeders:** Broccoli, cabbage, corn, cucumbers, squash, tomatoes

If you plan to practice rotation, it's important to keep records and a year-by-year map of your garden. Flashcards also can be useful in the garden planning process. Using this technique, flashcards are made for each crop, with a copy of the flashcard for that crop for every year in the rotation (e.g., three potato flashcards for three years of potatoes). You can then manipulate the cards for a three-to-five-year timeline for the entire garden. This exercise, using the botanical family as the guide to the rotation, is outlined in *The New Organic Grower* by Eliot Coleman (see "Additional Resources").

Common vegetables and their botanical families are listed in Table 21.1.

Soil Fertility and Organic Fertilizers

A central tenet in sustainable and organic agriculture is to "feed the soil to feed the crop"—restoring and maintaining the soil organic matter that ultimately feeds crop plants. Soil organic matter accumulates through use of organic amendments such as composts, manures, cover crops, and mulches. Over time, these amendments sustain fertility, relieve compaction, improve both drainage and water-holding capacity, and improve nutrient retention. However, organic amendments are delivered more slowly and less consistently than standard synthetic fertilizers because they become available as microbes and other soil organisms decompose.

Table 21.2 shows the nutrient contents (N-P-K) of several common sources of fertility in organic gardens.

Organic fertilizers rarely contain the N-P-K ratios to match recommendation from a soil test report. However, you can use the steps below to figure out how much fertilizer you need, whether you use the values in Table 21.2 or those listed in the nutrient analysis of a purchased amendment.

To calculate the organic fertilizer required from several sources, complete the following steps, based on a soil test report:

1. Calculate the nitrogen (N) recommendation first.
2. Calculate the phosphorus ($P_2 0_5$) recommendation next.
3. Calculate the potassium (K_2O) recommendation next.

An example of these calculations is provided in Figure 21.3.

It's fairly easy to use organic sources to meet your garden's fertility requirements, and organic fertilizers are increasingly accessible. However, it is important to understand that for nutrients to become available from most organic sources (other than minerals and rock powders), they must be decomposed by soil organisms. Thus, it is important to understand how temperature, moisture, and other environmental factors affect soil organisms and the decomposition process. The effects of pH and temperature are described briefly below. For additional information, Jeff Lowenfel's book, *Teaming with Microbes*, is

Table 21.1. Common garden vegetables and their botanical families.

Botanical Family	Common Family Name	Crop
Solanaceae	Nightshade	Tomato, pepper, potato, egg-plant, tomatillo
Brassicaceae	Cole crop	Broccoli, cauliflower, cabbage, kale, Brussels sprouts, radish, rutabaga, turnip
Cucurbitaceae	Gourd	Winter squash, summer squash, melons, cucumber, pumpkin
Apiaceae	Carrot	Carrot, parsley, celery, parsnip
Chenopodiaceae	Goosefoot	Beet, chard, spinach
Fabaceae	Legume	Pea, bean
Asteraceae	Sunflower	Lettuce
Liliaceae	Lily	Onion, garlic, shallot, leek
Poaceae	Grass	Corn

Table 21.2. Nutrient content and release rates of organic fertilizers.

Materials	N (%)	P_2O_5 (%)	K_2O (%)	Relative Availability
Alfalfa meal	3.0	1.0	2.0	Medium-Slow
Blood meal	12.0	1.5	0.6	Medium-Rapid
Bone meal	0.7-4.0	11.0-34.0	0.0	Slow-Medium
Feather meal	11.0-15.0	0.0	0.0	Slow
Fertrell "Super N"	4.0	2.0	4.0	Slow
Fish meal	10.0	4.0	0.0	Slow
Fish emulsion	5.0	1.0	2.0	Medium-Rapid
Greensand	0.0	1.0-2.0	5.0	Slow
Kelp[1]	0.9	0.5	1.0-4.0	Slow
Manure[2] (fresh)				
Cattle	0.25	0.15	0.25	Medium
Horse	0.3	0.15	0.5	Medium
Poultry (50% water)	2.0	2.0	1.0	Medium-Rapid
Poultry (15% water)	6.0	4.0	3.0	Medium-Rapid
Manure[2] (dry)				
Dairy	0.7	0.3	0.6	Medium
Steer	2.0	0.5	1.9	Medium
Horse	0.7	0.3	0.5	Medium
Marl	0.0	2.0	4.5	Very Slow
Mushroom compost	0.7	0.9	0.6	Medium
Sulfate of potash magnesia (K-Mag)	0.0	0.0	22.0	Rapid-Medium
Soybean meal	6.7	1.6	2.3	Slow
Wood ashes[3]	0.0	1.0-2.0	3.0-7.0	Rapid

Source: Adapted from How to Convert an Inorganic Fertilizer Recommendation to an Organic One, University of Georgia Cooperative Extension. Adapted from Boyhan, 2009. See Additional Resources.

[1] Kelp also contains common salt, sodium carbonates, and sodium and potassium sulfates.

[2] Manure contents may vary with amount of straw/bedding included, feed quality, and method of storage. (See the health and safety questions in the Cooperative Extension publication *Composting* (ID-192).

[3] Potash content depends on the tree species burned. Wood ashes are alkaline and contain approximately 32% CaO.

A soil test report recommends 2-3 lb of N, 1-2 lb of P2O5, and 3-5 lb of K2O per 1,000 square feet of garden.

1. Calculate the nitrogen (N) recommendation first. In this example, we will use blood meal for the nitrogen source (12-1.5-0.6, see Table 21.2). For the 3 lb of N recommended, the quantity of blood meal required to meet the nitrogen recommendation can be calculated as:

$$(3 \text{ lb N} \div 1000 \text{ ft}^2) \times (1 \text{ lb blood meal} \div 0.12 \text{ lb N}) = (25 \text{ lb blood meal} \div 1000 \text{ ft}^2)$$

2. Calculate the phosphorus (P_20_5) recommendation next. Subtract the amount of P supplied by the N source (blood meal):

$$25 \text{ lb blood meal} \times (0.015 \text{ lb } P_2O_5 \div 1 \text{ lb blood meal}) = 0.375 \text{ lb } P_2O_5$$

Use bone meal (approx. 1-11-0) for the phosphorus source to fulfill the remaining P requirement.

$$1.5 \text{ lb } P_2O_5 - 0.375 \text{ lb } P_2O_5 \text{ from blood meal} = 1.125 \text{ lb } P_2O_5$$

$$(1.125 \text{ lb } P_2O_5 \div 1000 \text{ ft}^2) \times (1 \text{ lb bone meal} \div 0.11 \text{ lb } P_2O_5) = (10 \text{ lb bone meal} \div 1000 \text{ ft}^2)$$

3. Calculate the potassium (K_20) recommendation next. The quantity of K supplied in the bone and blood meal is negligible, so the K recommendation can be calculated without subtracting the K present in the N and P sources. Using K-mag (sulfate of potash magnesia) to complete the fertility plan:

$$(4 \text{ lb } K_2O \div 1000 \text{ ft}^2) \times (1 \text{ lb K-Mag} \div 0.22 \text{ lb } K_2O) = (18 \text{ lb K-Mag} \div 1000\text{ft}^2)$$

Based on these calculations, meeting the soil test report fertilizer recommendations will require 25 lb blood meal, 10 lb bone meal, and 18 lb K-Mag for 1000 square feet of garden space.

Figure 21.3. Example calculation to determine organic fertilizer required to meet soil test report recommendations for 1,000 square feet of garden space.

an excellent gardener-friendly primer on soil ecology and the activity of soil microorganisms (see “Additional Resources”).

pH and Liming

Garden plants typically grow best in a pH from 6.0 to 6.5, and microbial activity is restricted when pH is less than 5.5. Soil testing and adjusting pH according to lime recommendations helps ensure that soil organisms are operating under optimal conditions. Calcium, the neutralizing agent in agricultural lime, will not spread quickly throughout the soil profile. For that reason, it must be thoroughly incorporated before planting—ideally two to three months before planting—throughout the rooting zone, at a depth of six to eight inches. If you can’t apply lime this early, it will still help if you can apply and incorporate it at least a month before seeding or transplanting.

Temperature

Cool temperatures in early spring also limit microbial activity. Soils must be warm enough to stimulate microbial activity in order to decompose organic fertilizers and make nutrients available to crop plants. Growth may be stunted early in the season if plants don’t get enough nutrients or those nutrients are immobilized by decomposing microbes (also known as “N rob”).

To avoid stunted growth, use a readily available organic fertilizer such as fish emulsion or other liquid organic fertilizer when you transplant, and use it weekly for one to two weeks after transplant. Using healthy transplants with enough fertility in the transplant mix to carry some nutrient forward into the garden bed will also help make up for insufficient soil nutrients early in the season.

Organic Transplants and Seed Sources

Organic seedling mix can be expensive, and nutrient delivery tends to be less consistent than with conventional seedling mixes (though there are notable exceptions). Add fertilizer once the first set of true leaves appear. Typically, organic gardeners use a liquid, fish emulsion-based organic fertilizer. To avoid burning plants, follow dilution directions on the packaging.

The cost of organic seedling mixes increases rapidly with soil or compost-based mixes, so many organic gardeners and farmers make their seedling mix. Several common recipes used in organic seedling production are listed in Table 21.3. For additional information on organic seedling mix ingredients, nutrient release rates, and additional recipes, see the publication *Potting Mixes for Certified Organic Production* at http://attra.ncat.org/attra-pub/potmix.html. Note that one recipe is intended for use with *soil blockers*, which are hand tools designed to form free-standing blocks of potting soil that substitute for peat pots, seedling flats, etc. Soil blockers have been popular among small-scale producers, and are readily available through some garden suppliers specializing in organic production (see “Additional Resources”).

Table 21.3. Common recipes for organic potting and germination mixes.

Organic substitute for Cornell Mix	Classic soil-based mix[1]	Soil blocking mix	Organic potting mix	Vegetable transplant recipe
• ½ cu. yd sphagnum peat • ½ cu. yd vermiculite • 10 lb bone meal • 5 lb ground limestone • 5 lb blood meal	• ⅓ mature compost or leaf mold, screened • ⅓ garden topsoil • ⅓ sharp sand	• 3 buckets[2] • brown peat • ½ cup lime (mix well) • 2 buckets coarse sand or perlite • 3 cups base fertilizer (blood meal, colloidal phosphate, and green sand mixed together in equal parts) • 1 bucket soil • 2 buckets compost	• 1 part sphagnum peat • 1 part peat humus (short fiber) • 1 part compost • 1 part sharp sand (builder's) To every 80 qt of this add: • 1 cup greensand • 1 cup colloidal phosphate • 1½ to 2 cups crabmeal, or blood meal • ½ cup lime	Equal parts by volume of: compost, peat moss, and perlite or vermiculite

Sources: For the blocking and organic potting mixes, Coleman's *The New Organic Grower: A Master's Manual of Tools and Techniques for the Home and Market Gardener*. For the vegetable transplant recipe, Rynk's *On-Farm Composting Handbook*. (See Additional Resources.)

1 This mix is heavier than modern peat mixes but still has good drainage. Compost promotes a healthy soil mix that can reduce root diseases. Vermiculite or perlite can be used instead of sand. Organic fertilizer may be added to this base.

2 Standard 10-qt bucket.

Pest Management: Weeds, Insects, Diseases

One of the main differences between organic gardening and conventional gardening is the use of pesticides. Organic gardeners choose not to use any synthetic chemicals to control weeds, insects, or diseases. Instead, they use a combination of cultural, physical, and biological controls. The philosophy behind organic pest control is that using "many little hammers" allows the organic gardener to beat back pests to a manageable threshold even though these techniques lack the chemical strength of many conventional garden inputs.

Cultural controls, used to prevent pests from ever becoming a threat, are the first line of defense in the garden. They include proper plant selection, fertility management, crop rotation, and physical exclusion. Physical or mechanical controls manually remove pests from the garden. Biological controls, which can be organic pesticides or beneficial organisms, are used to manage an existing insect or disease problem. It is a common misconception that organic gardening prohibits the use of pesticides in any form. A number of pesticides that are derived directly from biological or mineral sources are organically approved. They may be highly toxic, but they typically break down much more quickly in the environment than their synthetic counterparts. Organic management of weeds, insects, and diseases integrating cultural, physical/mechanical, and biological controls is discussed below.

Weeds

Cultural controls for preventing weeds include the following strategies:

- crop rotation and spacing
- physical barriers on the soil
- bringing into the garden only materials that you know to be free of weed seed
- not allowing existing weeds to go to seed

Crops and cover crops planted in tight succession compete with weeds for light, nutrients, and water. The more these resources are in use by crop plants, the less available they are for weeds.

In addition, planting vigorous transplants on relatively tight spacing closes the plant canopy rapidly, helping crop plants out-compete weeds for light, water, and available nutrients. Techniques such as French biointensive gardening and square-foot gardening (described in more detail in books by John Jeavons and Mel Bartholomew, respectively, listed in the "Additional Resources" section) emphasize close plant spacing and arranging plants by vertical size to produce a dense canopy that maximizes crop production and minimizes weed pressure.

Mulches and Other Physical Barriers

Physical barriers such as mulches, plastic, landscape fabric, and even cardboard block light to germinating weeds. They greatly reduce weed emergence and also conserve water. When these barriers are plant-based, they add organic matter to the soil as well. Typically, a one-to-two-inch layer of straw or hay mulch, with some additional hand weeding, will suppress weeds for much of the season. More mulch can lead to outbreaks of fungal and bacterial disease in warm, wet years. To minimize diseases, keep mulches off crop plant stems. Also, on long-season, disease-sensitive crops such as tomatoes and peppers, remove lower leaves touching the mulch. Direct-seeded crops such as root vegetables and lettuces can be planted through a thin layer of mulch and still emerge. To promote crop emergence while minimizing weeds between the crop rows, you also can mulch with a thicker layer around the planting furrow and leave the furrow exposed.

Straw mulch is commonly used in home gardens, and it is effective in controlling weeds and conserving moisture. However, if it's not clean, straw may import weed seeds and create more weeds than it reduces. Mulches and hay and manures from animals eating them can contain herbicide residue, but most herbicides break down rapidly in the environment. However, picloram, clopyralid, and aminopyralid do not break down quickly, and, in concentrations as low as one ppb (parts per billion), they can be lethal to sensitive garden plants such as peas, beans, lettuce, spinach, tomatoes, and potatoes. These herbicides are used to control broadleaf, persistent weeds such as Canada thistle in pastures, under power transmission lines, and in hay and wheat crops. They are used because they are long-lived, effective, and low in toxicity to humans and other animals. They can, however, persist in the garden for several years. If you are buying hay or straw mulch from a local farm, you can avoid bringing in contaminated mulches by asking whether the field in which the crop was grown has been sprayed with picloram, clopyralid, or aminopyralid in the past two to three years. These herbicides are sold under the following trade names:

- **Picloram:** Tordon, Access, Surmount, Grazon, and Pathway
- **Clopyralid:** Curtail, Confront, Clopyr AG, Lontrel, Stinger, Millennium Ultra, Millenium Ultra Plus, Reclaim, Redeem, Transline
- **Aminopyralid:** Milestone, Forefront, Pharaoh, Banish.

Weeding techniques

Once weed pressure begins to mount—and it generally does—physically removing weeds is the organic gardener's only option. No consistently effective, approved organic herbicides are available at this time. The following methods are most commonly used.

Hand weeding—The oldest method of weed control is hand weeding, and it is still the most effective for commonly occurring weed species in Kentucky. Hand weeding is particularly effective for removing annual weeds with shallow root systems. With hand weeding, you can remove weeds growing in the row without harming growing crop plants. If you regularly hand-weed while performing other gardening tasks, you can do so rapidly and keep weed pressure low. Hand-weeding is also the easiest method to use when weeding in garden beds with mulches. However, if you're weeding on a large scale or have high weed pressure, you may need to use tools.

Hoeing—Hoeing can be both efficient and effective for removing small weeds or chopping out larger ones. It is most effective for weeding between rows of crop plants that have a wide spacing between plants so the crop plants won't be damaged. Hoe shallowly near plants so you do not damage their roots; hoe deeply when you need to unearth roots of persistent weeds such as curly dock, Johnsongrass, nut sedges, etc. A sharp hoe makes hoeing much easier, as does having the right hoe for the job (Figure 21.4). For light weeding in tight garden spaces or in fine seed beds, use a collinear hoe. It is a small, light tool that is dragged along the soil surface or slightly below it to kill weeds. For larger weeds or larger areas, a standard garden hoe is most commonly used. A stirrup hoe, or "hula hoe," is an alternative to the garden hoe. It has a spring-steel blade that cuts in both directions for high efficiency. Unlike a fixed-blade garden hoe, the head of a stirrup hoe has a limited swivel joint at the top that allows the blade to remove weeds by pushing and pulling the hoe without having to lift the hoe. The ability to move the hoe back and forth without having to lift the hoe has also led to stirrup hoes also being called "scuffle hoes." The stirrup hoe can work the soil deeper than a garden hoe in loose and light soils. To chop out larger or deeply rooted weeds, a chop or grub hoe is an aggressive tool that quickly unearths weeds. Although grub hoes are effective, they can be heavy and physically demanding to operate.

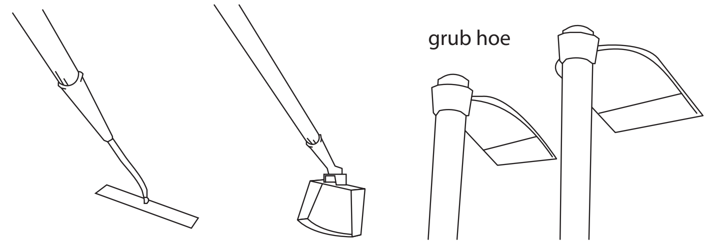

Figure 21.4. Specialty garden hoes.

Mechanical cultivation—Mechanical cultivation is generally used in large gardens that have wide spacing between rows. On a large scale, it can be much faster than hand weeding. Garden tillers are set at as shallow a depth as possible so nearby crop plants won't be damaged and soil disturbance at deeper depths will be minimized. Extensive, regular mechanical cultivation destroys soil structure and leads to increased breakdown of soil organic matter and organic amendments such as composts and manures. Mechanical cultivation should be conducted under proper soil moisture conditions to help minimize damage to soil structure. Soils that are too wet will stick to tillage implements, "smear" the soil, and create compacted conditions when the soil dries. In general, soil moisture can be estimated by taking a handful of soil and forming a ball by gently squeezing it. If the ball readily holds its shape, it may be too wet to till. Soils that crumble gently but still have some tangible moisture are in better condition for tillage.

Insects

Insect control in the organic garden begins with growing healthy plants. Weak plants, which have nutrient deficiencies, tend to be the first to succumb to insect pressure. Nutrient excesses (particularly nitrogen) can lead to outbreaks of insects such as aphids. Soil testing and proper fertility management can help minimize both nutrient deficiencies and excesses.

Timing is also important. For pests that increase throughout the season, such as corn earworms, tobacco hornworms, cucumber beetles, etc., early plantings can minimize pest pressure. For pests such as flea beetles that subside with onset of summer heat, delaying plantings of eggplant and other summer crops that are sensitive to flea beetles can minimize their damage.

Table 21.4. Guide to insects as biocontrols.

Beneficial Insect	Pest Insect Controlled
Green lacewing (*Chrysoperla rufilabris*)[1]	Aphids, mealybugs, immature scales and whiteflies, thrips, spider mites
Lady beetle	Aphids, Colorado potato beetles (egg stage), and other insect pests
Beneficial nematodes (various species)	Root knot nematodes, flea larvae, grubs
Praying mantis (*Tenodera aridifolia sinensis)*[1]	Foliar-feeding insects
Mealybug destroyer (*Cryptolaemus montrouzieri)*	Mealybug larvae
Trichogramma wasp	Over 200 species of moth eggs, including tomato hornworm, loopers, etc.
Spined soldier bug (*Podisus maculiventris*)[1]	Larvae of Mexican bean beetle, European corn borer, corn earworm, cabbage looper, cabbageworm, Colorado potato beetle, and flea beetles.

[1] These beneficial insects are general predators, shown with the pest insects against which they are particularly effective.

Row covers of lightweight fabric can be used as insect barriers to exclude insect pests from crop plants. When using row covers in the summer, the fabric should be of "insect-barrier" thickness so that temperatures under the fabric don't get too hot and maximum light penetrates the fabric. The fabric can be removed after the threat of pest damage has passed. For crops that bear fruit, the insect barrier should be removed during flowering to allow for pollination. Row covers are particularly effective in preventing imported cabbageworms and cabbage looper moths from laying their eggs on Brassica crops. Use wire hoops, which are available commercially, or homemade PVC frames to support row covers during the summer. Both hoops and frames will allow air to circulate around the plants. These supports can also be used with thicker fabrics and/or plastic to extend the growing season into spring or fall. Avoid pinning plants to plastic mulches, where they can be damaged by excessive heat.

A wide variety of traps can be made or purchased. For example, slugs and snails can be attracted to a shallow container filled with beer and buried level with the soil. The slugs and snails drown in the beer. (The beer must be changed every several days, as the trap fills and/or becomes foul.) Prepared sticky traps are available in garden shops for whiteflies and other insects but are best used for monitoring for insect pressure, not control. Japanese beetle traps, which rely on a synthetic lure or a sex pheromone to attract the beetles, are also available in garden shops. These traps are highly effective, even from long distances. However, beetles may linger and feed on crop plants, doing more damage than would have occurred without the traps. For that reason, these traps are not widely recommended. Instead, you might consider removing beetles and other insects by hand.

Trap crops are grown to lure pests away from more desirable crop plants. For example, flea beetles will feed on giant mustard over kales and other Brassica crops, and blue hubbard squashes are used as traps for cucumber beetles, which feed on a variety of cucurbit crops. Insect pests on the trap crop can either be left alone or destroyed by hand picking or with an organic insecticide. if you have to use pesticide to get rid insect pests, trap cropping helps limit how much you have to spray in addition to protecting crop plants.

Beneficial Insects

Beneficial insects, or "natural enemies," are used in the organic garden to control pests biologically. A number of species of beetles, parasitic wasps, flies, and nematodes are predators or parasitoids of pest insects. (Parasitoids are organisms that lay their eggs or larvae in the body of a host [pest] organism. The immature parasitoid feeds on the body fluids and organs of the host and eventually emerges and kills the host.) A number of beneficial insects are available commercially. Sources can be found online and in the UK Cooperative Extension publication *Vendors of Beneficial Organisms in North America* (ENTFACT-125) at http://www.ca.uky.edu/entomology/entfacts/ef125.asp. Common, commercially available beneficial insects and the insect pests they control are listed in Table 21.4.

In general, you can expect a delay between the time of beneficial insects' release and effective control of the pest. Effective control can be difficult if you release them after you notice a major pest outbreak, because a sufficient population has to build up to control the outbreak. You should release a large number of them at the first sight of the pests. Most importantly, you should create a habitat in which the beneficial insects can overwinter and persist in your garden or yard. Ideally, a year-round habitat for beneficial populations will limit outbreaks of pest insects. Typically, perennial vegetation, woody shrubs, crop residues, and even boards will provide overwintering habitat for beneficial insects and their offspring.

The most reliable way to control insect pests is to physically remove them from the plant by hand and drop them into a container of soapy water. Adding a squirt of dish soap to an empty quart jar, then adding water, creates a solution that effectively traps insects placed in the jar. The soap breaks the surface tension of the water, which prevents the insects from gaining traction and climbing out of the jar. This method works particularly well for beetles and caterpillars, which can generally be controlled at the garden scale by daily scouting and removal while you take care of other garden tasks. Physical removal is less effective for small or fast-moving insects, which will likely require some of the other techniques explained above.

Although organic insecticides, which are derived from botanical or mineral sources, do not persist as long as their conventional counterparts, a number of them are used in organic gardening. In general, an organic insecticide requires that the pest insect ingest it directly or at least come in contact with it. For example, organic gardeners can use *Bacillus thuringiensis* (Bt) to control caterpillars. It should be applied as a spray or powder every three to five days as needed during periods of caterpillar pressure.

Table 21.5. Insecticides approved for use in organic production.

Active Ingredient	Origin of Active Ingredient	Pest Insects Controlled
Bacillus thuringiensis (Bt)	A toxin produced by the soil bacterium *Bacillus thuringiensis*	Caterpillars, such as cabbage looper, hornworm, imported cabbageworm, corn ear worm, etc.
Diatomaceous earth	Fossilized remains of diatoms, algae with a silica-based hard shell	Particularly effective on soft-bodied insects but also deters beetle, flea, and ant activity on plants
Insecticidal soaps	Salts of fatty acids derived from coconut and other oils	Soft-bodied insects such as aphids, thrips, whiteflies, etc.
Kaolin clay	A naturally occurring clay mineralogy ground into a fine powder	Numerous. Kaolin clay is sprayed on crop plants, deterring pests from landing, feeding, and depositing eggs.
Neem	The neem tree *(Azadirachta indica)*, an evergreen native to the Indian subcontinent	Gypsy moths, leaf miners, whiteflies, thrips, loopers, caterpillars, and mealybugs (disrupts feeding and development)
Pyrethrins	Chrysanthemum *(Dendranthema grandiflora)* flowers	Numerous. Pyrethrins are general insecticides and affect beetles, caterpillars, and various sucking insects.
Sabadilla	Seeds of a tropical lily plant *Schoenocaulon officinale,* native to Central and South America	Sap-feeding insects, caterpillars, and thrips[1]
Spinosads	Soil actinomycete, *Saccharopolyspora spinosa*	Numerous. Disrupts neurotransmittors and feeding patterns in moths, caterpillars, leaf miners, thrips, Colorado potato beetles, and fire ants
Sulfur	The mineral sulfur	Spider mites, psyllids, and thrips

[1] Highly toxic to honey bees, so application at sunset is recommended.

Several general insecticides, such as pyrethins, are approved for organic production. These insecticides should be sprayed just before sunset, when pest insects are active but pollinators are not, in order to prevent contact with bees and other pollinators. Examples of insecticides approved for organic production and the organisms they control are listed in Table 21.5. Organically approved insecticides are available at some garden supply stores but are also available online in home garden quantities from commercial organic nursery and horticultural suppliers (see "Additional Resources").

Diseases

Cultural controls are the best way to prevent disease in organic gardening, since few options exist for biological control of diseases. Gardeners can best control diseases from the outset through cultural practices that deter buildup of disease organisms. Crop rotation is especially important in controlling diseases of Solanaceous crops (tomato, pepper, potato, etc.) as bacterial and fungal diseases are particularly problematic when these crops are produced organically. It is also best to avoid composting residue of diseased plants of any Solanaceous crops so that disease organisms won't build up in the compost pile. Instead, dispose of residue of diseased plants or any Solanaceous crops in sealed garbage bags and burn it or throw it away with municipal garbage.

It's also important to select disease-resistant cultivars. There are a number of sources for high-quality, untreated, and/or organic seed. Knowing disease issues that are problematic in your garden and in your region is key to proper cultivar selection. It should be noted that treated and/or genetically modified seeds are prohibited in USDA-certified organic production.

Disease organisms are spread by moving infected materials from plant to plant. To help avoid such spread, remove diseased plants when leaves are dry and place them in sealed plastic bags. This practice will help prevent bacteria or fungal spores spreading to healthy plants. To minimize disease transfer between plants, avoid harvesting or pruning tomato plants while the leaves are wet. Use a bleach-treated cloth to wipe down pruners between working tomato or tree crops, which will also help minimize disease spread.

Many diseases spread by insect vectors—insects transporting disease from plant to plant as they feed. In Kentucky, bacterial wilt of cucurbits is a classic example of this method of disease spread. Spotted and striped cucumber beetles carry bacterial wilt of cucurbits between cucumbers and other cucurbit plants as they feed. Therefore, this disease is controlled through the beetle vector, not the bacteria (*Erwinia tracheophila*) that causes the disease. This example highlights an important principle for the organic gardener: knowing the root cause of a disease or other problem in the garden requires understanding the entire garden as a ***system.*** One might view the disease as the problem because it may be the final fatal blow to the plant. However, if the root cause is insect or soil related, treating the disease is ineffective if the underlying condition or cause is not resolved.

Very few sprays are designed to control diseases organically. Copper-based products are considered synthetic but are allowed in USDA-certified organic production with certain restrictions. These products are restricted because they can accumulate in soil and create copper toxicity problems; are highly toxic to fish; and can also harm bees, beneficial soil bacteria and fungi, and earthworms. Copper-based products have been shown to be somewhat effective in controlling downy and powdery mildews, bean anthracnose, and tomato early blight. Bordeaux mix (a blend of copper sulfate mixed with hydrated lime) is considered a synthetic substance and is restricted in organic production due to its long residual activity and high toxicity to bees. Sulfur that is mined (elemental sulfur) rather than extracted through manufacturing/power generation can be used in certified organic production. In addition to serving as a trace mineral, sulfur has fungicidal effects.

Research and development of organically approved disease controls is occurring rapidly. Up-to-date information and new products can be found at Extension's eOrganic website (https://eorganic.info/) as well as Caldwell's Resource Guide for Organic Insect and Disease Management, listed in the "Additional Resources" section..

Additional Resources

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Boyhan, George. E. 2009. *Growing Vegetables Organically.* University of Georgia Cooperative Extension Bulletin 1011. Athens, GA. 10 pp. https://secure.caes.uga.edu/extension/publications/files/pdf/B%201011_4.PDF

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Gershuny, Grace, and Deborah L. Martin (eds). 1992 (Revised Edition). *The Rodale Book of Composting: Easy Methods for Every Gardener.* Rodale Press, Emmaus, PA. 278 pp.

Jeavons, John. 2004 (Sixth Edition). *How to Grow More Vegetables (and Fruits, Nuts, Berries, Grains and Other Crops than You Ever Thought Possible on Less Land than You Can Imagine).* Ten Speed Press, Berkeley, CA. 240 pp.

Kuepper, George. *Potting Mixes for Certified Organic Production. 2010 (reviewed edition).* ATTRA Publication #IP112. National Sustainable Agriculture Information Service, Butte, MT. 20 pp. https://attra.ncat.org/publication/potting-mixes-for-certified-organic-production/

Lowenfels. Jeff, and Wayne Lewis. 2006. *Teaming with Microbes: A Gardener's Guide to the Soil Food Web.* Timber Press, Portland, OR. 196 pp.

National Sustainable Agriculture Information Service (also known as ATTRA). An excellent source of information on all kinds of sustainable and organic agricultural practices, marketing, etc. www.attra.org.

Online Information Service for Non-Chemical Pest Management in the Tropics. Trap Cropping. Hamburg, Germany. http://www.oisat.org/control_methods/cultural__practices/trap_cropping.html

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Stephens, James M. 2003. *Organic Vegetable Gardening. Florida Cooperative Extension Service Circular 375.* University of Florida, Gainesville, FL. 12 p.

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Chapter 22

Growing Tree Fruits

By Jeff Olsen, Extension agent, Willamette Valley, and Anita Nina Azarenko, Extension horticulture specialist; both at Oregon State University. Adapted for Kentucky by John Strang, Extension horticulture specialist (ret.), University of Kentucky.

In this chapter:

Growing tree fruits or nuts can provide a great deal of satisfaction, but it takes a commitment to care for your trees year-round.

Planning

Variety Selection

When planning your orchard, choose varieties that not only are family favorites but are easy to care for. Remember that dwarf trees are always the best choice for home orchards.

Generally, the more varieties of fruit you grow, the more complex it is to manage them. However, if you enjoy a lot of different fruits and the management challenge, by all means plant a wide range.

Nearly all fruit- and nut-tree varieties (including some hazelnuts) are grafted to a genetically different root system, called a *rootstock.* When you choose a variety based on flavor, harvest period, disease resistance, color, etc., it is the grafted variety you are choosing—not the rootstock.

The ultimate size of a tree depends on the vigor of both the rootstock and the grafted variety. By knowing the vigor ratings of both, you can determine how big a tree will grow. See Table 22.1 for vigor ratings for some apple varieties. See the section on Rootstock Selection to learn more about vigor of various rootstocks.

Not all recommended varieties are included in the lists in this chapter. For apples alone, hundreds of varieties exist, and other fruits could have many more varieties. Consult the resources listed under "For More Information" to learn about additional varieties.

General types of apples include old style, cider, English, or flavor varieties. If you want to have fresh-off-the-tree apples for a long period of time in the summer and fall, choose varieties with staggered maturity dates (Table 22.2).

When buying trees for Kentucky, select disease-resistant varieties (Table 22.3) to reduce the impact of apple scab, cedar apple rust, fireblight, and powdery mildew.

Rootstock Selection

When choosing a fruit tree, check to see what rootstock it uses. Rootstocks are not chosen for their fruit. Most originally were selected for their ability to control overall tree size. Some were selected for other characteristics, such as the following:

- Efficient yield production
- Disease resistance
- Tolerance of different soil conditions, including poorly drained soils
- Cold hardiness

Apples

The greatest choice in rootstocks exists with apples. The most vigorous apple rootstocks are seedlings, which are simply sprouted apple seeds. When an apple variety is grafted onto a seedling rootstock, the tree can easily grow more than 30 feet tall. Most home orchardists can't efficiently spray, thin, and harvest a tree this tall.

Researchers in England developed the Malling series of apple rootstocks, which offers the opportunity to select trees that grow to specific heights. The height may be anywhere from dwarf (4 to 12 feet) to semidwarf (16 to 18 feet). Each rootstock in this series is identified by the letter "M" (for Malling) or "MM" (for Malling Merton) and a number. Higher numbers don't represent taller trees (Figure 22.1).

The following list shows approximate sizes as a percentage of the size of a tree on seedling rootstock:

Rootstock	Percent
MM.111	90
MM.106	60 - 75
M.7, G.30	55 - 65
M.26, G.11	40 - 50
M.9, Bud 9	25 - 35
M.27	< 25

Most home orchardists select dwarf rootstocks, such as Bud 9, which are especially appropriate if you want to train a tree to grow along a trellis. Dwarf trees should be supported by stakes, poles, or wires.

Table 22.1. Apple variety vigor ratings.

High vigor		**Low vigor**
Earligold Lodi Mutsu or Crispin		Spur Delicious Spur Golden Spur Granny Smith
Moderate vigor		**Very low vigor**
Akane Arkansas Black Cortland CrimsonCrisp Delicious (red) Empire Enterprise Freedom Fuji Gala Golden Delicious GoldRush Granny Smith Idared Jersey Mac	Jonagold Jonathan Liberty Melrose Mollies Delicious Newtown Pixie Crunch Pristine Redfree Sansa Rome Beauty Stayman Suncrisp Sundance William's Pride	Spur Arkansas Black Spur Delicious Spur Rome Super Spur

The M.27 rootstock is the only choice for growing apples in containers. For container plantings, use *spur-type* varieties, which are the least vigorous.

M.7 produces semidwarf trees that normally do not require staking. However, some support might be required if early production is encouraged.

MM.106 and MM.111 produce larger trees that require no staking and are suitable for the home orchard. In nursery catalogs, these trees are identified as semistandard.

The ultimate height of any tree can be greatly influenced by pruning, but rootstocks that impart more vigor make it harder to contain trees to the height and width desired.

Other commercially available apple rootstocks provide vigor control, disease resistance, and winter hardiness. The Budagorsky (Bud) series was introduced from central Russia. The G series was developed at Cornell University at the New York State Agricultural Experiment Station in Geneva, New York.

Cherries

Most cherry trees in Kentucky are grown on Mazzard rootstocks. However, recent research on growth-controlling rootstocks has produced more choices. New dwarf varieties are now being grown on Gisela rootstocks, and new European rootstocks are being tested each year. The most common Gisela rootstocks are Gisela 5, Gisela 6, and Gisela 12. They produce trees that are 50 percent, 70 to 90 percent, and 60 percent of Mazzard, respectively. Other new rootstocks include MxM2 (100 percent of Mazzard), MxM60 (100 percent of Mazzard), and MxM14 (75 to 85 percent of Mazzard). They bear earlier and have better disease resistance than Mazzard seedlings.

Sweet cherries generally do not survive or produce well in Kentucky. Some of these newer rootstocks are available to home gardeners from a few mail-order nurseries in the Pacific Northwest. See HortFact 3002, *Fruit and Nut Cultivar Nursery Sources,* which is listed in the "For More Information" section at the end of this chapter. See Table 22.4 for cherry varieties.

Pears

Most European pears are grown on one of many selections from the Old Home-Farmingdale cross. Asian pears sometimes use these rootstocks but also are grown on two species of *Pyrus*: *Pyrus betulaefolia* and *Pyrus calleryana*. See Table 22.5 for pear varieties.

Plums and Peaches

Plums are produced on a wide variety of *Prunus* rootstocks, such as peach, plum, apricot, and almond. Peaches usually are grown on peach seedling rootstocks. There are no suitable dwarfing rootstocks for peaches. See Tables 22.6 and 22.7 for nectarine and peach varieties.

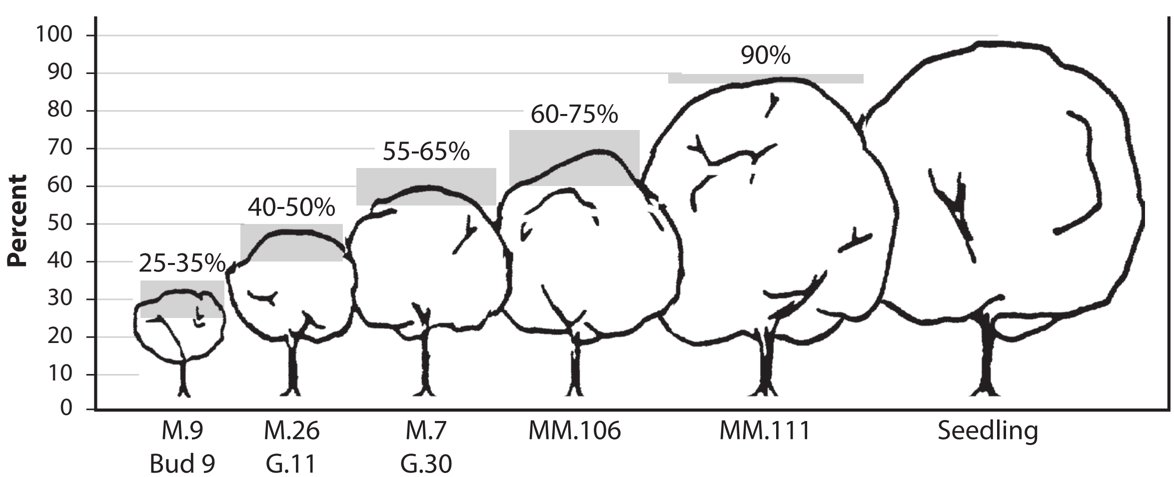

Figure 22.1. Approximate size of mature trees grown on various rootstocks, as a percentage of maximum height (100 percent) grown on seedling rootstock.

Pruning Terminology

Crotch angle—The angle formed between the trunk and a limb. The strongest crotch angle is 45° to 60°.

Leader—The uppermost portion of a scaffold limb.

Scaffold limb—A large limb that forms a tree's framework.

Shoot—The length of branch growth in one season. The bud scale scars (ring of small ridges) on a branch mark the start of a season's growth.

Spur—(1) A short shoot that bears flower buds on the end (terminally) or on the sides (laterally). (2) A short shoot that fruits.

Table 22.2. Apple varieties grouped by general time of maturity.

Early	Midseason	Late	
Akane Dayton Erligold Jersey Mac Lodi Mollies Delicious Monark Pristine Redfree Sansa	William's Pride Empire Freedom Gala Ginger Gold	Jonathan Liberty Arkansas Black Cortland CrimsonCrisp Delicious (Golden and Red) Empire Enterprise Fuji GoldRush Granny Smith	Idared Jonagold Melrose Mutsu or Crispin Newtown Pixie Crunch Rome Beauty Stayman Sun Crisp Sundance York

Table 22.3. Disease-resistant apples.[1]

Variety	Resistance To				Comments	Harvest	Stores Until	Skin Color
	AS	CR	FB	PM				
Pristine[2]	VR	S	S	R	Good quality for season, not as tart as Lodi, makes excellent applesauce	early July	short storage	Light yellow with red blush
Williams Pride	VR	S	MR	R	Good quality for season, corkspot frequently observed, subacid, yellow flesh	mid-July	short storage	70-80% dark red
Redfree[2]	VR	VR	S	S	Firm, summer apple, juicy	late July	Oct	90-100% dark red on yellow
Dayton[2]	VR	R	MR	R	Similar to Prima	mid-Aug	Sept	Up to 90% bright, medium red
Liberty[2]	VR	R[3]	R	R	Fruit similar to Macoun, crisp, juicy, yellowish flesh, tart at harvest	late Aug	Dec	90% dark-red stripes on green-yellow
Nova Easygro	VR	VR	R	S	Fruit similar to Cortland, fair quality (for trial)	early Sept	Dec	80% dark red on green-yellow
Spartan[2]	MR	R	MR	R	Firm McIntosh type, needs thinning to develop size	early Sept	Jan	Dark to pale red, depending on weather
Jonafree[2]	VR	S	S	R	Fruit similar to Jonathan, but less acid	early Sept	Dec	90% red stripes
Pixie Crunch[2]	VR	—	—	—	Small, sweet flavored, super crisp, kid's apple	early Sept	Dec	Deep red
Macfree	VR	VR[3]	MR	S	Similar to McIntosh, mealy under hot conditions	mid-Sept	Dec	75% medium red over green-yellow
Priscilla[2]	VR	VR[3]	VR	R	Tart, firm, somewhat coarse textured, crisp, juicy, small fruit size	mid-Sept	Nov	70-90% dark-red blush over yellow-green
SirPrize[2]	VR	S	R	R	Fine grain, crisp, tender, bruises very easily, sterile pollen	mid-Sept	Dec	Greenish yellow, slight red blush
CrimsonCrisp	VR	MR	S	S	Medium-sized red fruit, firm, crisp, tart, stores very well	mid-Sept	March	95% red
Enterprise[2]	VR	VR[3]	MR	R	Sprightly, subacid, slightly aromatic and spicy, crisp, fine-grained juicy flesh, stores well	early Oct	Feb	Washed, 90% light to medium red
GoldRush[2]	VR	S	MR	S	Fruit very crisp, firm, tart at harvest and sweetens up after storage, very susceptible to black rot. Will store for 11 months.	mid-Oct	April	Deep yellow with red blush
Sundance[2]	VR	VR	VR	VR	Excellent quality with fruity flavor like mild pineapple, fruit does not drop	mid-Oct	March	Yellow, occasionally russet in stem cavity

AS = Apple Scab, CR = Cedar Apple Rust, FB = Fire Blight, PM = Powdery Mildew
VR = Very Resistant, R = Resistant, MR = Moderately Resistant, S = Susceptible, — = Insufficient Information
Note: All apples require cross-pollination by a different variety. Winesap and SirPrize cannot serve as pollinizers because they have sterile pollen.
1 Resistance to diseases other than scab has not been fully evaluated and may differ in some locations from that reported here.
2 Produces high-quality apples in Kentucky.
3 Although these cultivars are resistant to cedar apple rust, they are susceptible to cedar quince rust.

Table 22.4. Cherry varieties.

Sweet
Black Gold
Hedelfingen
Lapins
Sweetheart
Tart
Danube
Montmorency
North Star
Surefire

Table 22.5. Pear varieties.

European
Blake's Pride
Harrow Sweet
Honey Sweet
Kieffer
Magness
Potomac
Seckel
Asian
Chojuro
Korean Giant
Olympic
Megietsu
Shinko
Yoinashi

Table 22.6. Nectarine varieties.

Nectarines
Fantasia
Flavortop
Red Gold
Sunglo

Table 22.7. Peach varieties.

Maturity		
July	**August**	**September**
Gala	Allstar	Encore
Harrow Diamond	Biscoe	Flamin' Fury PF-27A
Garnet Beauty	Blushing Star (White)	Flameprince
Redhaven	Bounty	Laurol
Sentry	Contender	Ouachita Gold
Topaz	Coralstar	Victoria
	Cresthaven	
	Ernie's Choice	
	Glowing Star	
	John Boy	
	Loring	
	Madison	
	Redskin	
	Summer Breeze	

Table 22.8. Nut varieties.

Hazelnuts (filberts)*	Walnuts, Persian
Gamma	Allegheny
Jefferson	Coble No. 2
Santiam	Kaiser
Yamhill	
Walnut, Black	
Leon Pounds II	
Neel No. 1	
Rowher	
Sauber No. 1	
Surprise	
Thomas-Myers	

*Complete resistance to eastern filbert blight (EFB).
Note: Gamma, Santiam and Jefferson are good pollinators for the best variety, Yamhill.

Pollination Methods

Trees can be grouped into two categories: those that bear fruit through self-pollination (called *self-fruitful*) and those that must be pollinated by another variety (called *self-unfruitful*). Peaches tend to flower during spring when frosts and cold weather are still very common in Kentucky. Peach trees can be grown throughout the state but the peach crop is often diminished due to cold temperatures in spring. The somewhat milder climate of Western Kentucky makes this region better for backyard peach production.

Cherries

Lapins, Black Gold, and Sweetheart are self-fruitful sweet cherry varieties, as are tart (pie) cherries.

Some sweet cherries do not set fruit unless they are pollinized by another pollen-compatible variety. Hedelfingen is pollinated by Lapins or Sweetheart.

Apples

Some apple varieties, such as Rome Beauty, Newtown, and Transparent, are self-fruitful, but most varieties of apples do not set fruit unless they are pollinated by another pollen-compatible variety. Most apple varieties that don't set fruit when self-pollinated do have pollen that sets fruit on other varieties. For example, Red Delicious doesn't set its own fruit with its own pollen, but sets fruit on Golden Delicious, and vice versa. Gravenstein requires an early-blooming pollinizer such as Lodi, but does not produce good pollen for other varieties. Mutsu does not pollinize other varieties, but requires another variety to set fruit itself. McIntosh is self-unfruitful but pollinizes other early-blooming varieties such as Gravenstein.

Other Fruits

Most varieties of pears do not set fruit unless they are pollinated by another pollen-compatible variety.

Most European plums are self-fruitful.

See Table 22.8 for nut varieties.

Planting for Pollination

Plant pollen-compatible trees within 100 feet of each other to ensure adequate pollination, which depends mostly on bees and to a lesser extent on other insect activity. For nuts, pollination depends on wind. The bloom periods of the main and pollinizer varieties must overlap enough to provide at least several days for cross-pollination to take place. Orchards with many pollinizers are more fruitful than those with only one pollinizer.

If no pollinizing varieties are growing nearby, cut a bouquet of blooms from another variety and place it in a pail of water beside your tree while it is in bloom. Or, if you have a single fruit tree that needs a pollinizer, graft a compatible variety onto the main variety.

Tree Spacing

Apple trees typically are spaced from six feet apart (high density) to more than 20 feet apart. Spacing between rows for other fruit trees ranges from 12 to 24 feet because they often lack growth-controlling rootstocks.

True genetic dwarf trees can, of course, be planted closer. Dwarf trees trained on trellises have the closest spacing.

In planning your orchard, compare the amount of space available to the number of trees you want to grow. Spacing trees very close together does push them into earlier production, but tightly spaced trees require more pruning at an earlier age in order to keep them productive, and foliage does not dry out as rapidly, which can lead to more disease problems.

Planting and Fertilizing

Orchard trees grow best in deep, well-drained soils. To have adequate room for root development, trees need at least four feet of soil above an impenetrable soil layer or water table. In poor soil conditions, raised beds can be helpful. Always choose a spot that gets full sun.

Fruit trees usually are sold bare root. It's very important to plant a tree at the right level. Try to plant the tree at the same level at which it was growing in the nursery. Make sure the graft union is aboveground; if it is not, the rootstock will produce shoots that may overpower the grafted or budded stock. The scion (grafted variety) may also produce roots that lessen the effect of the rootstock.

Dig a hole large enough to comfortably accommodate the tree's root system. Don't leave smooth soil on the sides of the hole—roughen the sides with a shovel so the roots can grow into the soil. Place the roots over a low mound of soil in the hole.

Paint the trunk with a white, water-based indoor latex paint to reflect sunlight and help prevent sunburn. To save paint and make it easier to apply, you can dilute the paint with water to 50 or 70 percent paint. A tree protector placed around the trunk will protect it from damage from small animals and sunscald.

Protection from deer is important, too. Fencing is the best method, but caging also works. Hanging soap, human hair, animal scents, or other deer repellents will help prevent damage for only a short time.

A tree's need for fertilizer varies according to the amount of minerals available in the soil. Soil types vary within a specific area and regionally. For example, fruit trees generally don't need much phosphorus in the Central Kentucky area, but they respond to phosphorus applications in most other areas of the state. Consult your county Extension office for specific recommendations.

Fruit trees do need nitrogen. The amount needed varies from very little to two pounds of actual nitrogen per tree for fully mature trees. The best way to gauge nitrogen needs is to watch the amount of annual growth and check for yellowing of older leaves. If a tree has at least 12 to 18 inches of new growth each year, it is thriving. Overapplication of nitrogen may cause excessive tree growth as well as physiological problems in the fruit, such as bitter pit in apples.

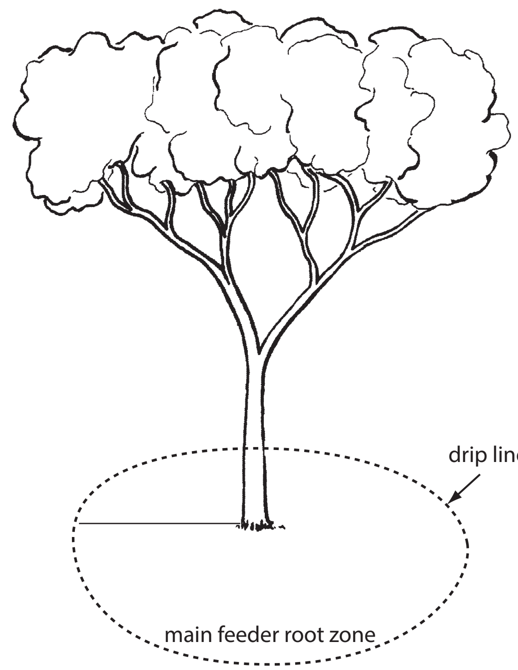

Figure 22.2. A tree's drip line.

Most gardeners use a complete fertilizer (one with nitrogen, phosphorus, and potassium) around the yard and vegetable garden. These fertilizers are fine for fruit trees, but if they are used every year, phosphorus and potassium levels build up far in excess of the tree's actual need.

Most home orchardists do not apply boron to their fruit trees. Although boron is needed only in small amounts (it is a micronutrient), it is essential for plant health and productivity, especially for fruit set. Trees that are low in boron have poor shoot growth and poor fruit set.

An easy source of boron is Borax. If you need to apply boron to a fruit tree, add a tablespoon of Borax to two gallons or more of water and apply it to the soil within the tree's drip line (Figure 22.2). If you think your soil has boron deficiency, it is best to have the soil analyzed before adding more. Too much boron is toxic to the trees.

Irrigating

The amount of water fruit trees need depends on rainfall and soil type. The best way to determine your trees' needs is to check the soil moisture in the root zone at 12 and 24 inches deep.

To test, remove some soil with a soil probe or shovel and squeeze a handful of it into a ball. If it crumbles when released, the trees are dry and need water. If the ball of soil stays together but does not feel wet, the trees have adequate moisture. If the soil ball drips water when squeezed, there is more than enough moisture.

Remember that young trees have an undeveloped root system and cannot absorb much water at a time. In warm weather, watering young trees regularly is very helpful to get them off to a good start.

Drip irrigation is preferred by many orchardists because it allows the foliage, flowers, and fruit to remain dry, an important factor in disease prevention. If you drip-irrigate, take care not to overwater, especially near the base of the trunk, where excessive moisture can lead to crown rot.

Fruit Thinning

Thinning of apples, peaches, and Asian and European pears is an important part of orchard management. It removes some of the developing embryos that otherwise would produce flowering inhibitors. It improves the size and quality of fruit and helps ensure an adequate crop the next year.

The effect of fruit thinning is greatest on cultivars that tend to have a heavy fruit set. Determine the size of fruit you want and thin accordingly.

There are three ways to thin fruit. Picking the tiny fruit or blossoms by hand is the most commonly used method. Mechanical thinning involves using a tool to knock fruit off the tree. Plant-growth regulators are sprayed onto apple and pear trees in commercial orchards during and after bloom to thin the crop.

Timing

Early thinning of blossoms or fruit helps stimulate flower initiation for the next year's crop, especially on cultivars that tend toward biennial bearing (bearing fruit every other year). Apples initiate flower buds for the following year's crop within 40 days of full bloom, so thinning has a positive effect on the next year's bloom if done within this period. Pears form buds a little later, so you can thin them within 60 days of full bloom. Attaining adequate return bloom on peaches is seldom a problem, but early thinning generally helps.

Thinning also helps increase the size of harvested fruit by stimulating cell division in the remaining fruit. More cell division means more cells per fruit and thus larger fruit. The period of cell division for apples lasts four to five weeks after petal fall. For peaches, it lasts four weeks after petal fall, and pears continue cell division for seven to nine weeks after petal fall. All fruits continue some cell division in the epidermis layer (the skin) much longer than in the main part of the fruit flesh.

Sometime during the cell-division phase, cell enlargement begins. Enlargement continues throughout the growth of the fruit and often is positively influenced by fruit thinning.

More information on the developmental stages of different fruit crops can be found in Figure 22.3.

How to Thin

Apples

Home orchardists generally thin by hand. With apples, remove the smaller fruit first, remembering that the relative sizes of the fruit do not change throughout the season and that the largest fruit early in the season will be the largest fruit at harvest.

Decide how much fruit to leave on the tree based on the vigor and general condition of the tree. In cultivars that tend toward biennial bearing (every two years), leaving every other spur without fruit and spacing fruit six inches apart helps ensure adequate return bloom.

Asian Pears

Asian pears must also be thinned. Thin early to get large fruit. Each blossom cluster contains several flowers. Save the blossom/fruit in the middle and remove the rest. Research has shown that this middle fruit is the roundest. By keeping that in mind and by counting the flowers as they appear starting from the base of the cluster, you can determine which fruit to remove. For example, if there are seven flowers, save the fourth fruit from the base of the cluster. Depending on the tree's vigor, you might experiment by leaving two fruits per spur and checking the fruit size response.

Peaches

Thin peaches to about six to eight inches from one another. This spacing gives them adequate room to mature to full size.

Harvest and Handling

Nursery catalogs, Cooperative Extension publications, and other sources give a general idea about when given varieties ripen. However, ripening times may vary from year to year depending on the weather. Keep in mind that apples with codling moth damage drop about one to one-and-a-half weeks before the crop is ripe.

The best and most time-tested method of judging when to pick fruit is the taste method. When enough starch has been converted to sugar and the flavor is developed, the fruit is ready to eat. Fruit continues to ripen in cold storage, so pick fruit before it is ripe if you intend to store it.

Fruit changes color as it ripens. The *base color*, or ground color, is the color underneath the red striping or blush of peaches, apples, pears, and cherries. In most fruits, the fruit is ripening when the ground color turns green to yellow. The surface color may develop before the fruit is actually mature.

If storing fruit, cool it as soon as possible after picking. The sooner heat is removed from freshly picked fruit, the longer the fruit will keep.

Handle fruit for storage gently. Bruises and wounds allow pathogens to infect the fruit, and disease will spread to adjacent fruits once it gets started.

	Apple	Pear	Peach	Tart Cherry	Plum and Prune
Stage **1**	**Dormant**	**Dormant**	**Dormant**	**Dormant**	**Dormant**
Stage **2**	**Silver tip** 10% kill 15° F 90% kill 2° F	**Swollen bud** 10% kill 15° F 90% kill 1° F	**Swollen bud** 10% kill 18° F 90% kill 2° F	**Bud burst** 10% kill 17° F 90% kill 5° F	**Swollen bud** 10% kill 14° F 90% kill 1° F
Stage **3**	**Green tip** 10% kill 18° F 90% kill 10° F	**Bud burst** 10% kill 20° F 90% kill 7° F	**Half-inch green** 10% kill 23° F 90% kill 5° F	**Green tip** 10% kill 25° F 90% kill 14° F	**Bud burst** 10% kill 18° F 90% kill 3° F
Stage **4**	**Half-inch green** 10% kill 23° F 90% kill 15° F	**Green cluster** 10% kill 26° F 90% kill 15° F	**Pink** 10% kill 25° F 90% kill 18° F	**Tight cluster** 10% kill 26° F 90% kill 17° F	**Green cluster** 10% kill 26° F 90% kill 16° F
Stage **5**	**Tight cluster** 10% kill 27° F 90% kill 21° F	**White bud** 10% kill 26° F 90% kill 22° F	**Bloom** 10% kill 27° F 90% kill 24° F	**Swollen bud** 10% kill 27° F 90% kill 24° F	**White bud** 10% kill 26° F 90% kill 21° F
Stage **6**	**Pink** 10% kill 28° F 90% kill 25° F	**Bloom** 10% kill 28° F 90% kill 23° F	**Petal fall** 10% kill 28° F 90% kill 25° F	**Bloom** 10% kill 28° F 90% kill 25° F	**Bloom** 10% kill 27° F 90% kill 23° F
Stage **7**	**Bloom** 10% kill 28° F 90% kill 25° F	**Petal fall** 10% kill 28° F 90% kill 24° F	**Fruit set: shucks on** 10% kill 28° F 90% kill 25° F	**Petal fall** 10% kill 28° F 90% kill 25° F	**Petal fall** 10% kill 28° F 90% kill 23° F
Stage **8**	**Petal fall** 10% kill 28° F 90% kill 25° F	**Fruit set** 10% kill 28° F 90% kill 24° F	**Fruit set: shucks off**	**Fruit set** 10% kill 28° F 90% kill 25° F	**Fruit set**
Stage **9**	**Fruit set** 10% kill 28° F 90% kill 25° F				

Figure 22.3. Phenology (growth development) stages of several fruit crops.

Insect and Disease Management

Many insect and disease problems can affect home orchards. You can control or prevent them by knowing the probability of such problems and by closely monitoring trees. Keep insects in check through a system called *integrated pest management* (IPM), which integrates cultural, mechanical, chemical, and biological controls in addition to taking the environment into consideration.

The IPM approach differs from a standard calendar approach, which uses dates and developmental stages of the plant to determine when to apply control sprays regardless of whether pests are present.

Successful IPM programs are based on solid research and practical experience. One of IPM's cornerstones is accurate pest monitoring. You can use visual inspection, trapping, and *phenology* models (crop development stage models) to determine the presence or absence of a pest and then measure its population density. Figure 22.3 shows growth stages of several tree fruits.

Economic thresholds are the level at which pest damage justifies the cost of control. Economic thresholds are important in IPM. Of course, economics are not as important in home orchards as in commercial situations. Each orchardist must decide how much damage to allow before applying a control. The level of damage considered acceptable can vary from one gardener to another.

Pheromones are chemical messengers used by animals to communicate with each other. Pheromones are used in IPM in the following ways:

- Female sex pheromones are used to attract males to a trap.
- Small pieces of glass or plastic containing female sex pheromones are spread throughout an area to confuse males.
- Pheromones are mixed with pesticides, such as an insecticide, to attract pests to the chemical control.

The UK Cooperative Extension publication *Kentucky Backyard Apple Integrated Pest Management Manual* (IPM-9) provides a more in-depth discussion of IPM.

Learning the life cycles of important insects and diseases that may attack your orchard is part of IPM. The next section discusses some of the more common orchard insect pests and their IPM-control strategies.

Codling Moth

Following are the stages in the life cycle of the codling moth, which typically produces three generations per year.

- It overwinters as a mature larva under loose bark on trees, in leaf litter under trees, or in other protected places.
- It pupates in spring and emerges as an adult in late May to early June.
- Adults begin depositing eggs two or three days after emergence and continue depositing eggs for a month.
- Eggs hatch in 12 to 14 days, and larvae enter fruit.
- Larvae feed for about three weeks then pupate in protected places.
- Second-generation adults emerge one to two weeks later, in early July.
- These adults lay eggs on fruit during July and August.
- Eggs hatch in six to seven days, and larvae enter fruit to feed.
- Larvae stay in fruit for a month then emerge and look for overwintering sites.

Pheromone-Trapping Program for Codling Moth

- Place traps in the orchard by mid-May.
- Place the traps along all sides of the orchard.
- Check the traps once per week through mid-September. Replace the lures every four weeks.
- If you want to use a threshold approach, apply an insecticide control 250 degree days, base 50°F, after you catch five moths per week in a trap.
- Follow spray recommendations for codling moth control listed in the UK Cooperative Extension publication *Disease and Insect Control Programs for Homegrown Fruit in Kentucky Including Organic Alternatives* (ID-21).
- If you want to use a calendar approach to control, spray 15 to 21 days after petal fall for the first generation and again two weeks later.
- For the second generation, spray the first week in July and again two weeks later.

Sprays for Disease and Insect Control

Dormant (Winter) Sprays

Most home orchardists try to control overwintering mites, aphids, and scales with a dormant (winter) oil spray, which essentially smothers the pests.

Winter sprays are also used to control diseases that enter the tree through the buds.

Follow two general rules when applying winter sprays on fruit trees:

- Use a *sticker*, unless the label says not to. Stickers improve the spray's adherence to leaves.
- Obtain good coverage. Timing and the choice of material are important, but if the spray doesn't cover the tree and stay in place, pests will not be controlled.

Peaches need winter sprays to control peach leaf curl and bacterial canker. For peach leaf curl, which causes reddish, twisted, distorted leaves, spray after leaf drop in the fall. Chlorothalonil or fixed coppers are effective.

Blossom Sprays

Ideally, blossom sprays should be applied at three stages: pink, full bloom, and petal fall (Figure 22.3). Use fungicides and insecticides listed in the UK Cooperative Extension publication *Disease and Insect Control Programs for Homegrown Fruit in Kentucky Including Organic Alternatives* (ID-21).

Cherries, peaches, and plums—Applying protective fungicide sprays before, during, and after the blossom period can control brown-rot blossom blight on cherries, peaches, and plums.

Brown-rot blossom blight is caused by fungi. These fungi overwinter on infected peach, plum, and cherry fruit (causing what's called "fruit mummies") and on buds and cankers. The fungal spores are spread mostly by wind but also by splashing rain.

The fungi infect blossoms, and from there they can travel into twigs to cause twig blight and cankers. They also infect fruit later in the season, entering maturing fruit more easily than green fruit.

Apples and pears—Blossom sprays can also control apple scab, cedar apple rust, and powdery mildew on apples and pears.

Apple scab must be controlled each year on most varieties. Scab infects leaves and fruit. It overwinters on leaves, so sanitation can help control the problem by removing sources of *inoculum* (fungal spores). Apply sprays at the prepink, pink, calyx, and first-cover stages.

Cedar apple rust must also be controlled annually on most apple varieties with sprays from pink through second cover.

Fire blight is a serious problem on susceptible apple and pear varieties. A final copper spray during the dormant period and streptomycin sprays during bloom are recommended.

Powdery mildew sprays are recommended for four stages: prepink, pink, calyx, and first-cover.

Summer Sprays

If an orchard has a mite, aphid, or scale problem, a dormant oil spray in winter can reduce populations of these insects. However, some summer control often is necessary.

Look for scale in June. The timing of summer control is important for these tiny insects. You must apply the spray when the insects are in the crawler stage, which is when the young scales move out from their protective shells and are vulnerable to pesticides.

Place double-sided sticky tape or black electrical tape with the sticky side out around infested branches. This traps the crawlers so you can see them with a hand lens (20-power is good). Spray when there is substantial insect activity.

Bagging

Bagging individual apples and pears on a tree when they are about an inch in diameter provides excellent insect and disease control for the rest of the season. See the *Apple Bagging Alternative Pest Management for Hobbyists* (ENTFACT-218) and the video *Apple Bagging* (VHO-1386). Both are available through county Extension offices.

Pruning

Pruning is a necessary part of home orchard care. Prune trees to direct growth, maintain health, and manage fruit-bearing potential. For a more complete discussion of pruning, see Chapter 17. The discussion here covers only guidelines specific to pruning fruit trees.

Fruiting Habits

Pruning strategy should take into account the fruiting habit of each tree. The type and age of wood that bears fruit varies with the kind of tree. Some fruits bear on more than one kind of wood. For example:

- Persian walnuts produce fruit on the *current season's shoots*.
- Hazelnuts, nectarines, and peaches produce fruit on the *previous season's shoots*.
- Sour cherries, some apples, and some pears produce fruit on the *previous season's spurs and shoots*.
- Some apples, sour cherries, sweet cherries, pears, and plums (European and Japanese) produce fruit on *long-lived spurs*.

Good light penetration is necessary for fruit spur formation and productivity, so trees that fruit on spurs should be maintained in a fairly open form. Those that form their crop on one-year-old wood (such as peaches and hazelnuts) benefit from pruning because it stimulates new wood formation (and more fruit).

Pruning Guidelines

- Prune all fruit and nut trees at planting time. Cut just above the height where you want the lowest branches to grow (usually 30 to 40 inches above the ground).
- Prune young trees very lightly; heavy pruning delays fruiting.
- Prune mature trees more heavily, especially if they have shown little growth.
- Prune the top portion of trees more heavily than the lower portion.
- Train young trees in the first few years after planting to avoid corrective pruning later. Spread main scaffolds to a 45° to 60° angle from the trunk.
- To keep trees small (unless they are dwarf trees), prune moderately every year and do not apply excess fertilizer, manure, or compost.
- Prune during the dormant season (after fall or early winter freezes, but before full bloom in spring).
- When removing large limbs, first cut partially through from the underside about six inches out from the collar, then make a second cut from the top a little farther out, cutting all the way through until the branch falls away. Finally, cut the stub back to the branch collar. Do not remove the branch collar.
- There is no need to paint pruning wounds. The best protection for a wound is to leave the branch collar intact so the tree is protected from wood-rotting fungi.

For More Information

UK Cooperative Extension publications

Fruit/General

Cultivar Evaluations of Apple, Peach, and Grape
Disease and Insect Control Programs for Homegrown Fruit in Kentucky Including Organic Alternatives (ID-21)
Dry Pesticide Rates for Hand-Held Sprayers (HO-83)
Fertility Guidelines for Home Fruit and Nut Plantings (HortFact-3004)
Fruit and Vegetable Insect and Disease Identification Picture Sheets
Fruit Insect-Pest Calendar for Kentucky
Home Composting: A Guide to Managing Yard Waste (HO-75)
Home Fruit Variety Recommendations (HortFact-3003)
Fruit and Nut Cultivar Nursery Sources (HortFact-3002)
Rootstocks for Kentucky Fruit Trees (HO-82)
Reproducing Fruit Trees by Graftage: Budding and Grafting (HO-39)

Nuts

European Red Mite (ENTFACT-205)
Nut Tree Growing in Kentucky (ID-77)
Nut Weevils (ENTFACT-206)
Pecan Insects (ENTFACT-210)

Tree Fruit

Apple Scab (PPA-24)
Bagging Apples: Alternative Pest Management for Hobbyists (ENTFACT-218)
Apple Cultivar Performance (HortFact-3006)
Cherry Fruit Flies (ENTFACT-217)
Codling Moth (ENTFACT-203)
Controlling Apple Insect Pests (ENTFACT-201)
European Red Mite (ENTFACT-205)
Fire Blight (PPA-34)
Green Fruitworms (ENTFACT-214)
Growing Peaches in Kentucky (HO-57)
Peach Fruit Diseases (PPFS-FR-T-09)
Kentucky Backyard Apple Integrated Pest Management Manual (IPM-9)
Leafhoppers on Apples (ENTFACT-215)
Leafrollers (ENTFACT-216)
Lesser Peachtree Borer (ENTFACT-213)
Oriental Fruit Moth (ENTFACT-212)
Peach Cultivar Performance (HO-6)
Peachtree Borer (ENTFACT-200)
Plum Curculio (ENTFACT-202)
Rosy Apple Aphid (ENTFACT-211)
Rust Diseases of Apple (PPA-23)
San Jose Scale (ENTFACT 204)
Training and Culture of Dwarf Apples Using the Vertical Axis System (HortFact-3501)

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