SUSTAINABLE HORTICULTURE FOR WYOMING

A MASTER GARDENER HANDBOOK

UNIVERSITY OF WYOMING EXTENSION

master gardener

About this handbook

The University of Wyoming Master Gardener Handbook is a basic gardening text, used as one component in master gardener training programs for Extension volunteers in Wyoming. It also is a useful resource book for any gardener in the Rocky Mountain west, covering topics in gardening, landscaping, and pest management.

The title "Master Gardener—University of Wyoming" is to be used only and exclusively in the University of Wyoming Cooperative Extension Service Master Gardener program, through which trained and certified master gardeners provide gardening information.

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Introduction: Sustainable Gardening

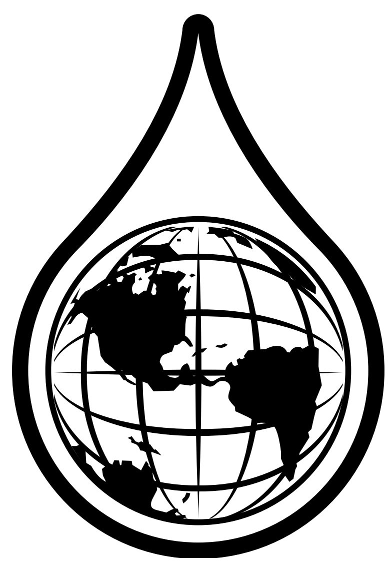
A thoughtful balance between resources used and results gained

Enjoyed by millions, gardening is among the most popular leisure activities in America and throughout the world. Gardening can contribute to your enjoyment and appreciation of nature, and how you garden can have a significant impact—both positive and negative—on your local and regional environment. As a result, gardeners are becoming more aware of environmental protection and improvement practices.

Sustainable gardening is a straightforward concept that requires only slightly more planning than conventional gardening. A sustainable garden is one that thrives with minimal inputs of labor, water, fertilizer, and pesticides. Sustainable gardening also may mean altering your perception of the "perfect garden." Lawns that are lush, green, and weed-free; plants with no insect damage; and unblemished fruit may be desirable, but they carry a price. Sustainable gardens achieve a balance between inputs and outcome.

You can do a number of things to reduce the inputs necessary to make your garden thrive. The first and most important concerns the soil. Starting with soil that has the correct pH, good drainage, adequate fertility, and few weeds is a critical first step in sustainable gardening. Research has shown that nearly 80 percent of plant problems are related to poor soil. Completing an initial soil test can give you guidance on how to improve your soil.

Selecting plant material adapted to your area is the next step. Choosing plants that are well suited to your yard's climate, light exposure, annual precipitation, and other environmental conditions helps ensure that your plants will grow well. Additionally, selecting species that are disease- and insect-resistant can drastically reduce your need for insecticides and fungicides.



By Ann Marie VanDerZanden, Extension master gardener state coordinator, Oregon State University. Adapted for Wyoming by Karen L. Panter, Extension horticulture specialist, University of Wyoming.

You can also incorporate resource conservation practices into your gardening repertoire. Composting pruned limbs, leaves, and other garden by-products is a good way to create a constant supply of nutrient-rich organic material. Incorporating this composted material into the soil not only improves soil fertility and drainage, but also reduces the burden that garden waste adds to landfills. Likewise, a mulching lawn mower keeps finely chopped clippings on the lawn, where they can decompose and return nutrients to the soil, at the same time eliminating the need to bag clippings and send them to a landfill.

Covering bare soil with mulch leads to many garden benefits. The mulch layer reduces soil water evaporation and runoff, thus allowing water to be used more efficiently. Reduced weed growth is another benefit. Suppressing weeds eliminates the need for herbicide applications and reduces the competition for water between weeds and desired plants. A mulch layer also can minimize fluctuations in soil temperature and reduce root damage from temperature extremes. Additionally, as organic mulches (such as bark chips and leaves) decompose, they add organic matter to the soil and improve soil fertility.

As the world population grows, the planet's natural resources face increasing stress. Contrary to popular perception, gardening methods do have implications beyond the backyard. If all gardeners, new and experienced, continue to adopt and refine the principles of sustainable gardening, they will further enhance the environment for people, plants, and wildlife. This book is designed to help you do just that.

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Botany Basics

1

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 structures. However, their internal structures and functions are often 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). These differences will be important in our discussion of plant growth and development.

Topics in this chapter

- Plant life cycles
- Internal plant parts
- External plant parts
- Plant growth and development
- Environmental factors affecting growth
- Plants in communities
- Plant hormones and growth regulators

By Ann Marie VanDerZanden, extension master gardener state coordinator, Oregon State University. Adapted for Wyoming by Karen L. Panter, Cooperative Extension Service horticulture specialist, University of Wyoming.

Table 1.—Comparison between monocots and dicots.

Structure	**Monocots**	**Dicots**
Seed leaves	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.
Floral parts	Usually in threes or multiples of three.	Usually in multiples of four or five.
Leaves	Often parallel veined.	Generally net veined.

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 that separates the xylem and phloem and continuously produces new xylem and phloem cells.

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

Chloroplast—A specialized component 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 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 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 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.

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 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 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.

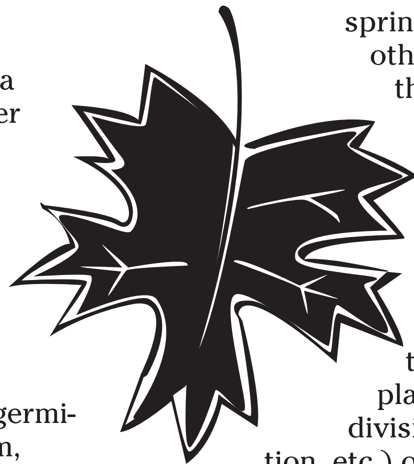
Turgor—Cellular water pressure; responsible for keeping cells firm.

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

Xylem—Water and nutrient-conducting tissue.

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 in controlling it.

A *biennial* requires all or part of two years 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, 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 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. For example, 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.

See Chapter 20, *Propagation*.

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, is controlled by a complex array of internal plant hormones but can also be influenced by environmental conditions. In many cases, meristems can be manipulated to make a plant do something 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 works together to perform a specific function. These structures can be divided into two groups: sexual reproductive and vegetative. *Sexual reproductive* parts produce seed; they include flower buds, flowers, fruit, and seeds. *Vegetative* parts (Figure 1) include roots, stems, shoot buds, and leaves; they are not directly involved in sexual reproduction. Vegetative parts are often used in asexual forms of reproduction such as cuttings, budding, or grafting.

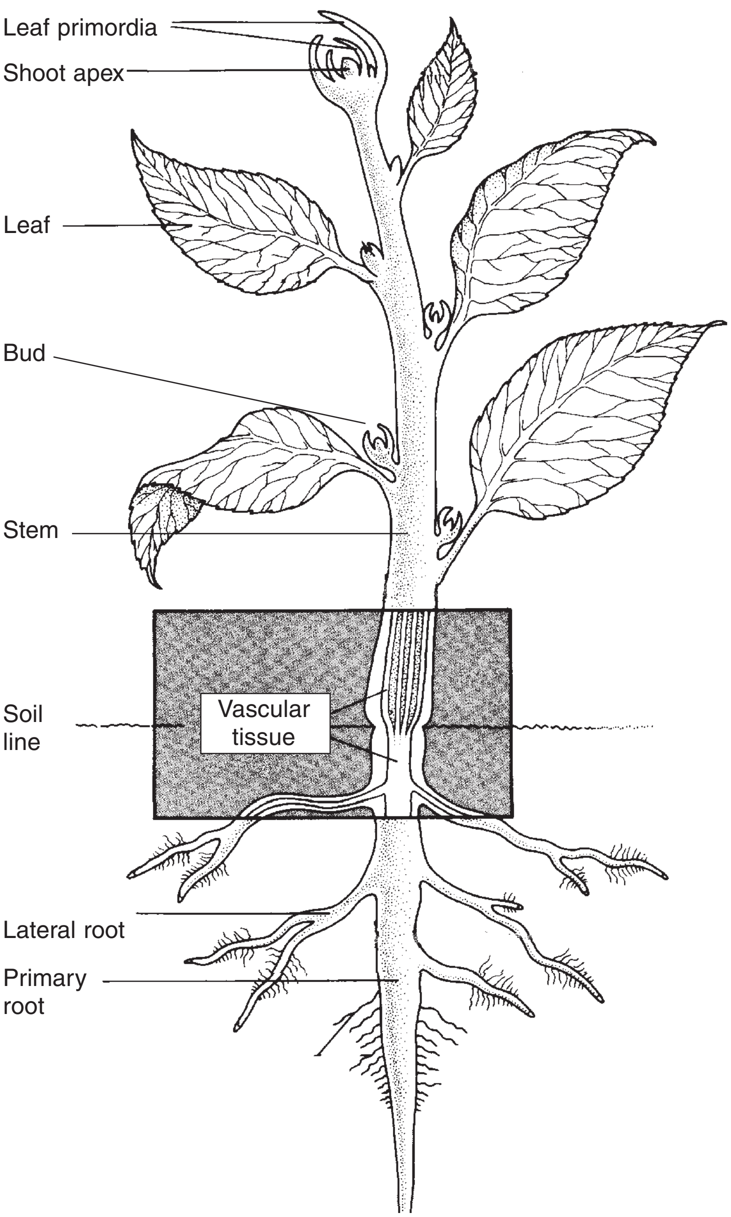


Figure 1.—Principal parts of a vascular plant. (Adapted by permission from Plant Physiology, *The Benjamin/Cummings Publishing Company, Inc., 1991.)*

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.

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 2):

- The *meristematic zone* is at the tip and manufactures 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.
- 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 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 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 certain fungi, which improves the plant's ability to absorb water and nutrients. This beneficial association is called *mycorrhizae* (fungus + root).

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 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 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 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

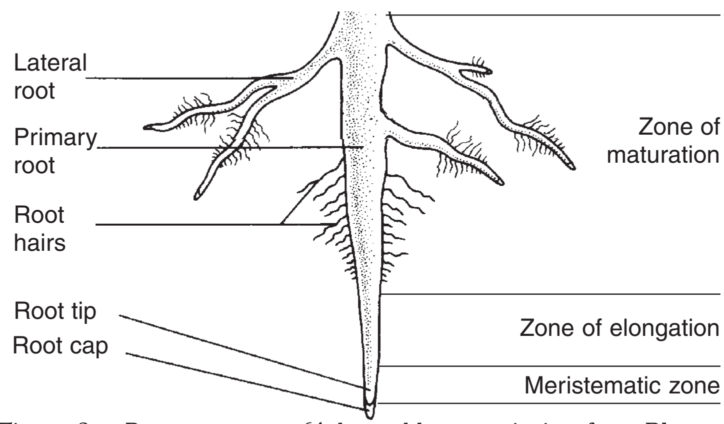


Figure 2.—Root structure. (Adapted by permission from Plant Physiology, *The Benjamin/Cummings Publishing Company, Inc., 1991.)*

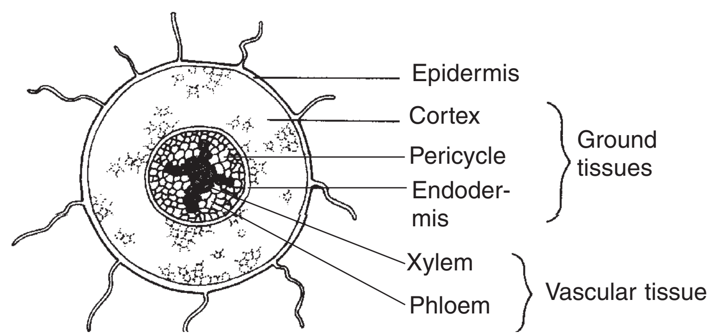


Figure 3.—Cross section of a root. (Adapted by permission from Plant Physiology, *The Benjamin/Cummings Publishing Company, Inc., 1991.)*

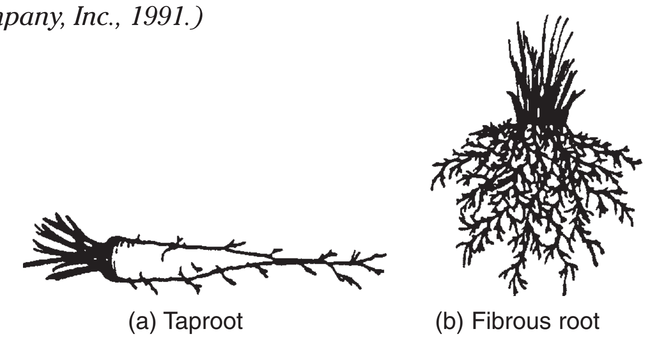


Figure 4.—Taproot of a carrot (a) and fibrous root of grass (b).

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:

See Chapter 2, *Soils and Fertilizers*.

- 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 are also susceptible to cold damage because the limited amount of soil surrounding their roots may not provide adequate insulation.
- In addition to growing downward, roots grow laterally and often extend well beyond a plant's dripline. Keep this extensive root system in mind when disturbing the soil around existing trees and shrubs.

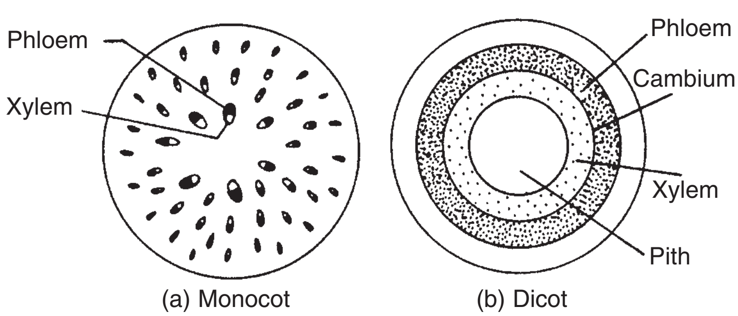


Figure 5.—Cross sections of stems: (a) Discontinuous vascular system of a monocot stem; (b) continuous vascular system of a woody dicot stem.

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 continuously 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. For example, the 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.

Stem terminology

Shoot—A young stem (1 year old or less) with leaves.

Twig—A young stem (1 year old or less) that is in the dormant winter stage (has no leaves).

Branch—A stem that is more than 1 year old, typically with lateral stems radiating from it.

Trunk—A woody plant's main stem.

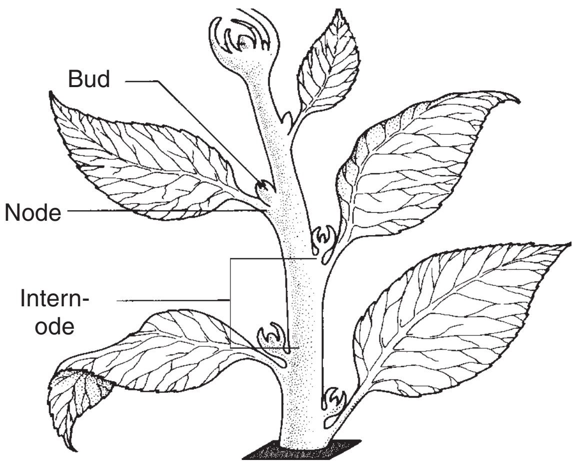


Figure 6.—Stem structure. (Adapted by permission from Plant Physiology, *The Benjamin/ Cummings Publishing Company, Inc., 1991.)*

The vascular systems of monocots and dicots differ (Figure 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 and eventually becomes part of the bark in mature woody stems. The xylem forms the inner ring. In woody plants, it is called the sapwood and heartwood.

The difference in the vascular systems of monocots and dicots is of practical interest to gardeners because some herbicides affect only one group. For example, 2,4-D kills only plants with a continuous vascular system (dicots). *Nonselective* herbicides, on the other hand (e.g., glyphosate), kill plants regardless of their type of vascular system.

Nodes

A node is an area on a stem where buds are located (Figure 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, 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.

See Chapter 16, *Pruning*.

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 house-plants 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.

Types of stems

Stems may be long with great dis-tances 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 above ground, they sometimes grow below ground in the form of rhizomes, tubers, corms, or bulbs. All stems must have buds or leaves to be classified as stem tissue.

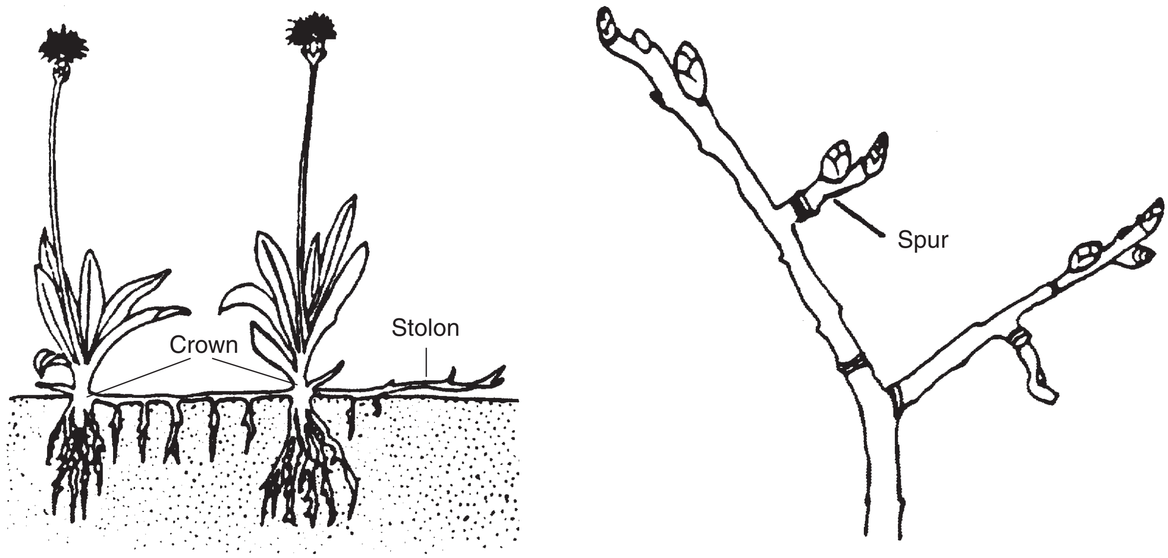


Figure 7.—Diversified above-ground stem development.

Specialized above-ground stems

Some plants have specialized above-ground stems known as crowns, spurs, or stolons (Figure 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 below-ground stems

Potato tubers, iris rhizomes, and tulip bulbs are underground stems that store food for the plant (Figure 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, it is important that each piece contain 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.

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). Quackgrass 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, one 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

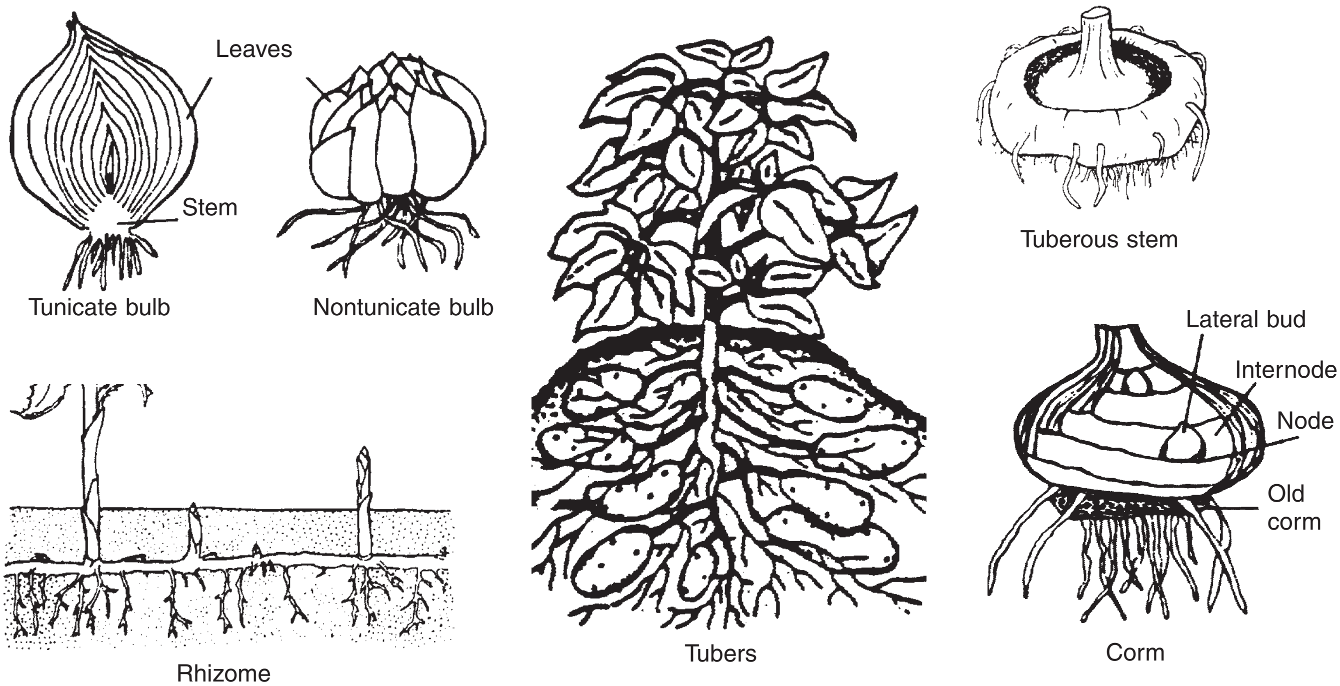


Figure 8.—Diversified below-ground stem development.

begins growing in the spring, it utilizes 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, they have finished producing the food that will be used for next year's flowering.

There are two types of bulbs: tunicate and nontunicate (Figure 8). *Tunicate* bulbs (e.g., daffodils, tulips, and onions) have a thin, papery covering which is actually a modified leaf. It helps protect the bulb from damage during digging and from drying out once it is out of the soil. *Nontunicate* (scaly) bulbs (e.g., lilies) do not have this papery covering. They are very susceptible to damage and drying out, so handle them very carefully.

Corms are another kind of below-ground 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, scale-like leaves. Gladiolus and crocuses produce corms.

Some plants (e.g., tuberous begonias and cyclamen) produce a modified underground stem called a *tuberous stem*. These stems are short, flat, and enlarged. Buds and shoots arise from the top (crown), and fibrous roots grow from the bottom.

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

Stems and propagation

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

See Chapter 20, *Propagation*.

Below-ground stems are also good propagative tissues. One can divide rhizomes into pieces, remove small bulblets or cormels from their 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 are usually 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* (the central strength-giving tissue). They usually live only one or two years. Examples of plants with canes include roses, grapes, and raspberries. For fruit production it is important to know which canes to prune, how to prune them, and when to prune them.

See Chapter 11, *Berry Crops*.

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 creeper).

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, 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.

A leaf bud is composed of a short stem with embryonic leaves. Leaf buds are often less plump and more pointed than flower buds (Figure 9).

A flower bud is composed of a short stem with embryonic flower parts. In the case of fruit crops, flower buds are sometimes 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.

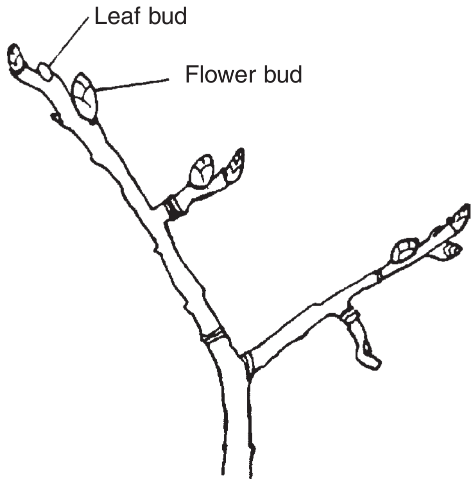


Figure 9.—Elm leaf and flower buds.

Location

Buds are named for their location on the stem (Figure 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.

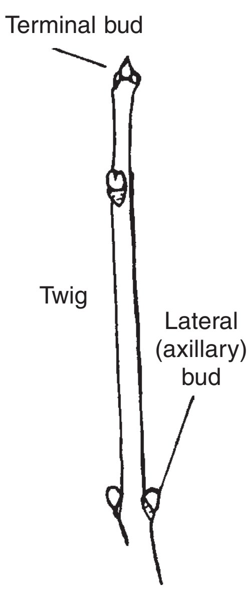


Figure 10.—Bud location.

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 artichokes, 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 is the expanded thin structure on either side of the midrib and is usually the largest, most conspicuous part of a leaf (Figure 11).

A leaf is held away from its stem by a stem-like 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.

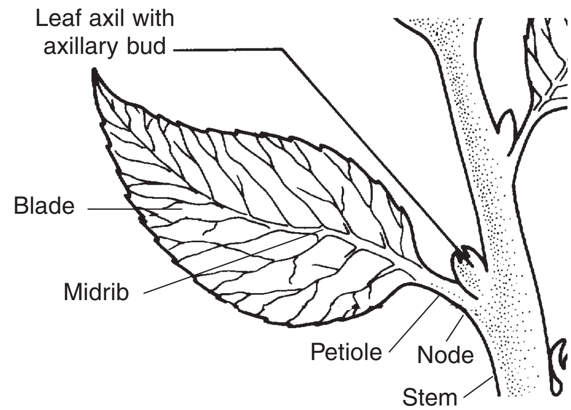


Figure 11.—Leaf parts. (Adapted by permission from Plant Physiology*, The Benjamin/Cummings Publishing Company, Inc., 1991.)*

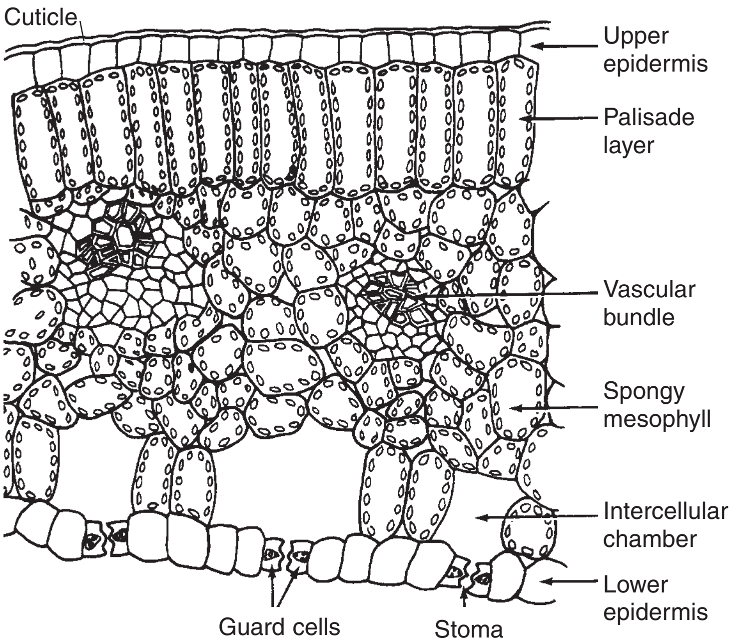


Figure 12.—Leaf cross section. (Reprinted by permission from Plant Science: Growth, Development, and Utilization of Cultivated Plants*, Prentice Hall, 1988.)*

A leaf blade is composed of several layers (Figure 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.

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 undersides 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.

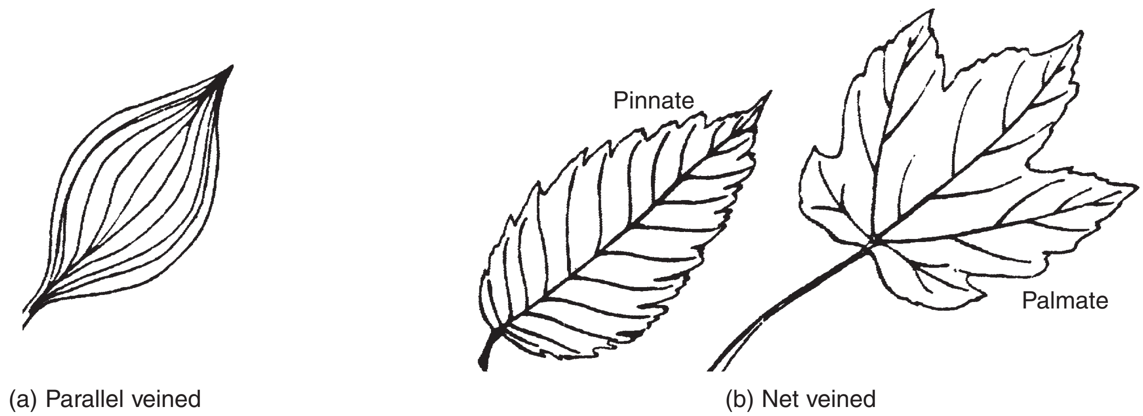


Figure 13.—Types of venation: (a) Parallel veined; (b) net veined.

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 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. Another type of parallel venation is found in plants such as banana, calla, and pickerelweed, whose veins run laterally from the midrib.

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* 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 14–16).

Leaf type (Figure 17) is also 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 is also used in plant identification (Figure 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.
- *Rosulate* leaves are arranged in a rosette around a stem with extremely short nodes.

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Leaves and plant identification

Common blade shapes (Figure 14)

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.

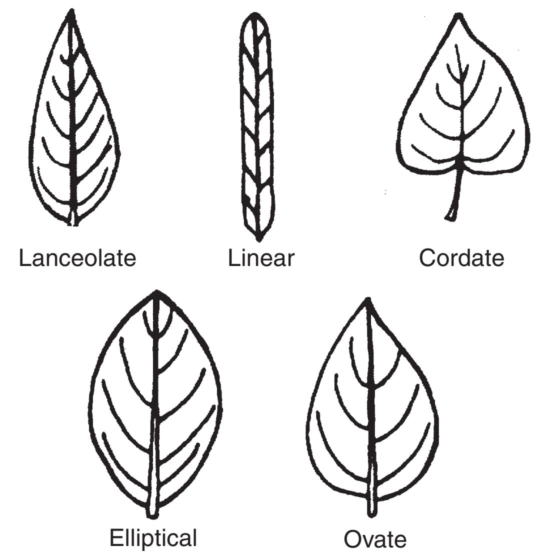

Figure 14.—Common leaf blade shapes.

Common margin forms (Figure 15)

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.

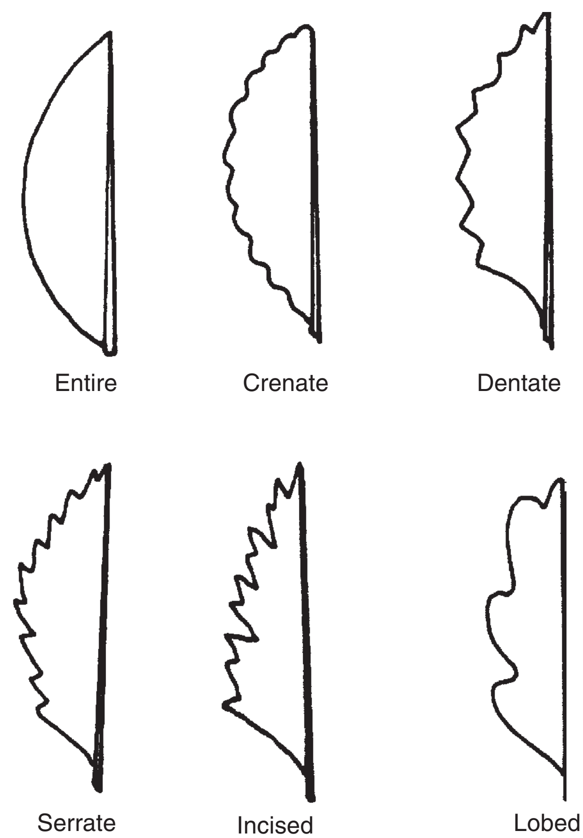

Figure 15.—Common leaf margin shapes.

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Leaves and plant identification (continued)

Common apex and base shapes (Figure 16)

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.

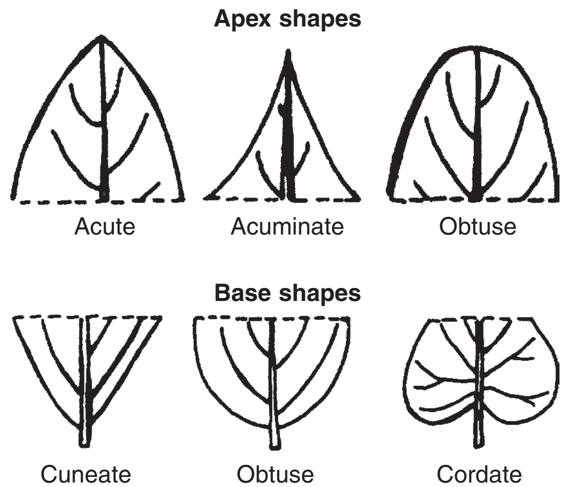


Figure 16.—Common leaf apex and base shapes.

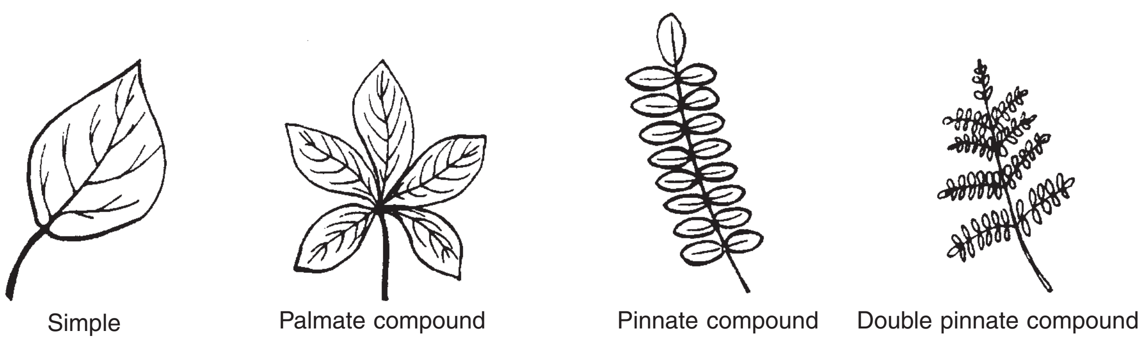


Figure 17.—Leaf types.

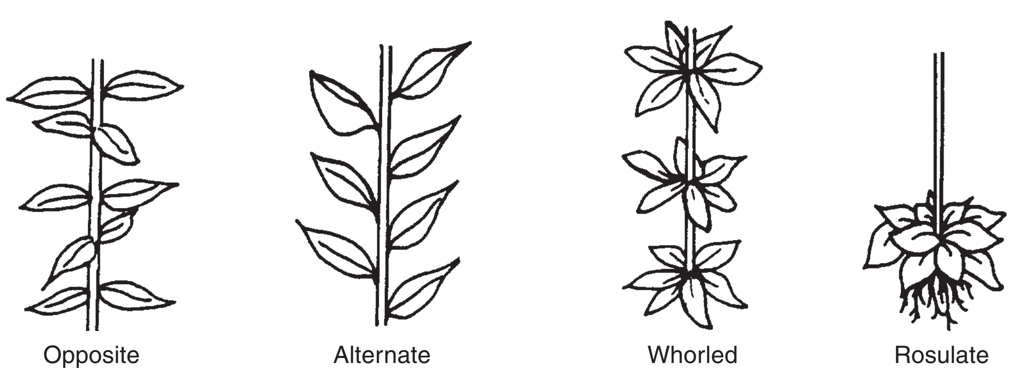


Figure 18.—Leaf arrangement.

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 or birds) that 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, a knowledge of flowers and their parts is essential for anyone interested in plant identification.

See Chapter 18, *Plant Identification.*

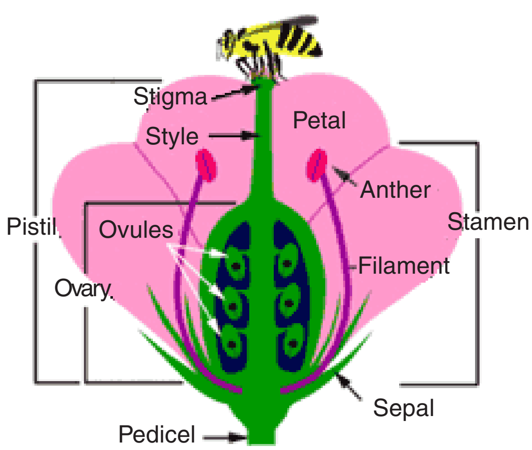


Figure 19.—Complete flower structure.

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 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 dispersement by wind, insects, or birds.

The *pistil* is a plant's female part. It is generally 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 are generally the highly colored portions of a flower. Like nectar glands, petals may contain perfume. Collectively, the petals are called a *corolla*. The number of petals on a flower is often 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 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 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 separate male and female flowers on the same plant (e.g., corn and spruce). 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 Kentucky coffeetree and cottonwood. In order to set fruit, male and female plants must be planted close enough together for pollination to occur. In some instances (e.g., coffeetree) the fruit may be desirable. In the case of cottonwoods, however, the fruit is not desirable due to its messy, cottony nature. Honeylocusts are complicated because they may have one plant with bisexual flowers and another plant with only male flowers. The plant world doesn't always have 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

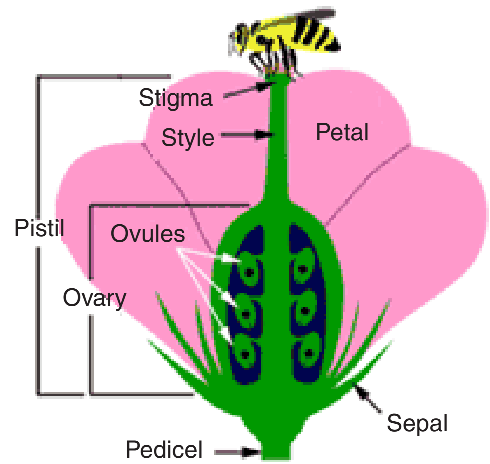


Figure 20.—Imperfect (pistillate) flower structure.

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.

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. Cross-pollinated plants usually are more successful than self-pollinated plants. Consequently, more plants reproduce by cross-pollination than by self-pollination.

Fruit

Structure

Fruit consists of fertilized, mature ovules (seeds) plus the ovary wall, which may be fleshy, as in an apple, or dry and hard, as in an acorn. In some fruits, the seeds are enclosed within the ovary (e.g., apples, peaches, oranges, squash, and cucumbers). In others, seeds are situated on the outside of fruit tissue (e.g., corn and strawberries).

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 21). *Simple* fruits develop from a single ovary. They include fleshy fruits such as cherries and peaches (drupes), pears and apples (pomes), and tomatoes (berries). Although generally referred to as a vegetable, tomatoes are technically a fruit because they develop 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 (legumes), poppies (capsules), maples (samaras), and walnuts (nuts).

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

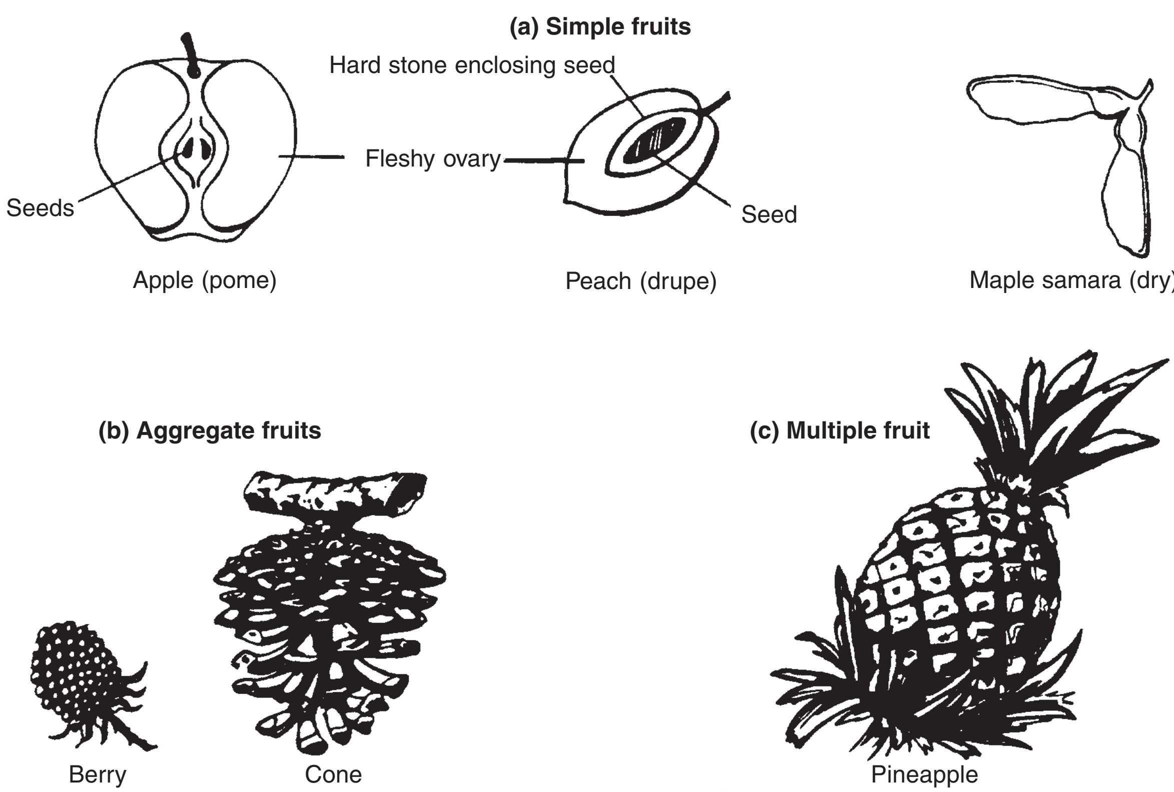


Figure 21.—Types of fruit: (a) Simple fruits (apple, peach, and maple); (b) aggregate fruits (berry and cone); (c) multiple fruit (pineapple).

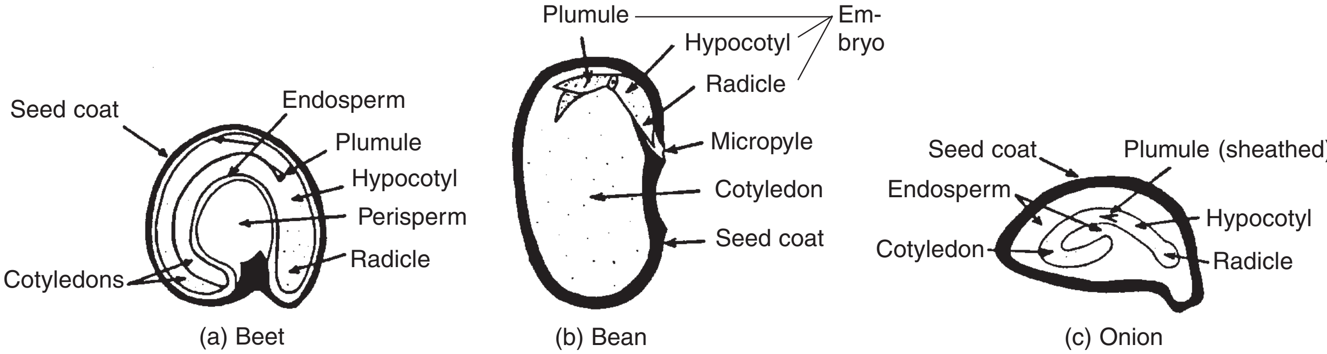


Figure 22.—Parts of a seed: (a) beet; (b) bean; (c) onion.

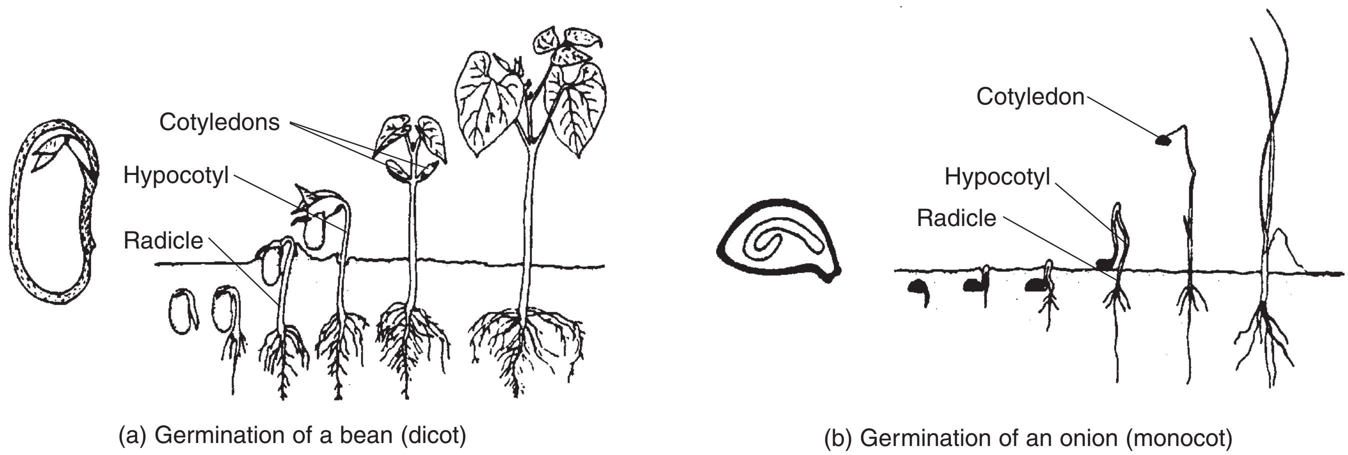


Figure 23.—Germination of a dicot (a) and a monocot (b).

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.

Seeds

A seed contains all of the genetic information needed to develop into an entire plant. It is made up of three parts (Figure 22):

- 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) 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 also prevents 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 23). Before any visible signs of germination appear, the seed must absorb water through its seed coat. It must also 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 leaf-like structure is the *hypocotyl*, which grows upward in response to light.

The seed leaves or *cotyledons* encase the embryo. They are usually shaped differently from the leaves the mature plant will produce. 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 their 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. Species rose, locust, and many other ornamental trees and shrubs exhibit this type of dormancy.

See Chapter 20, *Propagation*.

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. It 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 penstemon. 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° 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 is generally less viable than young seed, and if it 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.
- Seeds must be planted at the proper depth. If they are too shallow, they may wash away with rain or watering; if too deep, they won't be able to push through the soil.
- Seeds must have a continual supply of moisture; however, if over watered, 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 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. During photosynthesis, it splits carbon dioxide into carbon and oxygen, adds water, and forms carbohydrates (starches and sugars). Oxygen is a by-product.

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, or builds them into complex energy compounds such as oils and proteins. All of these food products are called *photosynthates*. The plant uses them when light is limited 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 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.

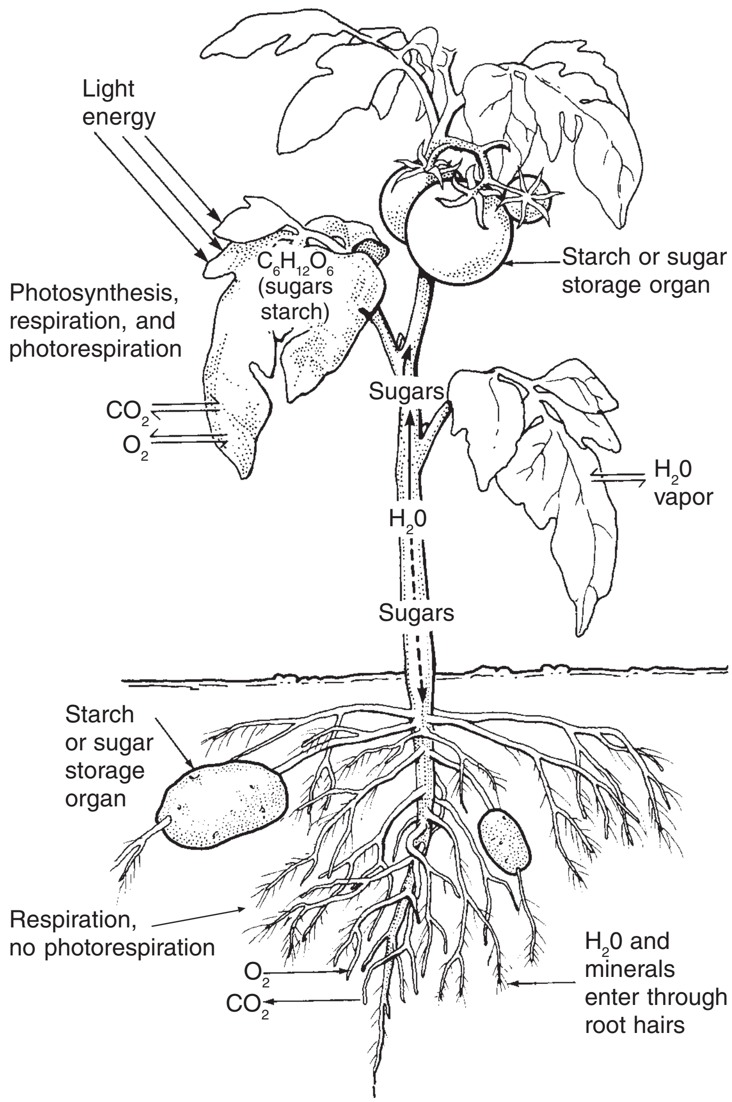


Figure 24.—Schematic representation of photosynthesis, respiration, leaf water exchange, and translocation of sugar (photosynthate) in a plant. (Reprinted by permission from Plant Science: Growth, Development, and Utilization of Cultivated Plants*, Prentice Hall, 1988.)*

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 only a 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.

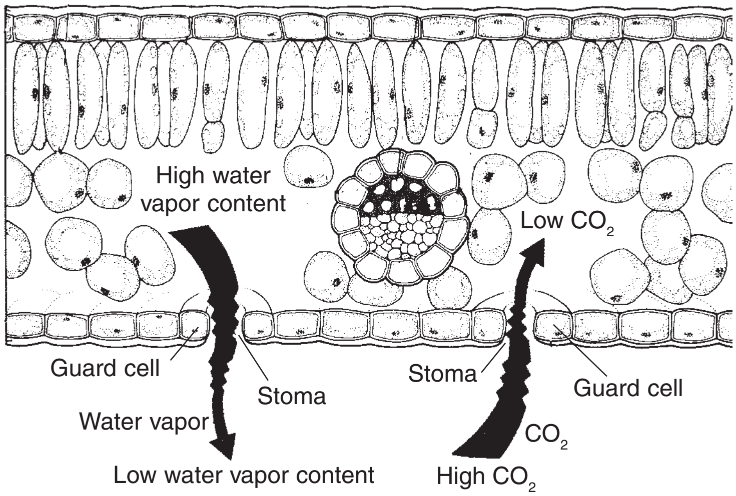


Figure 25.—Stomata open to allow carbon dioxide (CO_2) to enter a leaf and water vapor to leave. (Reprinted by permission from Plant Physiology, *The Benjamin/Cummings Publishing Company, Inc., 1991.)*

Carbon dioxide

Photosynthesis also requires carbon dioxide (CO_2), which enters a plant through its stomata (Figure 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 generate 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° and 85°F and decreases at higher or lower temperatures.

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:

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

This equation is essentially the opposite of photosynthesis. Photosynthesis is a building process while respiration is a breaking-down process (Table 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.

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

Table 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

transpiration stream is responsible for several things:

- Transporting minerals from the soil throughout the plant.
- Cooling the plant through evaporation.
- Moving sugars and plant chemicals.
- Maintaining cell firmness.

The amount and rate of water loss depends on factors such as temperature, humidity, and wind or air movement. Transpiration is often greatest in hot, dry (low relative humidity), windy weather.

A balancing act

In order for a plant to grow and develop properly, it must balance photosynthesis, respiration, and transpiration. Left to their own devices, plants do a good job of managing this intricate balance. If a plant photosynthesizes at a high rate but its respiration rate is not high enough to break down the photosynthates produced, photosynthesis will either slow down or stop. On the other hand, if respiration is much more rapid than photosynthesis, the plant won't have adequate photosynthates to produce energy for growth. Hence, growth will either slow down or stop altogether.

When stomata are open, transpiration occurs, sometimes at a very high rate. A corn plant may transpire 50 gallons of water per season, but a large tree may move 100 gallons per day! Plants have problems if they lose too much water, so stomata close during hot, dry periods when transpiration is highest. However, CO_2, which is needed for photosynthesis, also enters the plant through open stomata. Thus, if stomata stay closed a long time to stop water loss, not enough CO_2 will enter for photosynthesis. As a result, photosynthesis and respiration will slow down, in turn reducing plant growth.

Many herb plants produce lots of high-energy oils which help them survive in the dry landscapes where they evolved. These oils help them survive extended periods of stomatal closure.

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, people may be able to manipulate plants to meet their needs, whether for increased leaf, flower, or fruit production. By recognizing the roles of these factors, people will also be better able to diagnose plant problems caused by environmental stress.

See Chapter 13, *Diagnosing Problems*.

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 and the minimum in winter. Up to a point, the more sunlight a plant receives, the greater its capacity for producing food via photosynthesis.

One 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 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.

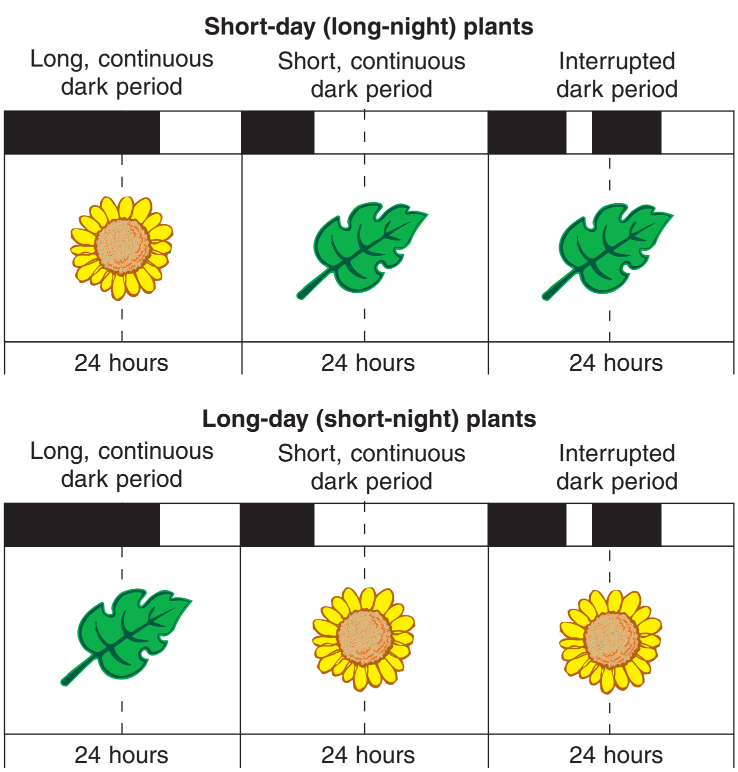


Figure 26.—Periodicity of plants. Short-day (long-night) plants require a long period of uninterrupted darkness to flower. Long-day (short-night) plants require a short period of uninterrupted darkness to flower.

Duration

Duration or *photoperiod* refers to the amount of time a plant is exposed to light. Photoperiod controls flowering in many plants (Figure 26). Scientists initially thought the length of the light period triggered flowering and other responses within plants. Thus, they describe plants as short day or long day, depending on what conditions they flower under. We now know 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 about 12 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 12 hours. 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.

One can easily manipulate photoperiod to stimulate flowering. For example, chrysanthemums normally flower in the short days of spring or fall, but one can get them to bloom in midsummer by covering them with a cloth that completely blocks out light for 12 hours each day. After several weeks of this treatment, the artificial dark period is no longer needed, and the plants will bloom as if it were spring or fall. This method is also used to make poinsettias flower in time for Christmas.

To bring a long-day plant into flower when day length is less than 12 hours, expose the plant to supplemental light. After a few weeks, flower buds will form.

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° to 65°F while warm-season crops (e.g., tomatoes, petunias, and lobelias) germinate best at 65° to 75°F.

See Chapter 10, *Vegetables*.

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 26). To encourage a Christmas cactus to bloom, place it in a room with more than 12 hours of darkness each day and a temperature of 50° 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° and 45°F before breaking their rest period and beginning growth. Lilies need six weeks of temperatures at or slightly below 40°F before blooming.

Daffodils can be forced to flower by storing the bulbs at 35° to 40°F in October. The cold temperature allows the bulbs to mature. When transferred to a greenhouse in midwinter, they begin to grow, and flowers are ready to cut in three to four weeks.

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.

See Chapter 7, *Woody Plants*.

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 are normally hardy to 10°F may be killed if they are in containers and the roots are exposed to 20°F.

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 then turn brown. To minimize the risk of this type of injury, make sure plants go into the winter well watered.

Water and humidity

Most growing plants contain about 90 percent water. Water plays many roles in plants. It is:

- A primary component in photosynthesis and respiration
- Responsible for *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
- Responsible 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 4 grams of water vapor, and there are only 3 grams of water in the air, then the relative humidity (RH) is:

3 ÷ 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 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 is usually 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.

Plant nutrition

Plant nutrition is often 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.

See Chapter 2, *Soils and Fertilizers,* and Chapter 10, *Vegetables*.

Plants need 17 elements for normal growth. Three of them—carbon, hydrogen, and oxygen—are found in air and water. The rest are found in the soil.

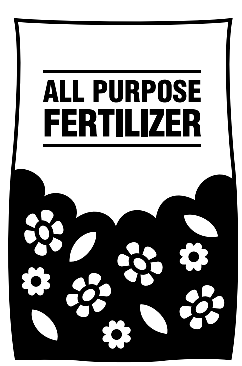
Three soil elements are called *primary nutrients* because they are used in relatively large amounts by plants. They are nitrogen, phosphorus, and potassium. Calcium, magnesium, and sulfur are called *secondary nutrients* because they are used in moderate amounts. Often, primary and secondary nutrients are collectively called *macronutrients* (Table 3).

Eight other soil elements are used in much smaller amounts and are called *micronutrients* or trace elements (Table 4). They are iron, boron, zinc, copper, manganese, molybdenum, chlorine, and nickel.

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.

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Table 3.—Plant macronutrients.

Element	Absorbed as	Leachability in soil/ 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. 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 when 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 can also be absorbed by leaves if sprayed in a weak solution. Dolomitic limestone can be applied in outdoor situations to correct a deficiency.

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Table 3.—Plant macronutrients (continued).

Element	**Absorbed as**	**Leachability in soil/ Mobility in plants**	**Signs of excess**	**Signs of deficiency**	**Notes**
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 is rarely 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 is usually in the form of air pollution.	General yellowing of affected leaves or the entire plant.	S is often 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 4.—Plant micronutrients.

Element	**Absorbed as**	**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.	
Nickel (Ni)	Ni	Darkening of leaf	Unlikely in most soils chlorosis in younger leaves	

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.

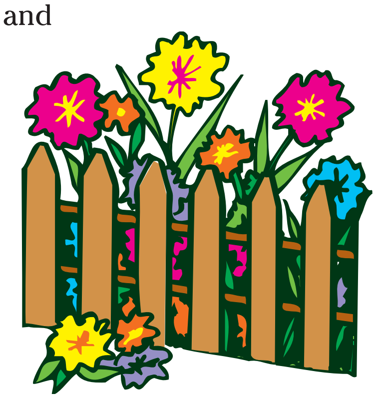
A plant's developmental stage or rate of growth also may affect the amount of nutrients absorbed. Many plants have a rest (dormant) period during part of the year. During this time, few nutrients are absorbed. Plants may also absorb different nutrients as flower buds begin to develop than they do during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

Plants in communities

The preceding discussion focused on the structure and physiology of individual plants. Interactions among plants are also 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 is often 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.



See Chapter 22, *Landscape Design*, Chapter 8, *Lawns,* and Chapter 5, *Weeds.*

As trees and shrubs grow and mature, one 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 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 is also a changing landscape. It starts out as a mix of several adapted grass species on bare ground. Other plants (which are often called weeds) sprout from seed reserves in the soil. Additional seeds and plants move in and grow if conditions are right. One competitive lawn weed is a grass called annual bluegrass. It prospers when desired grasses are less vigorous. Broadleaf weeds may also find niches. These changes are another example of plant succession.

To manage invasive plants, keep lawn grasses competitive by using proper cultural practices, periodically overseeding, and using herbicides in certain situations. In spite of one's 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 like an herbicide does 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 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 they may be natural hormones that were extracted from plant tissue (e.g., IAA).

Table 5.—Common growth-affecting materials.

Compound	**Effect/Use**
Hormones	
Gibberellic acid (GA)	Stimulates cell division and elongation, breaks dormancy, speeds germination.
Ethylene gas (C_2H_4)	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 (B-9, 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.

Applied concentrations of these substances are usually measured in parts per million (ppm) and in some cases parts per billion (ppb). These growth-regulating substances are most often 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; one 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 are often 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 are also 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 is often 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 trees. Ethylene is also 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.

For more information

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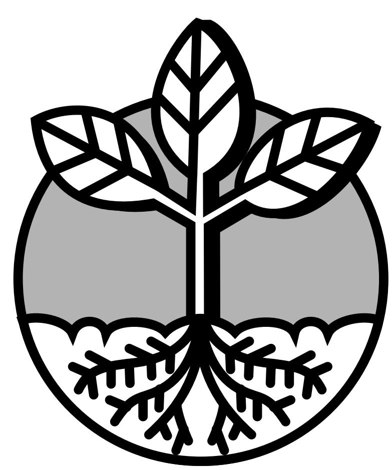

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Soils and Fertilizers

2

Soil is a mixture of weathered rock fragments 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 5 feet or more. Soil is roughly 50 percent pore space. 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.

Topics in this chapter

- Soil and water
- Soil organisms
- Soil nutrients
- Understanding fertilizers
- How much fertilizer to use
- When to fertilize
- Adding organic matter
- Soil pH
- Soil salinity

Soil and water

Soil pores, water, and productivity

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 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. Thus, 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

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Soils and fertilizers 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 mm 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 that involves 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.

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

Cover crop—A crop that is dug into the soil to return organic matter and nitrogen to the soil. Also called green manure.

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) is always listed first, phosphorus (P) second, and potassium (K) third.

Green manure—Same as 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 end product of decomposed animal or vegetable 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 include earthworm and root channels and control a soil's permeability and aeration.

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

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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 their ability to take up nutrients from the soil.

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 matter—Any material originating from a living organism (peat moss, compost, ground bark, manure, etc.).

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).

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 mm 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 mm in diameter).

Slow-release fertilizer—A fertilizer material that must be converted into a plant-available form by soil microorganisms.

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.

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 while 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 warm up in the spring. Runoff of rainfall and irrigation water is also more likely on these soils.

What affects soil porosity?

Several soil properties affect porosity including texture, structure, compaction, and organic matter. One can evaluate garden soil with respect to these properties to understand how they affect its porosity. The only tools needed are eyes and fingers and a shovel.

Soil texture

Texture describes how coarse or fine a soil is. 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 1).

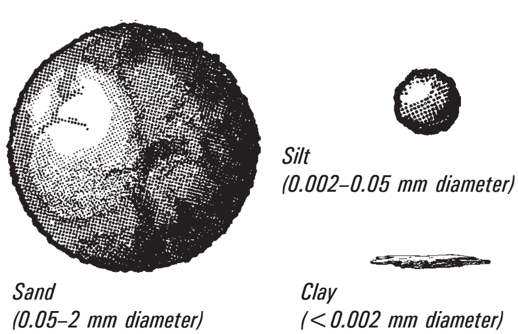


Figure 1.—Shapes of soil particles.

Clay particles are the smallest—about the size of bacteria and viruses—and can only be seen with a microscope. They typically have a flat shape, similar to a sheet of mica. Soils rich 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.

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

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

Nearly all soils contain a mixture of particle sizes and have a pore network containing a mixture of pore sizes (Figure 2). A soil with roughly equal influence from sand, silt, and clay particles is called a *loam*. Loams usually make good agricultural and garden soils because they have a balance of macropores and micropores. Thus, they usually have good water-holding capacity and moderate permeability.

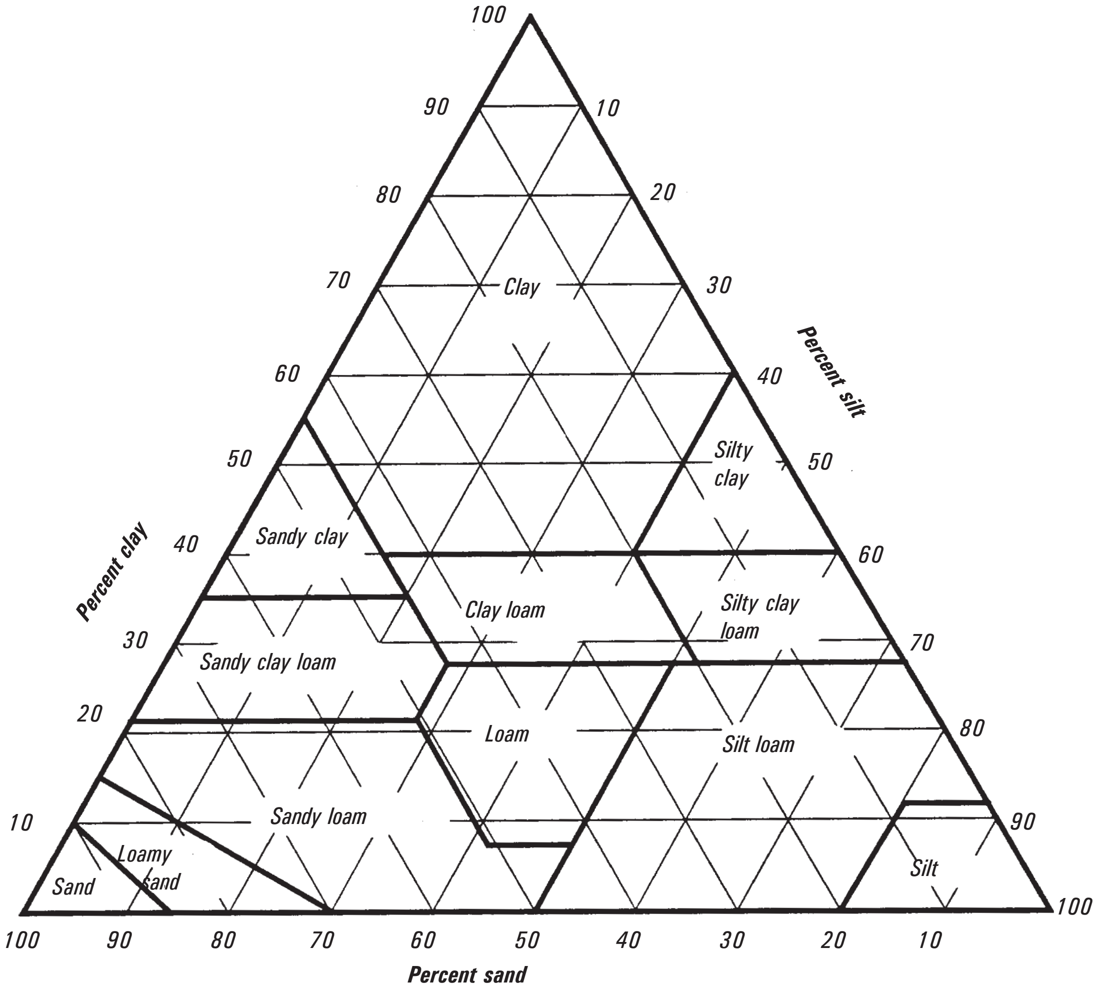


Figure 2.—Percentages of clay, silt, and sand in the basic soil textural classes.

A sandy loam is similar to a loam except that it contains more sand. It feels gritty yet has enough silt and clay to hold together in one's 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.

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 high water-holding capacity and low permeability.

Almost any texture of soil can be suitable for gardening as long as the gardener is aware of the soil's limitations and adjusts management techniques 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 one can plant them earlier in the spring. All soils can benefit from additions of organic matter as described below under "Adding organic matter."

Many soils contain coarse fragments, i.e., gravel and rocks. Coarse fragments do not contribute to a soil's productivity and can be a nuisance when digging.

Don't feel compelled to remove them all from the garden. Coarse fragments aren't harmful, and time is better spent doing other gardening tasks. The only time rocks are a problem is when there is nothing but rocks on the land. Then, water and nutrient-holding capacities are so low that it is difficult to grow healthy plants.

Soil 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 the recharge 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 downward through the macropores. Good structure is especially important in medium to fine-textured soils because it increases the soil's macroporosity, thus improving permeability and drainage.

Compaction and loss of structure

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

Compaction squeezes macropores into micropores and creates horizontal aggregates that resist root penetration and water movement (Figure 3). Compaction often occurs during site preparation or house construction, creating a difficult environment for establishing plants. Protect soil from compaction by avoiding unnecessary foot or machine traffic.

Tilling when soil is too wet also damages soil structure. If one can mold a piece of soil into a small wire or worm, it is too wet to till. If the soil crumbles, it is dry enough to till. Structural damage caused by human activity is usually most severe within the top foot of soil and can be overcome by proper soil management.

Organic matter

Adding organic matter is the best way to improve the environment for plants in nearly all soils. Organic matter helps build and stabilize soil structure in fine-

Figure 3.—Compacted soil resists root penetration and water movement.

textured and compacted soils, thus improving permeability and aeration and reducing the risk of runoff and erosion. When organic matter decomposes, it forms *humus*, which acts as a natural glue to bind and strengthen soil aggregates. Organic matter also helps sandy soils hold water and nutrients. See “Adding organic matter” later in this chapter for information on amending soil with organic matter.

Slope, aspect, depth, and water

Slope, *aspect* (direction of exposure), and soil depth affect water availability and use in a soil. Choose plants that are best suited to conditions on the property.

Ridgetops and side slopes tend to shed water while soils at the bottoms of slopes and in low areas collect water (Figure 4). Often, soils that collect water have high winter water tables which can affect the health of some plants. Soils on ridgetops are more likely to be droughty.

Site aspect is also important. South and southwest-facing exposures 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 soil volume available to roots is smaller. Dig below the topsoil in the garden. The deeper one can dig before hitting a restrictive layer, the greater the soil volume for holding water.

Water management in a garden

Soils and irrigation

Most gardens in Wyoming require summer irrigation. The need for irrigation varies, depending on soil water-holding capacity, weather, site aspect, the plants grown, and their 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, 1 inch of irrigation water is all that is needed. Any more will *leach* (move downward) through the root zone, carrying nutrients with it. A silt loam or clay soil can hold more than 2 inches of water, but one may need to irrigate more slowly to prevent runoff.

Wet soils

If the soil stays wet in the spring, 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 is probably well drained and has few wetness problems. Gray subsoils, especially those with brightly colored mottles, are often wet. If the soil is gray and mottled directly beneath the topsoil, it is probably saturated during the wet season.

Sometimes, simple actions can reduce soil wetness problems. For example:

- Divert runoff from roof drains away from the garden.

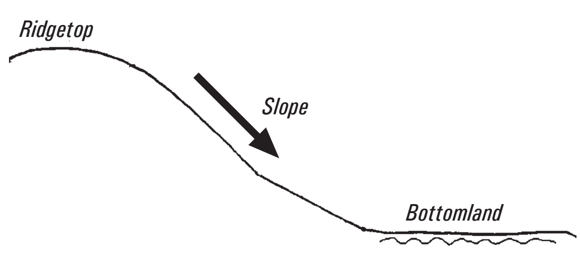


Figure 4.—Ridgetops and slopes tend to shed water while soils at the bottoms of slopes and in low areas collect water.

- 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. Installing drainage can be expensive, however. When considering drainage, make sure there is a place to drain the water. Check with local regulatory agencies to see whether there are restrictions on the project.

Soil organisms

Soil abounds with life. Besides the plant roots, earthworms, insects, and other creatures one can see, soil is home to an abundant and diverse population of microorganisms. A single gram of topsoil (about ¼ teaspoon) can contain as many as a billion microorganisms (Table 1). Microorganisms are most abundant in the *rhizosphere*—the thin layer of soil surrounding plant roots.

Table 1.—Approximate abundance of micro-organisms in agricultural topsoil.

Organism	**Number per 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

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 5). Mammals such as moles and voles are also part of the food web, feeding on insects and earthworms.

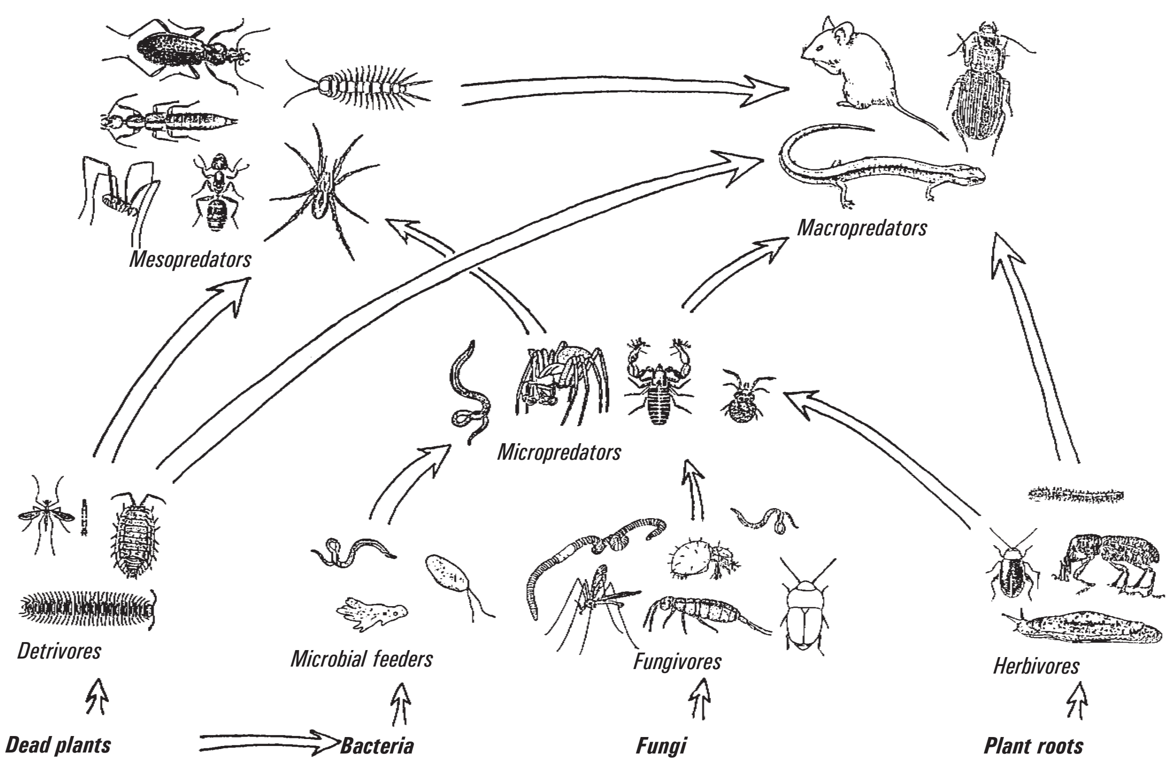


Figure 5.—The soil food web.

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 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 6).

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 Wyoming 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° and 100°F while earthworms are most active and abundant at about 50°F. Most organisms prefer moist soil. Because organic matter is at the base of the soil food web, soils with more organic matter tend to have more organisms.

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.

Soil nutrients

Soil supplies 14 essential plant nutrients that play one or more specific roles in plants. Nitrogen, 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 large amount 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.

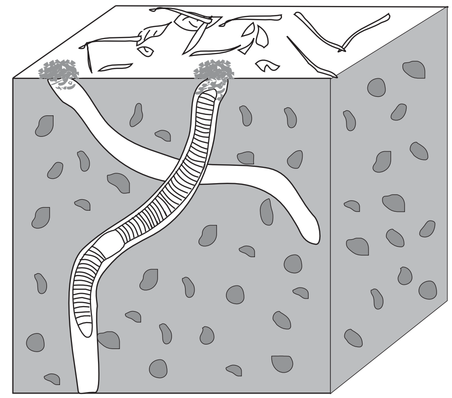


Figure 6.—Earthworm channels create macropores, which improve a soil's permeability and aeration.

See Chapter 1, *Botany*.

A soil nutrient is classified as a *primary nutrient*, *secondary nutrient*, or *micronutrient*, based on the amount needed by plants (Table 2). If a soil's nutrient supply is deficient, fertilizers can provide the additional nutrients needed for healthy plant growth.

Nutrient deficiencies

The most common nutrient deficiencies are for the primary nutrients—N, P,

Table 2.—Essential plant nutrients.

Name	Chemical symbol
Primary nutrients	
Nitrogen	N
Phosphorus	P
Potassium	K
Secondary nutrients	
Sulfur	S
Calcium	Ca
Magnesium	Mg
Micronutrients	
Zinc	Zn
Iron	Fe
Copper	Cu
Manganese	Mn
Boron	B
Molybdenum	Mo
Chlorine	Cl
Nickel	Ni

and K—which are in largest demand by plants. Nearly all soils lack enough available N for ideal plant growth and many lack sufficient P. Sands, loamy sands, and sandy loams may be deficient in K. Other soil textures usually have sufficient K in Wyoming, but only a soil test can confirm this.

Secondary nutrients are rarely deficient in Wyoming soils.

Except for iron and zinc, response to micronutrients is rarely seen in Wyoming. Iron deficiency is usually associated with high lime (high pH) or poorly drained soils. Zinc deficiency is also associated with high lime (high pH) soils.

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

See Chapter 1, *Botany*.

Excess nutrients

Excess nutrients can be a problem for plants and the environment. Excesses usually result because too much of a nutrient is applied or because a nutrient 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 without creating excesses that can harm plants or the environment.

See Chapter 17 *Water Quality*.

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; they are tied up in soil mineral and organic matter in insoluble forms. These nutrients become available to plants only after they are converted to soluble forms and dissolve into 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 1 to 4 percent of the nutrients in soil organic matter are released in soluble form each year. Locations above 6,000 feet in Wyoming will receive limited benefit from nitrogen release by soil organic matter.

Soluble, available nutrients are in *ionic* form. An ion has either positive or negative charges. Positively charged ions are *cations*, and negatively charged ions are *anions*. Potassium, calcium, and magnesium are examples of cations. Chlorine is an example of an anion.

Clay particles and soil organic matter have negative charges on their surfaces and can attract cations. They hold nutrient cations in a ready reserve form that can be released rapidly 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 one become a better nutrient manager (Figure 7).

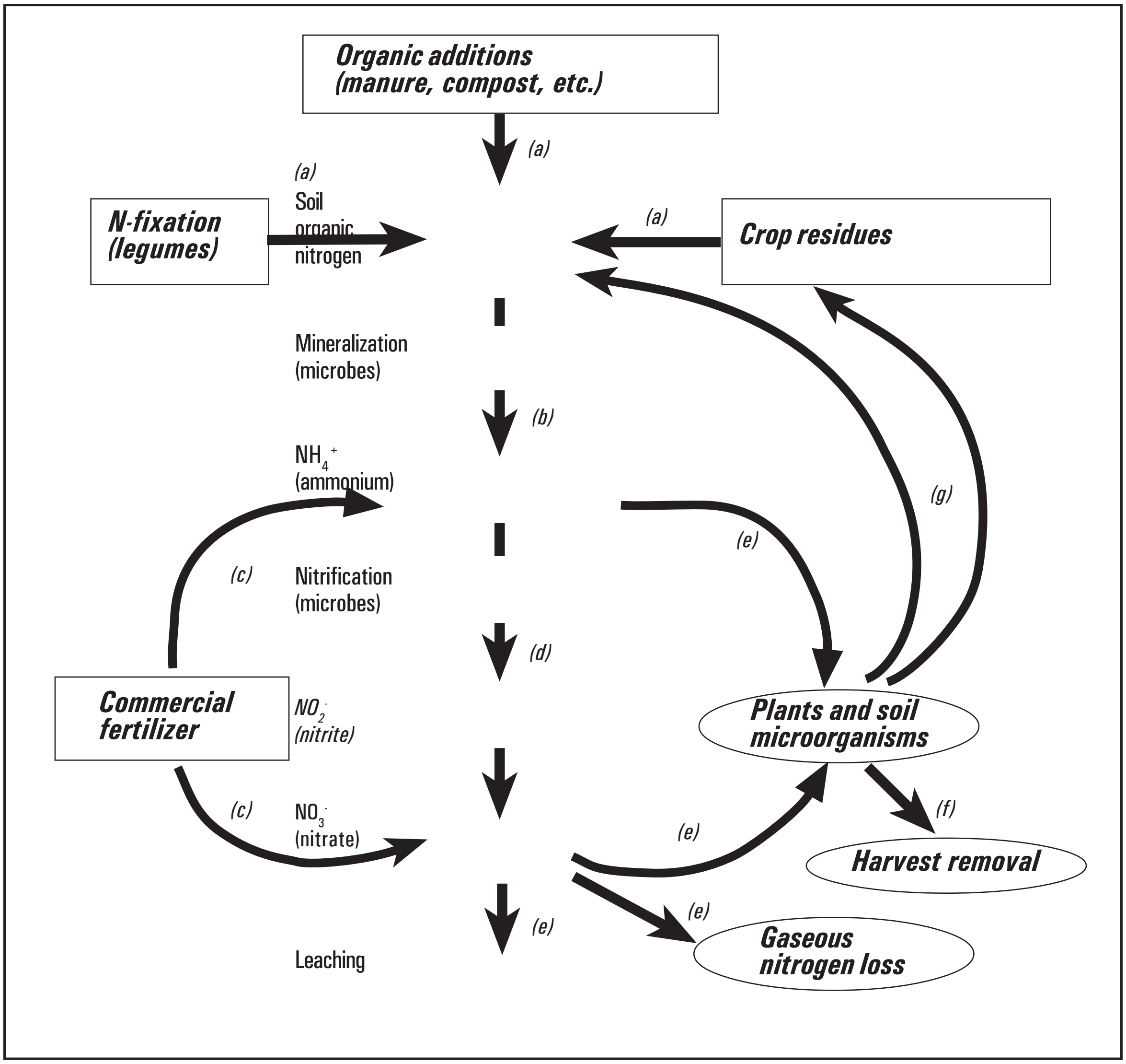


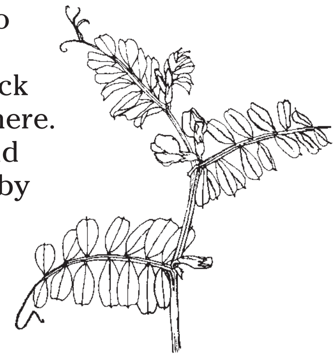
Figure 7.—Nitrogen cycle: (a) Legumes, soil organic matter, crop residues, and organic additions (manures, composts, etc.) are sources of organic N. (b) Organic N is mineralized into ammonium (NH_4^+) by soil microbes. (c) Commercial fertilizer supplies N as ammonium or nitrate (NO_3^-). (d) Microbes 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 17, Water Quality.*)*

Nitrogen is found in four different forms in the soil (Table 3). Only two of them—ammonium and nitrate—are usually used directly by plants.

Most nitrogen in soil is tied up in organic matter in forms such as humus and proteins. 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^+). Ammonium is a soluble ion that is available to plants and soil microbes. When the soil is warm, a group of microbes called *nitrifiers* convert the ammonium to nitrate (NO_3^-). 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 readily lost 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.

See Chapter 17 *Water Quality*.



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 available forms.

The nitrogen cycle is a leaky one with losses to leaching and to 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 N within the plant. Legumes such as peas, beans, alfalfa, clover, and Scotch broom are common nitrogen fixers. Growing legumes as a cover crop will supply nitrogen to future crops.

Table 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 percent of the soil atmosphere. Source of N for N-fixing plants. Not available to other plants.

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.

One can use processed fertilizers, organic fertilizers, or a combination of the two to supply soil nutrients.

Table 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, ground limestone	Ammonium sulfate, processed urea, potassium chloride
Nutrient availability	Usually slow-release; nutrients are released by biological and chemical processes in soil	Nutrients are usually immediately available to plants
Nutrient content	Usually low	Usually high

Comparing organic and processed fertilizers

Processed fertilizers are manufactured or are 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) and mineral materials (Table 4). 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 nutrients more slowly. Thus, 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 is usually inexpensive or free but can be inconvenient to apply. Packaged organic blends, on the other hand, are convenient but often expensive.

Nutrient release

Nutrients in most processed fertilizers are available 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. 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 P_2O_5 (phosphate). Similarly, fertilizer potassium is expressed as K_2O (potash). This practice is still used for fertilizer labels and recommendations even though there is no practical reason for the system except that people are accustomed to it. (To convert from P to P_2O_5, the conversion is 1 lb P = 2.3 lb P_2O_5. For potassium, the conversion is 1 lb K = 1.2 lb K_2O.)

Thus, a bag of fertilizer labeled 5-10-10 contains 5 percent nitrogen, 10 percent phosphorus expressed as P_2O_5, and 10 percent potassium expressed as K_2O. 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 5.

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 fertiliz-

Table 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 percent 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.

Table 6.—Examples of processed phosphorus and potassium fertilizer materials.

Material	Analysis	Comments
Triple superphosphate	0-46-0	—
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	—
Potassium magnesium sulfate	0-0-22	Also contains 11 percent magnesium and 18 percent sulfur.
Potassium sulfate	0-0-50	Also contains 18 percent sulfur.

ers are potassium sulfate salts, which supply sulfur as well as potassium.

Table 6 lists examples of processed phosphorus and potassium fertilizers.

Mixed fertilizers

Mixed 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

Animal manure

Farmyard manure can be an inexpensive source of nutrients. For people with 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 are usually 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 age and handling of the manure. For example:

- Fresh manure has higher levels of nutrients than aged manure and is usually too strong for immediate use in the garden.

Table 7.—Average nitrogen, phosphate, and potash content of common manures available to gardeners.

Source	Nitrogen (%)	P_2O_5 (%)	K_2O (%)
Composted chicken manure*	3.0	2.0	2.0
Separated dairy solids**	1.5	1.0	0.6
Dry stack cattle manure**	1.3	2.0	2.0
Horse manure with bedding	0.5	0.2	0.6

*Chicken manure compost data are from labels on commercial products sold in the Northwest.

**Data on dry stack manure and separated dairy solids come from Washington and Oregon.

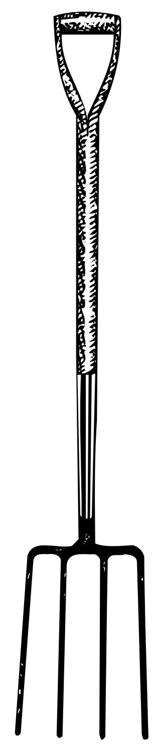
Remember that manure nutrient content can vary depending on the source and the age and handling of the manure.

- 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 7 compares average nutrient contents of typical manure products.

It doesn't take much aged manure to fertilize a garden. One 5-gallon bucket of aged cow manure is enough for about 50 square feet of garden. The same amount of aged poultry manure covers 100 to 150 square feet. Larger amounts can harm crops and leach nitrogen into groundwater.

Uncomposted or insufficiently composted manure can carry disease-causing pathogens. Be sure to read the



sidebar on manure safety before using uncomposted manure.

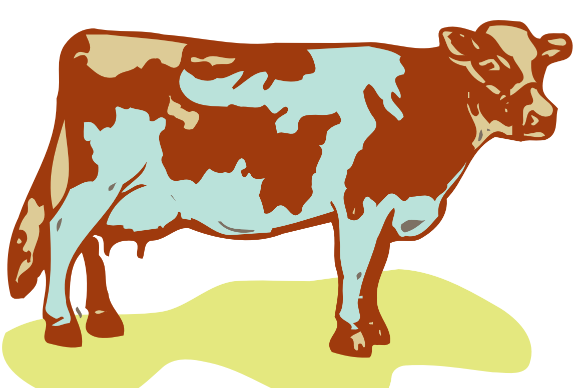
It takes larger amounts of diluted or leached manure to provide the same amount of nutrients as aged manure. Increase the amount of manure applied based on how much it is aged, diluted, and/or leached. Composted manure solids from dairy farms also have low nutrient availability, so one can apply them at higher rates than aged manure. Use these manures as much for the organic matter they supply as for nutrients. One can add as much as 1 to 2 inches of a manure with very low nutrient availability and low salt content.

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

To use manure, simply spread it over the soil and turn it in if desired.

Timing manure applications

The best time to apply manure is in the spring before planting. One also can apply manure in the fall, but some of the nutrients may be lost during the winter. Environmental risks of leaching and runoff also increase in winter. If manure is applied in the fall, apply it early and plant a cover crop to help capture nutrients and prevent runoff. See "Green manure" 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 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. The University of Wyoming does not recommend using uncomposted manure on any crops for human consumption. It is difficult to be sure that manure has been composted adequately, especially in a cold climate. If there is any question about the adequacy of the composting process, even composted manure should not be used on crops intended for human consumption

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, however, so do not add these manures to a garden or compost pile.

See Chapter 15 *Composting.*

Biosolids

Biosolids are a by-product of wastewater treatment and are available to gardeners from some wastewater treatment plants.

A common form of biosolids is a spongy, black substance called "cake." Biosolids cake is about 20 to 25 percent dry matter and 75 to 80 percent water. It typically contains about 3 to 6 percent nitrogen and 2 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. A 5-gallon bucket of biosolids cake is enough to fertilize 50 square feet of garden. Apply biosolids as one would apply manure.

Biosolids are also an ingredient in some commercial composts. Like other composts, biosolids compost releases nutrients very slowly. It is a good source of organic matter and provides small amounts of nutrients to 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 have lived long in the soil. Check with the wastewater treatment plant to find out whether their biosolids meet Class A requirements and are available for home use.

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 one applies 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 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 8 shows that most organic fertilizer materials contain one main nutrient. The other nutrients are present in smaller amounts. Thus, 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 nutri-

Table 8.—Total nitrogen, phosphate, and potash content of some organic fertilizers.

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

*Contains a substantial amount of quickly available nitrogen that plants can use early in the season.

**Very low P availability (only 2–3 percent). Useful only in acid soils.

ents than either processed fertilizers or manures. Sometimes the difference in price is substantial. Nevertheless, many gardeners use these products because of convenience or quick availability of nutrients. 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.

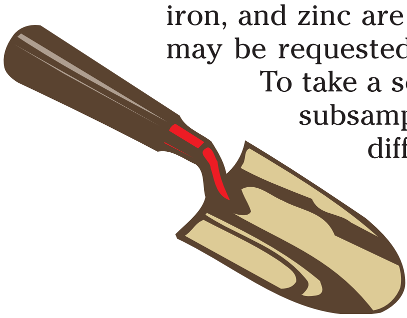
How much fertilizer to use

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 referring to information provided in extension publications are two standard methods for estimating fertilizer needs.

Soil tests

A soil test gives information on the levels of nutrients in soil and recommends how much fertilizer to add each year based on the test results and the crops you grow. One doesn't need to test soil every year. If there are no problems, every three to five years is often enough.

A garden soil test in Wyoming typically includes the following: phosphate, nitrate, organic matter, qualitative lime, hand texture, and a salt estimate. The test also includes soil pH. Potassium, iron, and zinc are additional tests that may be requested.



To take a soil sample, first collect subsamples from at least 10 different spots in the garden. Avoid any unusual areas such as the site of an old trash dump, burn pile, or rabbit hutch. Sample the top foot of soil (0- to 12-inch depth). Air dry the samples and mix them together well. Send about a quart of the mixed sample to the lab.

Because management and fertilizer recommendations vary for different crops such as vegetables, lawns, and berries, send separate samples for each area.

The University of Wyoming can perform the soil test or the samples can be sent to another regional laboratory. Before choosing a lab, call to make sure they test and make recommendations for garden soils. Ask the lab:

Does it routinely test garden soils for plant nutrients and pH? Does it use Wyoming test methods and fertilizer guides? Does it give recommendations for garden fertilizer applications? Are there forms to fill out? What information is needed? How much does a test cost? How quickly will results be sent?

Extension publications

If the cost of a soil test is large compared with normal gardening costs, one can estimate fertilizer needs using extension publications. These publications usually give recommendations for processed fertilizers, but some give guidelines for organic fertilizers as well. The University of Wyoming has published fertilizer recommendations on a variety of crops. See "For more information" at the end of this chapter. Also see other chapters in this handbook for information on specific crops.

Typical extension recommendations are for 2 pounds of nitrogen per 1,000 square feet of garden, usually applied in a mixed fertilizer with a 1:1:1 ratio. Gardens with a history of fertilizer application may need less phosphorus and potassium than these rates supply. Fast-growing crops such as sweet corn need more nitrogen.

Calculating fertilizer amounts

Fertilizer recommendations are usually given in pounds of nutrient (such as nitrogen) per unit area (typically 100 or 1,000 square feet for gardens). Convert the recommendation from pounds of nutrient to pounds of fertilizer.

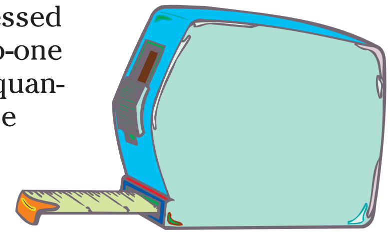
Example: A fertilizer recommendation in an extension publication is being followed that calls for adding 2 pounds of N per 1,000 square feet of garden using a fertilizer with a 1:1:1 ratio of nitrogen, phosphorus, and potassium. Follow these steps to find out how much fertilizer to use:

1. *Choose a fertilizer with an appropriate analysis*. For example, one can choose an 8-8-8 fertilizer, but not a 21-4-4.
2. *Calculate how much 8-8-8 is needed for 1,000 square feet.* Divide the amount of nitrogen recommended for 1,000 square feet (2 pounds) by the fraction of nitrogen in the fertilizer (8% or 0.08):
   2 pounds ÷ 0.08 = 25 pounds per 1,000 square feet
3. *Calculate the area of the garden.* If it is a rectangle, the area is length times width. For example, a garden 25 feet long by 20 feet wide has an area of:
   25 feet x 20 feet = 500 square feet
   If the garden is an odd shape, divide it into rectangles, calculate the area of each rectangle, and then add them together.
4. *Calculate the amount of fertilizer needed.* Divide the area of the garden (500 square feet) by the area in the fertilizer recommendation (1,000 square feet). Then multiply by the fertilizer amount calculated in step 2 above:
   (500 ÷ 1,000) x 25 = 12.5 pounds of 8-8-8 fertilizer
   This is the amount of fertilizer needed.

Estimating organic fertilizer rates

Estimating how much organic fertilizer to use can be a challenge because one 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 as 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 (e.g., 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 5 gallons per 100 to 150 square feet for high-nitrogen chicken manure to 1 to 2 inches deep for steer or horse manure composted with bedding. Estimate application rates based on the type of manure.
- Observe crops carefully. Lush plant growth and delayed flowering and fruiting are signs of high amounts of available nitrogen and may indicate over-fertilization.
- Experiment with different fertilizer rates in different parts of a row and see whether there are differences in crop performance. Plan the experiment carefully so as to be 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 nutrient status. Many established gardens have high levels of soil fertility, and crops grow well with little fertilizer.

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. Nutrient loss is not only inefficient but also 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 and earlier for spring plantings of lettuce and other greens. Plants also need available nutrients (especially phosphorus) 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 is usually adequate because nutrient release is usually fastest just before plant demand is greatest.

For perennial plants, timing depends on the plant's growth cycle. For example, June-bearing strawberries are fertilized after harvest. Refer to other chapters in this handbook and to extension publications for information on timing fertilizer applications for specific crops.

See Chapters 6-12

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 is also a long-term, slow-release storehouse of nitrogen, phosphorus, and sulfur, which continuously become available as soil microorganisms break down 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 over-fertilization.

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, one 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 using materials with a high C:N ratio in a 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 one mixes 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. One can make compost at home or buy commercially prepared compost.

Making 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). One doesn't need additives to stimulate a compost pile. One just needs to provide conditions favorable for natural composting organisms.

Home composting can be done in hot or cold piles, in worm bins, or in soil trenches:

- 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.
- One can compost fruit and vegetable scraps in a worm bin. This method works well for urban gardeners who have little space.
- One can bury fruit and vegetable scraps and allow them to decompose in the soil.

See Chapter 15 *Composting*.

Commercial compost

Yard debris is the major raw material in most commercial compost. 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.

Using compost

Adding 1 to 2 inches of compost each year helps build a productive garden soil. One can till or dig compost directly into a garden or use it as a mulch before turning it into the soil. One cubic yard of compost covers about 300 square feet 1 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 (e.g., poor growth or yellow leaves), add extra nitrogen fertilizer (either organic or inorganic). In following years, most compost contributes small amounts of available nitrogen to the soil.

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 organic matter. The value of cover crops goes beyond their contribution of organic matter, however. They can also do the following:

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

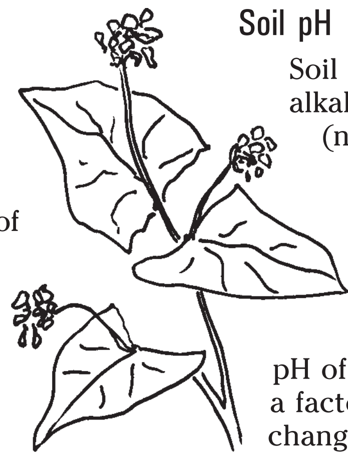
No one cover crop provides all of these benefits. Deciding which cover crop or combination to grow depends on which benefits are most important and on which cover crops best fit into a garden plan (Table 9). With the exception of buckwheat, all of the cover crops listed in Table 9 are suitable for fall planting and spring tillage.

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

If a garden contains crops into late fall, it will not be possible to plant early cover crops over the entire area. In this case, plant cover crops in areas harvested early and use mulch in those harvested later. For example, plant a cover crop in a sweet corn bed immediately following harvest and mulch a bed of fall greens after removing the crop. One can also 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 one cannot till a cover crop before it blooms, cut it off and compost it for later use. One still will get the short-term benefit of organic matter from the crowns and roots when tilling the garden.

The organic matter benefits of cover crops last only about one year. Make cover crops an annual part of garden rotation. If they do not fit into a garden plan 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 1-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:

- It affects availability of plant nutrients (Figure 8).
- It affects availability of toxic metals.
- It affects the activity of soil microorganisms which in turn affects nutrient cycling and disease risk.

Table 9.—Examples of cover crops.

Cover crop	Characteristics
Annual ryegrass	Hardy, tolerates wet soils in winter, difficult to till once established.
Austrian winter pea	Legume, fixes nitrogen, does not compete well with winter weeds.
Buckwheat	Fast-growing, frost-sensitive, summer cover, ready to till in 30 days.
Cereal rye	Very hardy, grows quickly, matures rapidly in spring.
Common vetch	Legume, fixes nitrogen, easier to till than hairy vetch.
Crimson clover	Legume, fixes nitrogen, grows more slowly than vetch.
Hairy vetch	Legume, fixes nitrogen, starts slowly, grows quickly in spring, good companion crop for cereal rye, can be difficult to till.
Spring barley	Not as hardy as rye, tolerates drought, leafy growth in spring.
Spring oats	Not hardy, tolerates wet soils.
Winter triticale	Produces more vegetation than cereal rye, may decompose more easily.
Winter wheat	Leafy, covers soil well, matures slowly.

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.

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 it causes no problems for plants. As pH declines and aluminum availability increases, aluminum toxicity can become a problem.

Microbes are also 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.

Most garden crops perform best in soil with pH of 6 to 8, but some are adapted to more strongly acid soils. It is difficult to lower pH on a landscape basis. Consult with a soil testing laboratory before trying to lower pH. Before amending soil to adjust pH, it is important to know the preferred pH ranges of plants. Most Wyoming soils are alkaline, and liming (which raises pH) is an inappropriate practice. Do not add lime unless a soil test indicates an acid soil.

Although wood ashes are a readily available source of potassium, calcium, and magnesium, they react like lime and raise soil pH. High rates of wood ashes may also cause short-term salt injury. The use of wood ashes on alkaline soils is not recommended.

Gypsum

Gypsum (calcium sulfate) is not 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

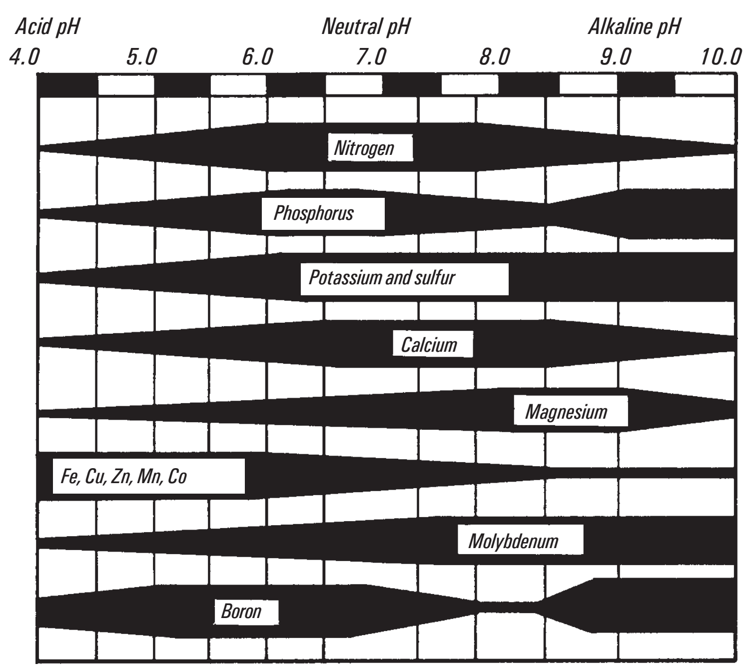


Figure 8.–Effect of soil pH on the availability of plant nutrients.

Table 10.—Soil salinity measured in conductivity units (millimhos/cm) and potential effects on plants.

Conductivity (mmho/cm)	**Interpretation**
4 or above	Severe accumulation of salts. May restrict growth of many vegetables and ornamental plants. Reduce salt by leaching.
2 to 4	Moderate accumulation of salts. Will not restrict plant growth, unless they are salt sensitive, but may require more frequent irrigation to prevent wilting.
Less than 2	Low salt accumulation. Will not affect plants.

the soil. Only a soil test can determine if gypsum will be a useful amendment for soil.

Soil salinity

Soil salinity can be a problem in many Wyoming soils. Salts from parent material, irrigation water, fertilizer, compost, and manure applications can accumulate to the point where they harm plant growth. A salinity test measures the total soluble salts in a soil. Table 10 shows how to interpret a salinity test.

One can leach salts from soil by applying good quality irrigation water in excess of the water-holding capacity of the soil. The excess water must drain downward through the soil to carry away excess salts. When leaching, apply water slowly enough that it drains freely through the subsoil.

For more information

University of Wyoming Cooperative Extension Service publications

Backyard Composting: Simple Small-Scale Methods (B-974R)

Soil Salinity, Salt Tolerance, and Growth Potential of Horticultural and Landscape Plants (B-988)

*Soils of Wyoming: A Digital Statewide Ma*p (B-1069)

Landscaping: Recommended Trees for Wyoming (B-1090)

Iron Deficiency Chlorosis on Woody Landscape Plants in Wyoming (B-1097)

Landscaping: Recommended Shrubs for Wyoming (B-1108)

Gardening: Growing Herbs in Wyoming (B-1144)

Gardening: Vegetables in Wyoming (B-1115)

Landscaping: Turf in Wyoming (B-1129)

Landscaping: Water-Wise Wyoming Gardens (B-1143)

Guide to Wyoming Fertilizer Recommendations (B-1045).

Other publications

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Brady, N.C. *The Nature and Properties of Soils* (Macmillan Publishing Co., Inc., New York, 1998). 896 pp.

Craul, P.J. *Urban Soil in Landscape Design* (John Wiley & Sons, New York, 1987). 396 pp.

Donahue, R.L., R.W. Miller, and J.C. Shickluna. *Soils: An Introduction to Soils and Plant Growth* (Prentice-Hall, Inc., Englewood Cliffs, NJ, 1990). 768 pp.

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Basic Entomology

3

The animal kingdom contains many distinct groups called *phyla* (plural). Each phylum (singular) is divided into a number of *classes*. Insects represent one of several classes of the phylum Arthropoda (jointed foot); their class is called Insecta or Hexapoda, which means six feet (Table 1). The insect class is further divided into *orders* (Table 2), *families*, *genera*, and finally *species*. The genus, species, and name of the author who first described it constitute the scientific name of a species; for example, the codling moth, *Cydia pomonella* (Linn.), was first described by Linnaeus. Often the author's name is omitted, and only the genus and species are listed (e.g., *Cydia pomonella*).

About 1 million insect species have been described, more than 90,000 of them in North America. It is believed that as many as 10 million may exist worldwide. The greatest numbers of species belong to the beetle, fly, moth/butterfly, and wasp/ant/bee orders.

Fewer than 1 percent of all insect species are serious pests that affect humans, their animals, crops, structures, or fiber. However, this small number can cause serious problems such as:

- Crop loss
- Structural damage
- Transmission of disease-causing pathogens between plants (e.g., fireblight bacteria by pollinating insects), humans (e.g., malaria by mosquitoes), or other animals (e.g., dog tapeworms by fleas).

Topics in this chapter

- Insect anatomy
- Insect development
- Classification
- Identification
- Common garden insects
- Strategy for insect management

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See Chapter 1, *Botany*.

Fortunately, most insects are either beneficial or harmless. Some are predators such as lady bird beetles, which feed on aphids. Some insects eat weeds. Others are *parasitic* (for example, some wasps). Parasitic insects kill other insects, often pests, by laying their eggs on or in their victims' bodies or eggs. Still others such as honeybees produce honey and pollinate flowering plants. Melons, squash, and many other crop plants require insects to carry their pollen before setting fruit. Many ornamental plants such as chrysanthemums, iris, orchids, and yucca are pollinated by insects.

Many insects are responsible for the decomposition of plant and animal matter. Insects condition the soil and promote fertility by burrowing through the surface layer. Also, their bodies and waste droppings serve as fertilizer. A good example is the termite. Obviously, when termites attack the timber of homes they are pests; however, when they break down fallen trees in the woods, they act as nature's recyclers and are harmless to humans. Some insects perform an essential service as scavenging, devouring dead animals and plants and burying carcasses and dung.

Size varies greatly throughout the insect world. The extremes include tiny wasps and beetles (less than a millimeter long), long-horned beetles (as much as 6 inches long), and tropical stick insects, which are giants at 12 to 18 inches long.

Insects also vary a lot in appearance. Some have bizarre-looking horns and spines while others resemble dead leaves. On the other hand, some insects are quite attractive. Some butterflies are beautiful, but "beautiful" hardly describes a cockroach.

Thus, while insects are fascinating to investigate, their classification is complex. It is important to learn the main differences among insects to be able to distinguish one group from another. Knowledge of insect classification, identification procedures, and life cycles is of primary importance in carrying out proper control procedures and quality pest management programs.

Proper insect identification is extremely important. If a beneficial or nondamaging insect is improperly identified as a pest, it could result in unnecessary and undesirable pesticide application and the disruption of natural control agents. This disruption may in turn necessitate additional chemical control. Sometimes such mistakes only cost money, but they can also be much more serious. In some cases, the result is crop loss or environmental damage.

Do not make recommendations based on a verbal description of a pest. Insist on seeing it or at least its damage before volunteering control information. If uncertain of a pest's identity, do not guess. Wrong identification leads to ineffective control measures and unnecessary expense or environmental problems. Many university extension and research personnel provide insect identification at no charge to master gardeners. There also are many extension publications (see "For more information") to help identify pests and pest problems. Also see Chapter 13, *Diagnosing Plant Problems.*

Insect Anatomy

Insects are animals, but unlike vertebrate animals they have no backbone. They have an outer support system called an *exoskeleton* rather than the inner support system (*endoskeleton*) characteristic of most large animals.

The tough exoskeleton is referred to as the *cuticle*. The cuticle contains a layer of wax that determines permeability to water (and to insecticides) and prevents *desiccation* (drying). Each segment's cuticle is formed into several hardened plates called *sclerites*, separated by *infolds* (sutures) which give it flexibility. The cuticle of larvae is usually not as hard as that of adults.

Insect terminology

Abdomen—The third (hind) body region. Composed of as many as 11 segments and lacking legs or wings.

Antenna (pl., antennae)—A segmented organ located on the head, usually used for smell.

Cell—An area in a wing between veins.

Cercus (pl., cerci)—A thread-like or sometimes forceps-like tail near the tip of the abdomen (usually a pair).

Complete metamorphosis—A type of insect development in which the insect passes through the stages of egg, larva, pupa, and adult. The larva is usually different in form from the adult.

Compound eye—An eye with many individual elements or facets.

Cornicle—A short, blunt horn or tube (sometimes button-like) on the top and near the end of an aphid's abdomen. Emits a waxy liquid that helps protect against enemies.

Elytron (pl., elytra)—One of a beetle's leathery or hard front wings. Usually covers a hindwing when at rest and sometimes called a wing cover.

Furcula—A forked "tail" on the underside of the abdomen of Collembola (springtails), used for jumping.

Gradual metamorphosis—See Simple metamorphosis.

Haltere—A small, knob-like organ (sometimes shaped like a baseball bat or bowling pin) located on the thorax of Diptera. Takes the place of hindwings and helps balance the insect in flight.

Honeydew—A sticky substance excreted by aphids and some other insects.

Incomplete metamorphosis—See Simple metamorphosis.

Instar—The life stage between molts.

Larva—The active feeding stage of insects that go through complete metamorphosis; precedes the pupal stage.

Mandible—The first pair of jaws: stout and tooth-like in chewing insects, needle or sword-shaped in sucking insects; the lateral (left and right) upper jaws of biting insects.

Membranous—Thin like a membrane. Clear or almost clear enough to see through—like cellophane or clear plastic sheeting.

Mesothorax—The second or middle thoracic ring, which bears the middle pair of legs and the first pair of wings.

Metamorphosis—The changes through which an insect passes from the immature or egg form to an adult.

Metathorax—The third or last thoracic segment. Joined to the abdomen. Bears the hind pair of legs and second pair of wings or rudiments of these wings, e.g., the halteres found on flies (Diptera).

Molt—The shedding of skin during growth.

No metamorphosis—Do not go through metamorphosis, only increase in size.

Nymph—The active feeding and growing stage of insects that go through simple metamorphosis.

Ovipositor—Tube from which a female insect deposits her eggs.

Palpus (pl., palpi)—A small "feeler" near the mouth, probably used to help select food.

Parasite—An insect that lives in or on another animal and damages its host.

Pheromone—Vapor or liquid emitted by an insect that causes a specific response from a receiving insect. Some pheromones are used to find a mate. Also used in pest control products.

Predator—An insect that eats another insect.

Proleg—A fleshy, unjointed false leg found on caterpillars (hooked) and the larvae of some sawflies (lacking hooks). Used for clinging to surfaces and for support in locomotion.

Pronotum—The upper side of the prothorax.

Prothorax—The first thoracic ring or segment; it bears the first pair of legs but lacks wings.

Pupa—The stage between larva and adult in insects that go through complete metamorphosis.

Insect terminology (continued)

Segment—A joint or division of an insect's body, leg, or antenna.

Simple metamorphosis—A type of insect development in which the insect passes through the stages of egg, nymph, and adult. The nymph usually resembles the adult.

Stylet—The tubular, sucking mouthpart of sucking insects.

Tarsus (pl., tarsi)—The "foot" of an insect; the last, small segment or joint near the end of the leg. The number varies from one to five.

Thorax—The second or intermediate region of the body, found between the head and abdomen; it bears the legs and wings if present. Made up of three rings or segments: first, prothorax; second, mesothorax; and third, metathorax.

Vector—An insect that carries a disease organism from one plant or animal to another.

Vein—The rod-like or vein-like stiffening or supporting frame of a wing.

Wing scale—A powder-like covering that gives color to butterfly and moth wings. Actually, a very small scale that overlaps other scales like shingles on a roof.

Table 1.—Major classes of the phylum Arthropoda.

Class	Examples	Body segments	Pairs of legs	Horticultural importance
Chilopoda	Centipedes	many	many	Feed on insects; can be beneficial.
Crustacea	Sowbugs, pillbugs	2	5	Can be minor pests.
Arachnida	Spiders, mites, ticks	2	4	Some mites are major pests.
Diplopoda	Millipedes	many	many	Can be minor pests.
Symphyla	Symphylans	2	12	Can be major garden pests.
Insecta	Beetles, aphids, bees, butterflies, etc.	3	3	Some beneficial, some pests.

Table 2.—Major orders of the class Insecta.

Order	Common name	Metamorphosis	Mouthpart	Wings
Coleoptera	Beetles	Complete	Chewing	2 pairs
Collembola	Springtails	None	Chewing	None
Dermaptera	Earwigs	Simple, gradual	Chewing	2 pairs
Diptera	Flies	Complete	Chewing or piercing-sucking	1 pair
Hemiptera	True bugs	Simple, gradual	Piercing-sucking	2 pairs
Homoptera	Aphids, scales, etc.	Simple, gradual	Piercing-sucking	2 pairs
Hymenoptera	Bees, wasps, ants	Complete	Chewing	2 pairs or none
Isoptera	Termites	Simple, gradual	Chewing	2 pairs
Lepidoptera	Butterflies, moths	Complete	Chewing or siphoning	2 pairs
Orthoptera	Grasshoppers, etc.	Simple, gradual	Chewing	2 pairs
Siphonaptera	Fleas	Complete	Chewing or piercing-sucking	None
Thysanura	Silverfish	Simple, gradual	Chewing	None

The following characteristics are useful in comparing insects with other animals.

Three body regions

An adult insect's body is made up of three parts: head, thorax, and abdomen (Figure 1). However, the division between thorax and abdomen is not always obvious.

The *thorax* is made up of three segments: *prothorax*, *mesothorax*, and *metathorax*. Each of these segments bears a pair of legs. The wings are attached to the mesothorax and/or metathorax, never to the prothorax (first segment).

The *abdomen* usually has 11 or 12 segments (although some insects have fewer), but in many cases they are difficult to distinguish. Some insects have a pair of appendages (*cerci*) at the tip of the abdomen. They may be short, as in grasshoppers, termites, and cockroaches; extremely long, as in mayflies; or curved, as in earwigs.

Wings

Insects are the only flying invertebrates. Most adult insects have one or two pairs of wings. Some, however, have no wings. Wing function for flight varies among insects. Wing surfaces may be covered with fine hairs or scales, or they may be bare.

The thickened front wings of beetles serve as protective covering for the hind wings when the beetle is not flying. The membranous hind wings are the actual flight mechanisms.

Venation (the arrangement of veins in the wings) is different for each group of insects; thus, it serves as a means of identification (Figure 2). Often wing venation is common to all members of a family or genus. There are systems for designating types of venation for descriptive purposes.

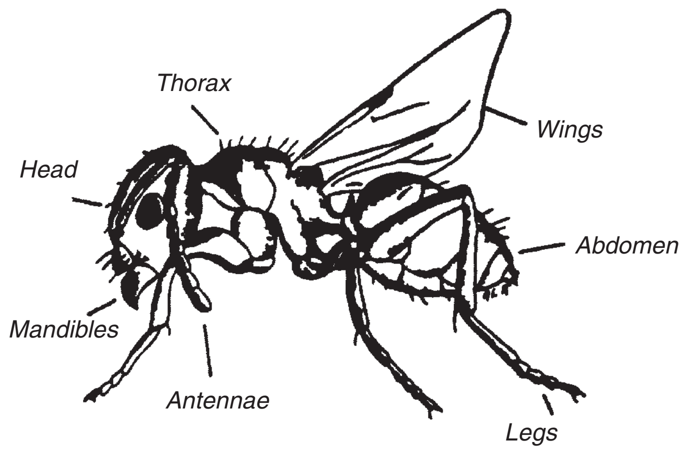

Figure1. Body regions. Parts of an adult insect.

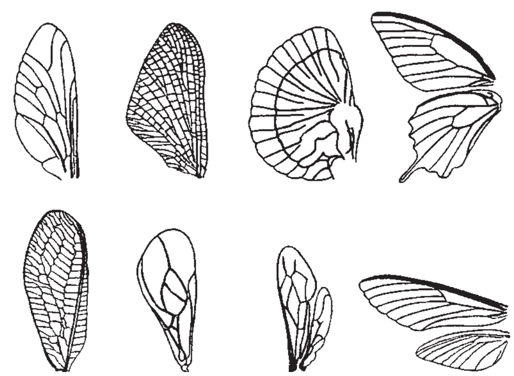

Figure 2. Wing venation.

The names of most insect orders end in "ptera," which comes from the Greek word meaning wing. Thus, each name denotes some feature of the wings. Hemiptera means half-winged, Hymenoptera means membrane-winged, Diptera means two-winged, and so forth.

Legs

Another important characteristic of insects is the presence of three pairs of jointed legs on the thorax. These legs are almost always present in adult or mature insects and generally are present in other

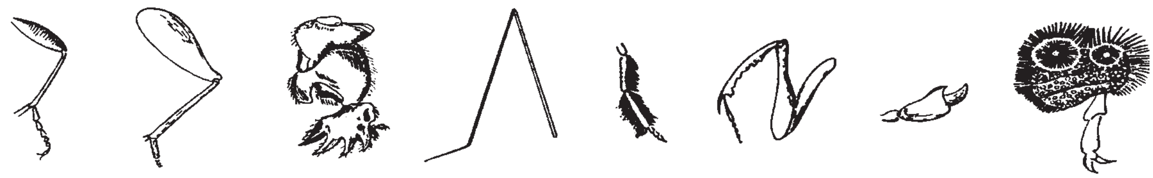

Figure 3. Legs with various functions.

stages as well. In addition to walking and jumping, insects often use their legs for digging, grasping, feeling, swimming, carrying loads, building nests, and cleaning themselves. Because insect legs vary so greatly in size and form, they are regularly used in classification, especially the extreme part of the leg (the feet, or *tarsi*). Figure 3 illustrates some examples of insect legs.

Prolegs (fleshy body projections or false legs) occur only on larvae of certain insect orders. They are used for clinging to plants.

Antennae

One of the main features of an insect's head are its *antennae* (Figure 4). All adult insects (except, at times, scale insects) have one pair. They are usually located between or in front of the eyes. Antennae are segmented, vary greatly in form and complexity, and are often referred to as horns or feelers, which is misleading. They are primarily organs of smell but serve other functions in some insects.

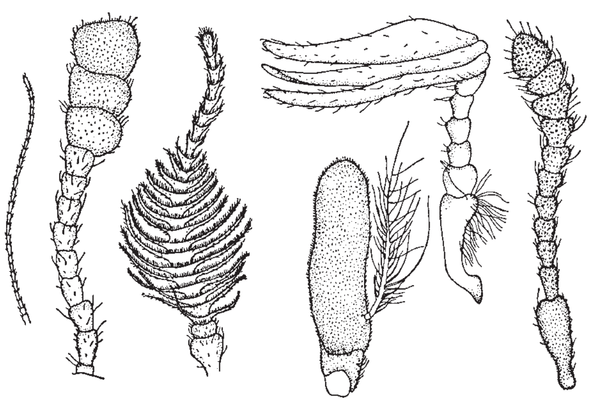

Figure 4. Antennae.

Mouthparts

The most remarkable structural feature of insects and the most complicated is the mouth (Figure 5). Mouthparts vary in form and function, but they fall into two basic types: *chewing* and *sucking*. Although the two types differ considerably in appearance, the same basic parts are generally found in both. There also are intermediate types of mouthparts: *rasping-sucking* (found in thrips) and *chewing-lapping* (found in honeybees, wasps, and bumblebees).

The chewing mouth type is more primitive and generally stronger than sucking types. Sucking types vary greatly. For example, *piercing-sucking* mouthparts are typical of Hemiptera (bugs), Homoptera (aphids, scales, and mealybugs), blood-sucking lice, fleas, mosquitoes, and the so-called biting flies. In *siphoning* types seen in butterflies and moths there are no mandibles, and the labial and maxillary palpi are greatly reduced. Houseflies have *sponging* mouthparts.

Some insects have different mouthparts as larvae and adults. Larvae generally have chewing-type mouthparts regardless of the kind they'll have as adults. Nymphs have mouthparts similar to those of adults. For some adult insects, the mouthparts are *vestigial* (no longer used).

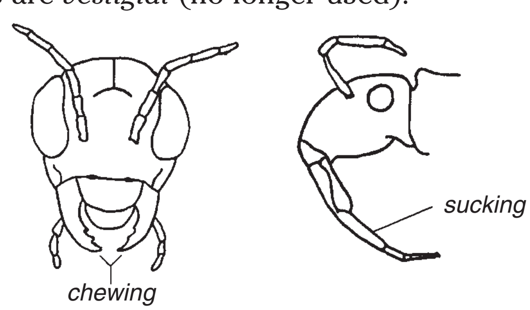

Figure 5. Mouthparts.

Insect Development

One of the distinctive features of insects is the phenomenon called *metamorphosis*. The term is a combination of two Greek words: meta, meaning change, and morphe, meaning form. It is commonly defined as a marked or abrupt change in form or structure and refers to all stages of development.

Only the most primitive insects do not go through metamorphosis. This group includes springtails, firebrats, and silverfish. The only change they undergo during development from egg to adult is an increase in size. In modern classification systems, these groups are not considered insects.

Insects that undergo *simple* (also known as gradual or incomplete) *metamorphosis* (Figure 6) change very little during development. They have three stages: egg, nymph, and adult. The *nymphs* develop wing buds early in life, but functional wings do not appear until the adult stage. Nymphs usually look very similar to adults and have similar feeding habits. Cockroaches, earwigs, termites, lice, true bugs, and aphids are examples of this group.

The more highly developed insects go through *complete metamorphosis* (Figure 7). This group includes most insects (e.g., beetles, flies, fleas, moths, wasps, and ants). They develop through the stages of egg, larva, pupa, and adult. In pest species, the larval stage is usually the most destructive although adults may also cause damage. The *pupa* is a non-feeding stage; in most cases it also is inactive.

In higher animals, the most important development takes place before birth (in the embryonic stage), but in insects it occurs after birth. The larval period is primarily one of growth when the insect feeds and stores food for the pupal and adult stages that follow. Many insects feed very little, if at all, during their adult lives.

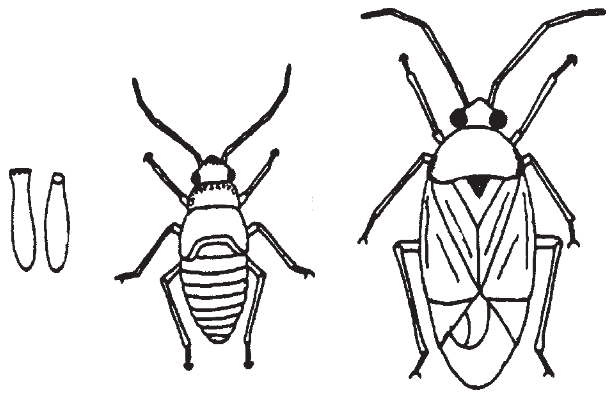

Figure 6. Simple, gradual, or incomplete metamorphosis.

Figure 7. Complete metamorphosis.

A young insect (larva or nymph) sheds its hard cuticle (*molts*) at various stages of growth because it outgrows the cuticle more than once. Insects do not grow gradually as many other animals do. They grow by stages. When the old skin gets too tight, it splits open and the insect crawls out, protected by a new, larger coat that has grown underneath the old one.

The stage between each molt is called an *instar*. Following each molt, the insect increases its feeding. Plant damage and the size of the insect's fecal pellets both increase. The number of instars or frequency of molts varies considerably, depending on species and, to some extent, on food supply, temperature, and moisture.

The pupal stage is one of profound change—a transformation from larva to adult. Many tissues and structures such as prolegs are completely broken down, and true legs, antennae, wings, and other adult structures are formed.

Hibernation takes place during winter. It may occur in an immature stage or in the adult stage, depending on species. It is an insect's way of adjusting to low temperatures and dwindling food supplies. Many insects start preparing for winter before the end of summer. This behavior is triggered by changes in the amount of daylight (*photoperiod*).

Adult insects do not grow. The adult period is primarily one of reproduction and sometimes is of short duration. Adults' food is often entirely different from that of the larval stage, and some adults do not eat at all.

Classification

The anatomy of an insect places it into a specific insect group called an order. Each order is divided into families, and each family is divided into genera and finally species. A specific insect is usually described by genus and species names; e.g., *Musca domestica* is the common housefly. To categorize insects, professionals observe differences in body parts through a microscope.

See Chapter 4, *Disease,* Chapter 13, *Diagnosing Problems,* and Chapter 14, *IPM.*

Gardeners generally classify insects by common name. Unfortunately, not all insects have common names, and common names often don't recognize significant differences. For example, ladybird beetles are a widely variable group, but there may or may not be common names that adequately differentiate among them. Also, some insects have several common names, depending on regional or personal preference.

Identification

Most home gardeners can use insect identification handbooks to classify an insect by the common name of its order, identifying it as a beetle, wasp, or butterfly. Knowing the insect order gives valuable information about many insects in the same order. This information includes:

- The type of mouthparts (explaining how the insect feeds and giving clues for its control)
- Life cycle (indicating best times for control)
- Type of habitation, including host(s) (where to find it)

Beyond the family category, however, identification is very difficult for all but the most common insects without a magnifying instrument such as a microscope.

The following identification strategies are useful for gardeners:

- *Experience*—Periodically attend plant clinics and hands-on advanced training to gain valuable practice in insect identification. Working with experienced master gardeners also helps develop valuable insight into solving plant problems when plant disease and other factors can make analysis difficult.
- *Specimen approach*—Use keys, photographs, drawings, and descriptions along with insect specimen data.
- *Symptoms approach*—Compare damage with the insect's physical characteristics (Figure 8). For example, because of their different mouthparts, a beetle can cause chewing damage, but an aphid cannot.

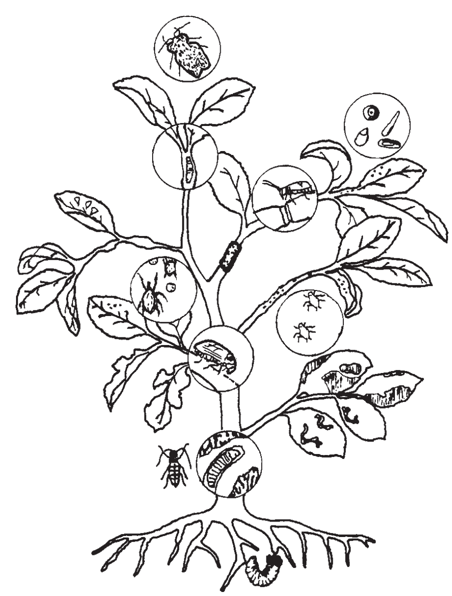

Figure 8. Systems approach to insect identification.

- *Host approach*—Check references that list hosts and potential insect damage. Like people, many insects have preferences for their meals.
- *Host location approach*—Use this method to exclude certain insects. For example, large praying mantid species are not expected to be found in Wyoming unless released. Also, some insects prefer dry or wet conditions.

Common garden insects

The following insect orders include many of the most common garden insects. Many of these orders include both beneficial insects and pests.

Coleoptera (beetles, weevils)

These insects undergo complete metamorphosis. Larvae have a head capsule, and most have three pairs of legs on the thorax but no legs on the abdomen. Weevil larvae, however, lack legs on the thorax.

Adults have a hard, horny outer skeleton, chewing mouthparts, and usually noticeable antennae. They have two pairs of wings; the outer pair is hardened, and the inner pair is membranous. A few beetles are practically wingless, and some have only an outer pair of hard wings.

Some species are beneficial as pollinators or as predators of harmful insect species. Others are pests of plant foliage and roots.

See Figure 9 for examples.

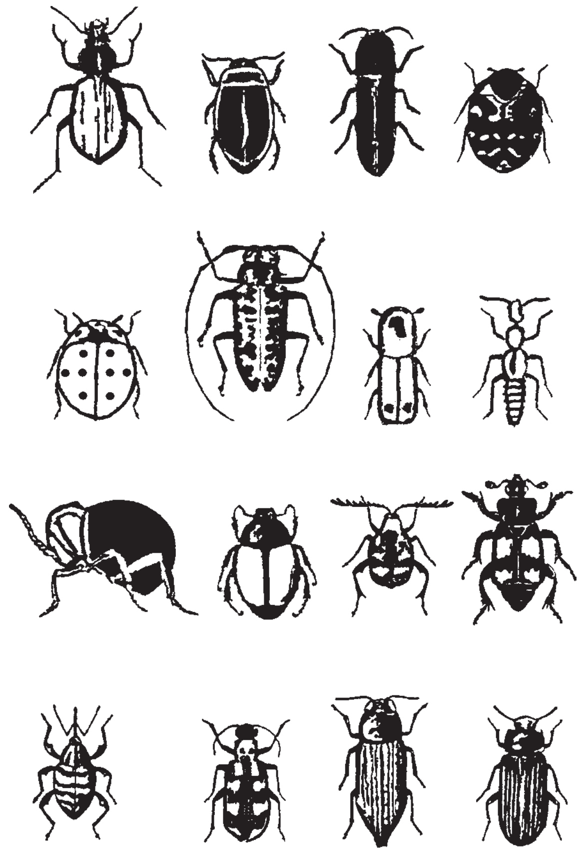

Figure 9. Coleoptera.

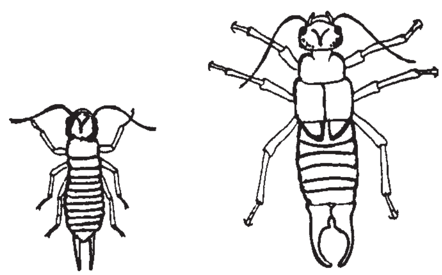

Figure 10. Dermaptera.

Dermaptera (earwigs)

These insects undergo simple metamorphosis. Nymphs are similar in appearance to adults.

Adults are moderately sized, elongated, flattened insects with strong, movable forceps on the rear end. They have short, hardened outer wings and folded, membranous inner wings. Mouthparts are the chewing type.

Earwigs are omnivorous. They sometimes feed on insects such as aphids, in which case they are beneficial. However, they also feed on fruit and flowers, making them plant pests. Mostly they are considered a nuisance.

See Figure 10.

Diptera (flies, mosquitoes, gnats, midges)

Species in this order undergo complete metamorphosis. Larvae may have mouth hooks or chewing mouthparts. Most are legless. Larvae of advanced forms (housefly and relatives) have no head capsule, possess mouth hooks, and are called maggots. Lower forms such as mosquito larvae and relatives have a head capsule.

Adults have only one pair of wings and are rather soft bodied and often hairy. They have either sponging (housefly) or piercing (mosquito) mouthparts.

This order demonstrates a multitude of lifestyles. Houseflies are a nuisance as adults, but their larvae are major recycling organisms. Mosquitoes and others are vectors of human and animal diseases. Many other members of this order are either parasitic or predaceous on other insects, which makes them among the most important beneficial insects.

See Figure 11.

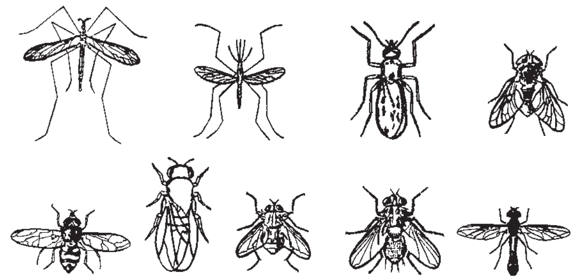

Figure 11. Diptera.

Hemiptera (stinkbugs, plant bugs, squash bugs, boxelder bugs)

Metamorphosis is simple in this order. Nymphs usually resemble adults.

Adults have piercing-sucking mouthparts and two pairs of wings; the first pair is membranous and thickened on the basal half, and the second pair is membranous throughout.

Adults and nymphs are both damaging in pest species. Some species, however, are predators of harmful insect pests.

See Figure 12 for examples.

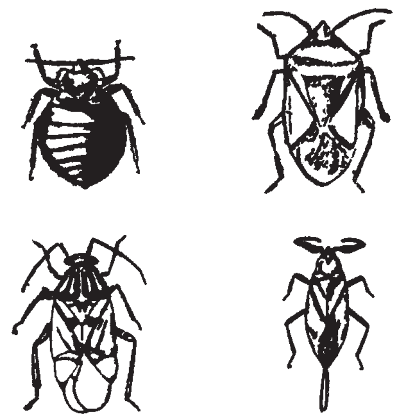

Figure 12. Hemiptera.

Homoptera (scale insects, mealybugs, whiteflies, aphids, cicadas, leafhoppers)

These insects undergo simple metamorphosis. Nymphs usually resemble adults.

Adults are generally small and soft bodied although cicadas may be large and hard bodied. There can be winged and unwinged adults within the same species. Adults have sucking mouthparts.

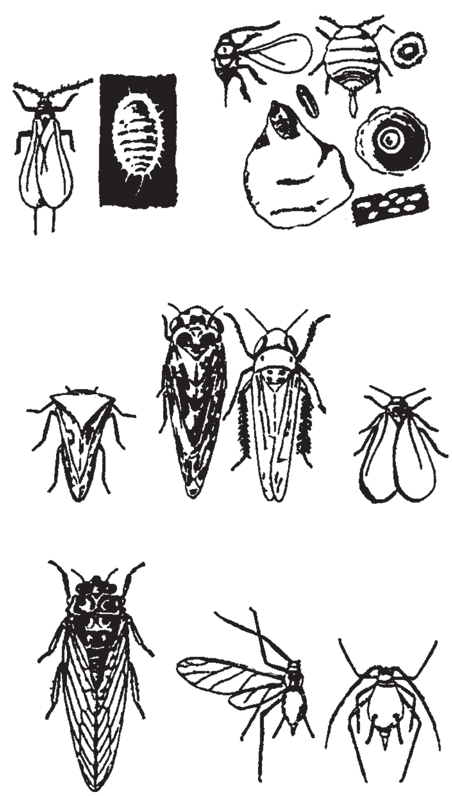

Figure 13. Homoptera.

Many members of this order are carriers of plant pathogens.

See Figure 13 for examples.

Hymenoptera (bees, ants, wasps, sawflies, horntails)

These insects undergo complete metamorphosis. Larvae either have no legs (wasps, bees, and ants) or legs on the thorax and prolegs on the abdomen (some sawflies).

Adults have two pairs of membranous wings. Adults are rather soft bodied or slightly hard bodied and generally have chewing mouthparts.

Many beneficial species of this order prey on or parasitize harmful insects. Others are important pollinators.

See Figure 14 for examples.

Lepidoptera (butterflies, moths)

Members of this order undergo complete metamorphosis. Larvae are wormlike caterpillars which vary in color and are voracious feeders. They have chewing mouthparts and generally have legs on both the abdomen and the thorax.

Adults are soft bodied with four well-developed membranous wings covered with small scales. The mouthpart is a coiled sucking tube. Adults feed on nectar.

Many moths and butterflies are major pollinators. The caterpillars of some, however, are plant pests.

See Figure 15 for examples.

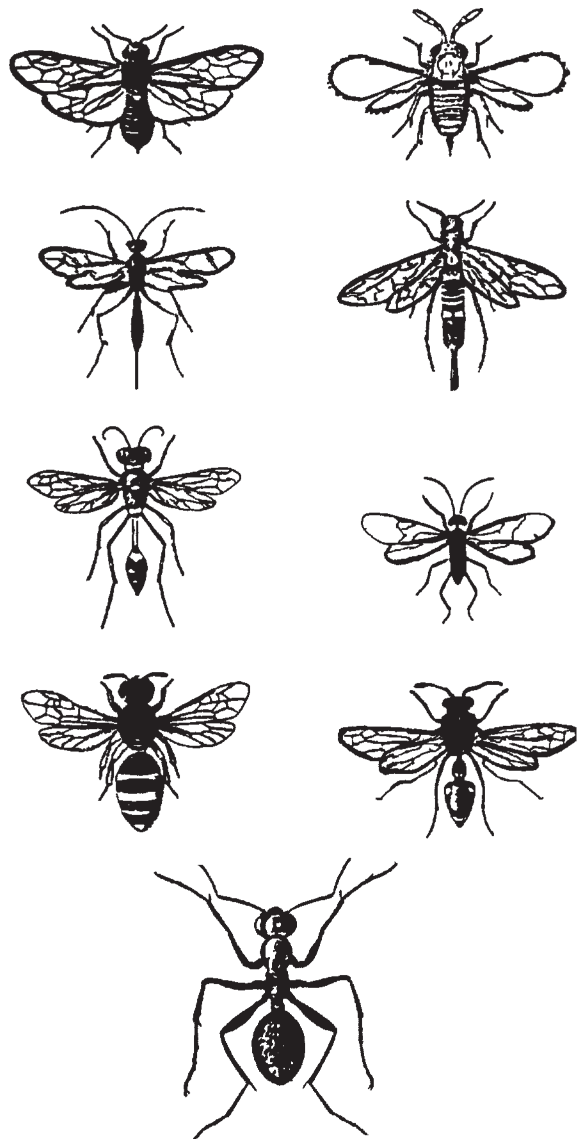

Figure 14. Hymenoptera.

Figure 15. Lepidoptera.

Neuroptera (lacewings, antlions, snakeflies, mantispids, dobsonflies, dustywings, alderflies)

Metamorphosis is complete in this order.

Adults have two pairs of similar wings and chewing mouthparts. Many are aquatic.

Many of these insects are important predators of garden pests.

See Figure 16 for examples.

Orthoptera (grasshoppers, crickets, praying mantids)

These insects go through simple metamorphosis. Nymphs resemble adults except for being wingless.

Adults are moderate sized to large and often rather hard bodied. They usually have two pairs of wings. Forewings are elongated, narrow, and hardened; hindwings are membranous with an extensive folded area. Adults have chewing mouthparts. The hind legs of forms other than cockroaches and walking sticks are enlarged for jumping.

Both adults and nymphs of many species are damaging. Praying mantids, however, are beneficial predators.

See Figure 17 for examples.

Thysanoptera (thrips)

The type of metamorphosis varies in this order (a mixture of complete and simple).

Adults are small, soft-bodied insects with rasping-sucking mouthparts. They have two pairs of slender wings which are fringed with hairs.

See Figure 18 for examples.

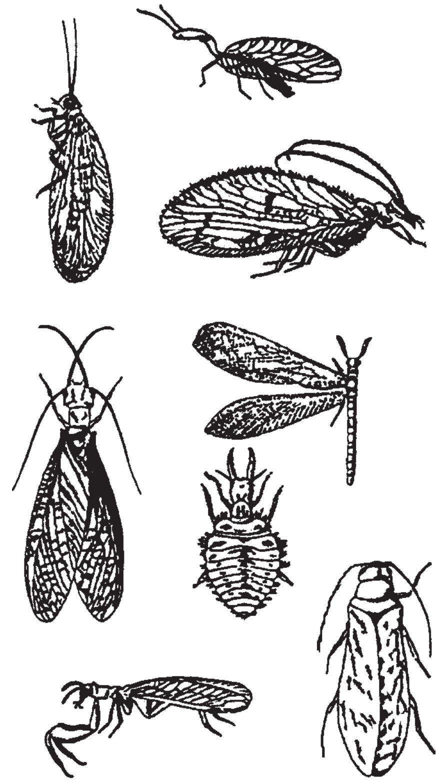

Figure 16. Neuroptera

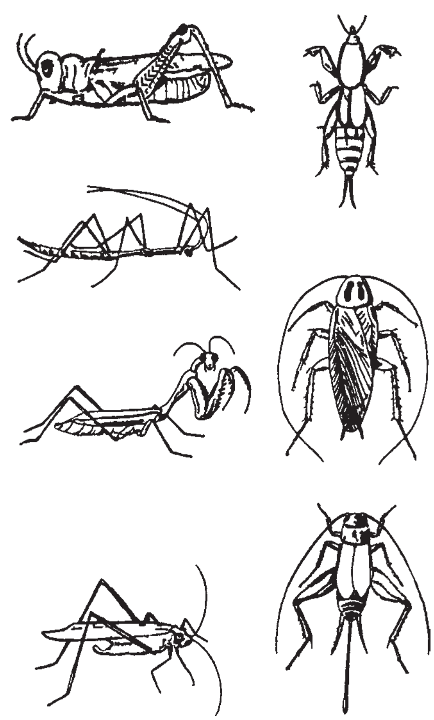

Figure 17. Orthoptera.

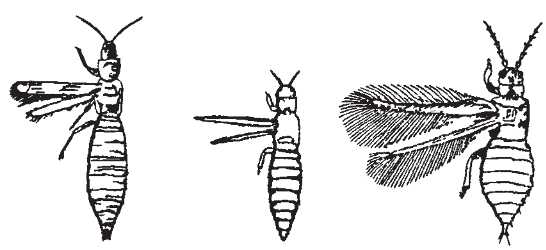

Figure 18. Thysanoptera

Strategy for insect management

1. Determine whether damage is caused by insects. Sometimes gardeners jump to conclusions and blame damage on insects that happen to be present. It is important to determine whether damage is caused by other factors such as cultural deficiencies or disease. Cultural deficiencies are the most common cause of damage, followed by disease and then insects.
2. Determine and apply an appropriate remedy. First apply nontoxic or low-toxic remedies. Use more toxic controls only as a last resort. Some gardeners want fast results, so they use the most toxic pesticides because advertising and labels promise a quick, effective cure. Unfortunately, this approach may have unintended side effects. For example, beneficial insects and other animals may be killed or sickened even if the pesticide is applied legally according to label directions. As a result, the insect infestation may worsen because nature's balance has been disrupted.
3. Monitor results.
4. Determine whether further remedy is necessary.

For more information

UW Cooperative Extension Service publications

Insects and Related Pests of Trees, Shrubs, and Lawns (MP-25R)

Pests of the Home Vegetable Garden (MP-24)

Insect Biology and Management Resource Manual (MP-76R)

The Poplar Vagabond Gall Aphid (B-1041)

Management of Hardwood Borers of Trunks and Large Branches (B-1050)

Scales and Mealybugs (B-1050.1)

Sowbugs and Pillbugs (B-1050.2)

Slugs, Snails and Slug Sawflies (B-1050.3)

Leaf and Stem-Feeding Aphids (B-1050.4)

Spiders (B-1050.5)

Landscape Pests: Integrated Pest Management Strategies for Controlling the Dastardly Dozen (B-1035)

Colorado State University Extension Service publications

Insects that Feed on Colorado Trees and Shrubs (506A)

Colorado Commercial Pesticide Application and Safety Training Guides (CE 100)

High Plains Integrated Pest Management Guide (546A)

Root Weevils in the Nursery and Landscape: Identification and Control (EC 1485)

Using Pesticides Safely: Are Pesticides Hazardous? That's Up to You! (EC 1497)

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Pyle, R.M. *Field Guide to North American Butterflies* (National Audubon Society, Chanticleer Press, 1997). 924 pp.

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Ross, H.H., C.A. Ross, and J.R.P. Ross. *A Textbook of Entomology*, 4th edition (Wiley, New York, 1982). 666 pp.

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World Wide Web sites

HortSense: *pep.wsu.edu/hortsense/*

Western Washington Master Gardener Information: *gardening.wsu.edu*

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Plant Disease

4

Quite often we need to determine why plants appear abnormal and what management measures, if any, are appropriate. This chapter introduces the reader to the subject of plant pathology, and the information it contains will aid in understanding how plant diseases develop as well as the various methods used for management.

Topics in this chapter

- The disease triangle
  - Pathogens
    - Fungi
    - Bacteria
    - Viruses
    - Nematodes
    - Parasitic plants
  - Hosts
  - Environment
- Conditions necessary for biotic diseases
- Disease development
- Disease diagnosis
- Plant disease management
- Fungicides for home gardeners

By Gary D. Franc, Cooperative Extension Service plant pathologist, University of Wyoming. Other material by Jay W. Pscheidt, extension plant pathologist, Oregon State University.

The Disease Triangle

Plant disease results when a specific agent such as persistent unfavorable environmental conditions or the activity of a pathogen disrupts physiological functions, causing plants to deviate from normal development. The word "persistent" is used to distinguish between a *disease* which develops over time and an *injury* which occurs, more or less, instantaneously.

Noninfectious diseases, perhaps more appropriately called *disorders,* do not spread from plant to plant. These disorders result from a plant's exposure to such factors as unfavorable weather, mechanical damage, nutrient deficiencies, excess salts, or toxic chemicals. In Wyoming, noninfectious diseases are very common due to the harsh growing environment. Although disorders can predispose plants to infection by pathogens, they are not directly treated using pesticides. The remainder of this chapter emphasizes infectious plant diseases caused by pathogens.

An infectious disease results when a *pathogen* lives in close association with a host plant. The pathogen is functioning as a parasite since such a relationship usually benefits the pathogen at the host's expense.

Although relationships resulting in disease are often complex, three critical factors must be present in order for a particular disease to result. The pathogen must be present, a susceptible host must be present, and the

continues on page 76

Disease terminology

General terms

Disease—Abnormal and harmful physiological condition brought about by living (biotic) agents such as fungi, bacteria, nematodes, or viruses or by nonliving (abiotic) factors such as nutrient deficiencies or water stress.

Dodder—A parasitic seed plant lacking chlorophyll; its thread-like yellow body twines around its host, from which it withdraws food and water.

Downy mildew—A group of fungal pathogens whose spore production looks like downy growth on the undersides of leaves.

Exclusion—A process by which certain plants are not allowed in an area to protect against pests and diseases from other areas.

Haustoria—A modified hyphal branch that grows into a plant cell to absorb food and water.

Host—A plant afflicted with a disease.

Hypha—A single filament of a fungus.

Immunity—A relationship between a plant and pathogen in which the plant does not become diseased.

Incubation—A period of development during which a pathogen changes to a form that can penetrate or infect a new host plant. Some fungi, for instance, grow a structure called a penetration peg that can grow through a plant's cell walls.

Infection—The condition reached when a pathogen has invaded plant tissue and established a parasitic relationship between itself and its host.

Inoculation—The introduction of a pathogen to a host plant's tissue.

Inoculum—The parts of a pathogen that infect plants.

Powdery mildew—A group of fungal pathogens whose spore production causes white to gray powdery mycelia on the outside of a host.

Quarantine—A regulation forbidding the sale or shipment of plants or plant parts in an area, usually to prevent disease, insect, nematode, or weed invasion.

Resistance—Qualities in a host plant that make it retard the activities of a pathogen.

Sanitation—The process of removing sources of plant pathogens from a growing area (for example, by cleaning up plant debris and sterilizing tools and growing media).

Spore—(1) The reproductive body of fungi and other lower plants, containing one or more cells. (2) A bacterial cell modified to survive in an adverse environment.

Stylet—A nematode's lance-like or hypodermic-needle-like mouthpart used to puncture and feed from plant cells.

Tolerant—A crop plant that will produce a normal yield even if diseased.

Pathogens

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

Fungus—A plant organism with no chlorophyll that reproduces via spores and usually has filamentous growth. Examples are molds, yeasts, and mushrooms.

Nematode—A microscopic roundworm, usually living in the soil; many feed on plant roots and can be disease pathogens.

Parasitic seed plant—A higher plant that lives parasitically on other seed plants. An example is mistletoe.

Disease terminology (continued)

Pathogen—A disease-producing organism.

Phytoplasma—A microscopic, bacteria-like organism that lacks a cell wall.

Virus—An infectious agent too small to see with a compound microscope; it multiplies only in living cells.

Symptoms (external or internal physical disease characteristics expressed by a host plant)

Blight—Rapid, extensive discoloration, wilting, and death of plant tissue.

Blotch—A blot or spot (usually superficial and irregular in shape and size) on leaves, shoots, or fruit.

Canker—A dead place on the bark and cortex of twigs, stems, or trunks; often discolored and either raised or sunken.

Chlorosis—An abnormal yellowish-white or gray color of plant parts resulting from incomplete destruction of chlorophyll.

Damping off—Decay of seeds in the soil or young seedlings shortly after they emerge; usually caused by *Rhizoctonia, Pythium,* or *Fusarium* fungi.

Dieback—Progressive death of shoots, branches, or roots, generally starting at the tips.

Dwarfing—The underdevelopment of any plant organ.

Enation—Epidermal outgrowths on leaves or stems.

Epinasty—An abnormal downward-curving growth or movement of a leaf, leaf part, or stem.

Etiolation—Development of yellow, long, spindly growth as a result of insufficient light.

Fasciation—A distortion of a plant that results in thin, flattened, and sometimes curved shoots.

Flagging—Loss of turgor and drooping of plant parts, usually following a water shortage.

Gall—An abnormal, localized swelling on leaf, stem, or root tissue.

Mosaic—Nonuniform foliage coloration with a more or less distinct intermingling of normal green and light green or yellowish patches.

Mottle—An irregular pattern of light and dark areas.

Necrosis—Death of plant tissue.

Phyllody—A change from normal flower structures to leafy structures.

Rot—Decomposition and destruction of tissue.

Rugose—Wrinkled.

Russet—Yellowish-brown or reddish-brown scar tissue on a fruit's surface.

Scab—A crust-like disease lesion.

Water-soaked—Lesions that appear wet and dark and are usually sunken and/or translucent.

Wilt—(1) Lack of freshness and turgor and drooping of leaves from lack of water. (2) A vascular disease that interrupts a plant's normal uptake and distribution of water.

Witches' broom—Abnormal brush-like development of many weak shoots.

Signs (physical evidence of a disease-causing agent)

Bacterial slime—A gooey or dried mass of bacterial cells that oozes out of plant tissues.

Conk—A fungal fruiting structure (e.g., shelf or bracket fungi) formed on rotting woody plants.

Cyst—The swollen, egg-containing female body of certain nematodes; can be seen on the outside of infected roots.

Fruiting body—A fungal structure that contains or bears spores.

Mycelia—Masses of fungal threads (hyphae) which compose the vegetative body of a fungus.

proper environment must be present, permitting infection of the host. These factors give the concept of the *disease triangle* (Figures 1 and 2).

Production practices followed by large growers and home gardeners serve to modify the interaction of these three factors to reduce (or unwittingly increase) the overall impact and severity of plant diseases. Plant growers use the disease triangle concept to make it easier to remember and understand how a particular disease develops and why various management strategies are used.

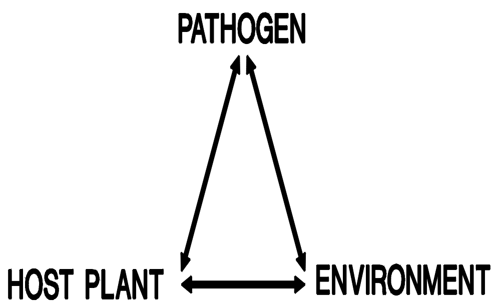
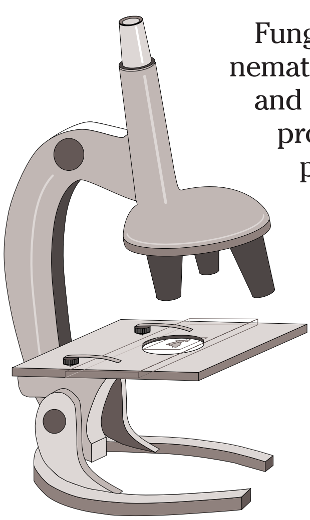


Figure 1.–The Disease Triangle. These three factors interact and must be present for disease development to occur.

The Pathogen



Fungi, bacteria, viruses, viroids, nematodes, parasitic plants (dodder and mistletoe), phytoplasmas, and protozoa are examples of various pathogens that cause plant diseases. General descriptions of the most common and economically important classes of pathogens are listed below. It is important to remember that many beneficial microorganisms exist in nature and that only a small fraction infects plants.

Fungi

Bread molds and mushrooms are examples of familiar fungi. Most of the 100,000 fungus species identified by scientists are only *saprophytes* and not capable of infecting plants. However, more than 8,000 plant pathogenic species have been identified, making fungi the most numerous and economically important class of plant pathogens. The great diversity of fungi and the complex and intricate life cycles of some plant pathogenic species make generalizations difficult.

Plant infection by fungi occurs via a great variety of mechanisms. Some species directly penetrate plant surfaces or enter through natural openings while others require wounds or injury for infection. During disease development, many species of fungi produce spores which are dispersed by wind, water, or other means. Each spore may cause a new infection, resulting in a rapid increase in disease incidence and severity. Some fungi form special resting spores which permit survival for long periods of time (several months or years) in soil or plant debris.

Fungi are identified primarily from their morphology with emphasis placed on their reproductive structures. Laboratory techniques can be used to induce sporulation in many fungi if reproductive structures are not visible on plant tissue.

Bacteria

Bacteria are perhaps the second most economically important class of plant pathogens. Bacteria are considered more primitive than fungi and generally have simpler life cycles. With few exceptions, bacteria exist as single cells and increase in numbers by dividing into two cells during a process called binary fission. Their ability to rapidly reproduce when environmental conditions are favorable gives bacteria their potential for causing an explosive increase in disease.

Some species are able to survive on healthy-appearing plant surfaces as epiphytes and only cause disease when environmental conditions are favorable or when injuries such as those caused by hail, occur. Overwintering weed hosts, infected seedstocks, or contaminated crop debris may serve as the initial source of bacterial inoculum. The presence of certain bacterial species on plant surfaces increases frost sensitivity while other species are able to move long distances in aerosols or irrigation water.

Bacterial ooze on plant surfaces or bacterial streaming can aid in the identification of bacterial diseases when working in the field. However, laboratory methods are usually required for identification.

Viruses and viroids

Viruses and viroids are extremely tiny particles consisting of protein and genetic material (viruses) or genetic material with no associated protein (viroids). Biologists sometimes disagree on whether viruses and viroids should be classified as "living" since they are true obligate parasites incapable of carrying out any physiological processes without a host.

In order for disease to spread, these particles must be physically inserted into a living host cell by vectors including insects or man, or they may be transmitted through seeds, tubers, grafts or merely by physical contact between healthy and infected plants. The method(s) of transmission for a specific virus or viroid is a characteristic of that pathogen and the disease it causes. Once inserted into a host, the physiological processes of the cell are redirected into the manufacture of more viruses or viroids. Chemical controls usually target insect vectors, and some disinfectants inactivate viruses, rendering them noninfectious.

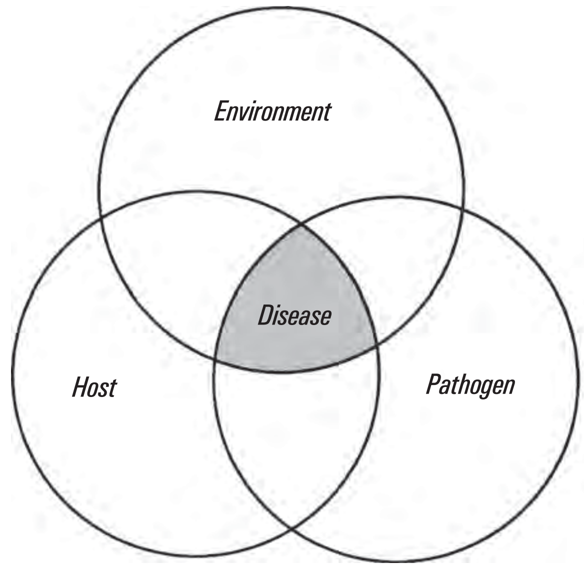


Figure 2.—Disease is a result of simultaneous interactions between the environment, host, and pathogen.

Most virus diseases are identified by characteristic symptoms coupled with electron microscopy and/or serological tests. Viroid identification requires even more specialized detection methods.

Nematodes

Nematodes are microscopic round worms that reside in the soil. Disease induced by nematodes usually results in poor plant growth and may be overlooked when there are no healthy plants available for comparison. Roots of poorly growing plants should be examined carefully for evidence of nematode feeding. Symptoms may be deformed roots or galls.

Feeding by plant-pathogenic species can cause disease by direct interference with normal plant development, by interacting with other disease causing organisms, or by acting as a vector for pathogens. Although most plant pathogenic nematodes affect only roots, some species infect stem, foliar, and bud tissues.

Parasitic plants

Some plants are parasitic to other plants. Dodder, for example, produces flowers and seeds but has no chlorophyll. Thus, it cannot manufacture its own food. It has a thread-like yellow body that twines around its host. Root-like *haustoria* penetrate the host plant and withdraw food and water. Some parasitic plants such as dwarf mistletoe manufacture chlorophyll but have no real roots and depend on their tree host (in this case, several conifer species) for water and nutrients. Seeds of parasitic plants are spread by birds or contaminated soil, or they may be shot out of plant structures like little projectiles.

Note that moss, lichens, and many other plants found on trees are not parasitic. They use trees only as a platform.

The Host

Levels of *resistance* or susceptibility of a host plant will affect disease development. Plants with high levels of resistance may appear immune or not susceptible while plants with lower levels of resistance may become infected but only allow a pathogen to develop slowly, limiting the economic impact of a disease to acceptable levels. Stress, such as that brought on by an unfavorable environment, poor fertility, or improper irrigation, will affect a host plant's ability to resist infection and, therefore, also affects disease development.

In some cases, resistance in a host is overcome by a pathogen, resulting in rapid and devastating disease development. This risk is increased if large production areas are planted to a monoculture of identical hosts. Therefore, genetic diversity of host plants will decrease the risk of catastrophic losses.

The Environment

Environmental conditions play a large role in disease development and disease severity. However, broad generalizations about environmental effects have many exceptions. The disease triangle shows that the environment influences disease development by interacting with both a host and pathogen. Furthermore, environmental stress can predispose plants to infectious disease. Several important environmental factors are given below.

Temperature

Temperature greatly influences disease development. Temperatures that are not ideal for a host plant induce stress and predispose plants to disease by lowering host resistance. This may occur for hosts determined to be resistant under normal growing conditions.

Temperature also affects the amount of inoculum available. Cold winters interrupt the disease cycle by killing pathogens or vectors that might otherwise persist until the next growing season. During the growing season, temperature will directly influence a pathogen's ability to reproduce and infect a host. This will directly affect the rate of disease development, disease severity, and whether diseased plants will develop in the first place.

Moisture

Abundant, prolonged, or repeated moisture is the predominant factor in the development of most epidemics caused by fungi, bacteria, and nematodes. Although relationships can be complex, rain, greater relative humidity, or prolonged dew periods will increase the likelihood of many but not all diseases.

Moisture affects a host by inducing new growth that may be more susceptible or resistant to infection. Moisture also induces sporulation of fungi, replication of bacteria, and mobility of nematodes, thus increasing the amount and dispersal of available inoculum. For other pathogens, rain may suppress the movement of insects acting as vectors of pathogens, thereby reducing disease spread.

Wind

Fungal spores, vectors, and, to a lesser extent, bacteria and nematodes can be dispersed by the action of wind. This will enable pathogens to move from infected plants to healthy plants. Wind can also injure hosts, providing an avenue for infection and/or increasing susceptibility to some pathogens.

Other factors

There are many factors including light intensity, light quality, soil pH, fertility, and soil type that influence disease development. Relationships can be complex with environmental influences being exerted on a host and a pathogen. Each disease must be studied carefully to determine what interactions are important for its development.

Disease diagnosis

Diagnosis requires knowledge of what is normal for a host plant as well as knowledge of problems that occurred in the past. Accurate diagnosis is critical for deciding if a disease is present and if effective management measures are available or justified. An accurate diagnosis is based on recognition of specific signs of a pathogen on a host as well as the presence of symptoms on a host.

Signs are defined as the visible presence of a pathogen or products of a pathogen on a host plant. Fungal spores, fruiting structures that bear spores, and bacterial ooze are all examples of signs. Signs, if present, greatly aid in the diagnosis of disease. In contrast, *symptoms* are the external and internal reactions or alterations of a plant as a result of disease. In other words, symptoms are a plant's responses to stress. For example, dead spots in leaves or bark, rotten spots in fruits or tubers, swellings on roots or branches, clustered branches, unnatural color or shape, and vascular discoloration in stems are all symptoms that may aid in the diagnosis of a plant disease. Symptoms are important clues for diagnosing disease but may be misleading due to overlap with similar symptoms caused by other diseases.

Because most diseases encountered have been previously characterized, it is usually possible to diagnose a specimen by comparing it with the symptoms and signs of pathogens already described for diseases of a particular host. Books, manuals, and pictures are very useful aids in the diagnosis of many plant diseases. Experienced diagnosticians recognize many diseases on sight or are able to quickly narrow down possibilities to several choices. Although experience is the best teacher, the general guidelines listed here will help focus attention on information needed for accurate diagnosis.

1. Carefully describe the characteristics that make a plant appear abnormal (symptoms).
2. Determine the distribution of symptoms in a host by looking at the *entire* plant.
3. Determine if evidence of a pathogen (signs) exists.
4. Determine the distribution of affected plants in the field.
5. Record the cropping history associated with the host.
6. Determine if any unusual weather occurred.

If diagnosis is still not possible, contact field experts or a local Cooperative Extension Service office. Specimens can be mailed to the University of Wyoming when additional assistance is required.

See Chapter 13, *Diagnosing Problems.*

Disease development

Every infectious disease requires a series of sequential events in order for it to develop. This series of events is called the *disease cycle* (Figure 3). Although the specific characteristics are unique for each disease, the general events in the disease cycle are (1) dispersal of a pathogen to a host, (2) penetration and infection of the host, (3) invasion and colonization of the host, (4) reproduction of the pathogen, (5) pathogen dispersal, and (6) pathogen survival between growing seasons and/or in the absence of a host.

The completion of the first five events constitutes one *generation* of the pathogen and, depending on the pathogen, can be repeated before the growing season ends at the last event. The generation time and the number of generations a pathogen completes during one season determine the dynamics of disease development and the potential for plant or crop loss. Graphic representations of disease severity over time are called *disease progress curves* and are discussed below for Figures 4, 5, and 6.

Monocyclic pathogens have a maximum of one generation per growing season and possess a characteristic disease progress curve (Figure 4). Pathogens are monocyclic because environmental conditions or other physical factors prevent repeating the first five events until the next growing season.

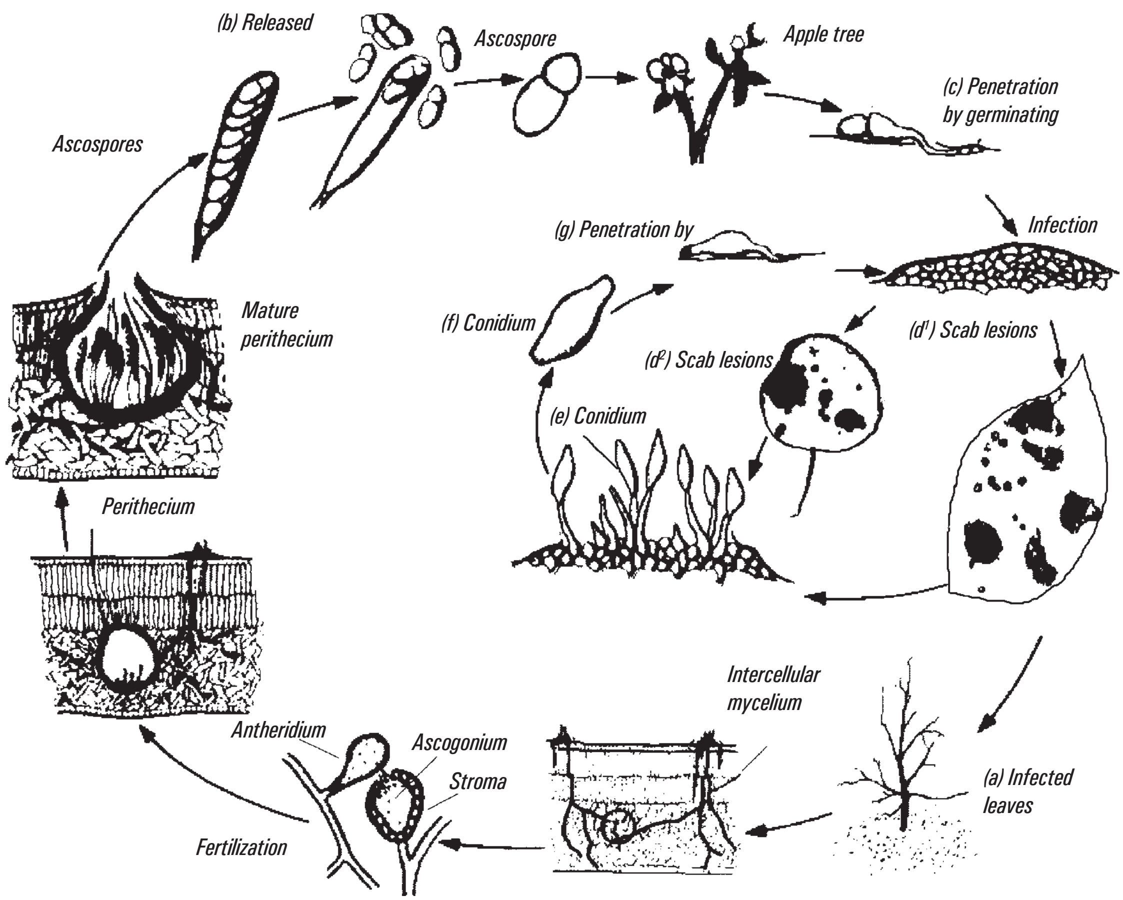


Figure 3—Disease cycle of apple scab: Overwintering fungi (a) produce sexual spores (b) that penetrate and infect trees in the spring (c). Soon scab lesions appear (d^1), within which asexual spores (e) are produced. These spores are released (f) and drift onto healthy tissue (g) where they cause more scab lesions (d^1 and d^2) and produce more spores (e) The cycle then begins again.

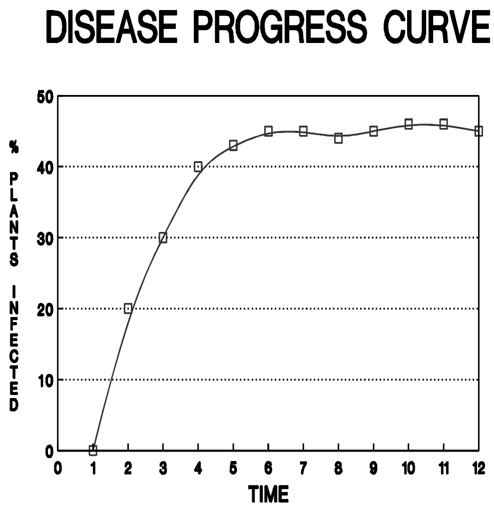


Figure 4. Monocyclic disease progression within a plant population. Time can be days, weeks, or months.

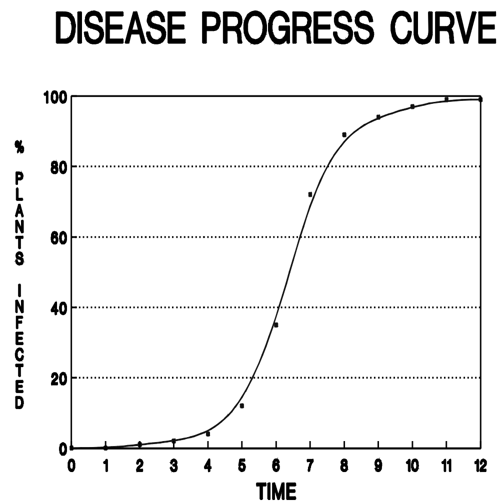
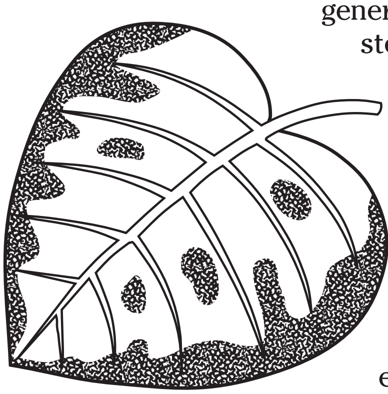


Figure 5. Polycyclic disease progression within a plant population. Time can be days, weeks, or months.

Examples are *Verticillium* wilt and some other soil-borne diseases. Other pathogens are monocyclic because their life cycle requires at least one season to complete; examples are cedar-apple rust and corn smut.

Polycyclic pathogens complete more than one generation per growing season and therefore are able to reproduce and infect additional healthy plants during the current growing season (Figure 5). As the potential for the number of generations increases (i.e., the generation time decreases), so does the potential for major loss. Some fungi have such short generation times that steps in the cycle of pathogenesis completely overlap, resulting in a continuous series of new infections giving the appearance of explosive disease development. Examples of polycyclic pathogens can be found in virtually all classes of pathogens including fungi, bacteria, nematodes, and viruses. Several examples are early and late blight of potatoes, apple scab (Figure 3, Steps d through g), and wheat and bean rust.



The time over which disease develops in a production area or region for both monocyclic and polycyclic diseases can vary from days to years and is a characteristic of the specific disease involved. Severe losses can occur regardless of the speed at which disease develops and can result from both monocyclic and polycyclic pathogens.

Plant disease management

Management measures are used to interrupt or weaken at least one of the six sequential events in the disease cycle by affecting the host plant, the environment, and/or the pathogen (see Figures 4 and 5) . In general, monocyclic diseases are most efficiently suppressed by reducing the amount of the initial inoculum at events one and/or six. Polycyclic diseases are most efficiently suppressed by reducing the initial inoculum and/or by reducing the rate of disease increase that occurs when events one–five are repeated. Various management methods commonly used to reduce or eliminate disease are categorized below; much overlap exists between categories.

Exclusion

The disease triangle illustrates that if a pathogen and host remain separated, no disease will develop. Disease management methods that maintain separation can be very effective. However, this approach to disease management is largely regulatory in nature and includes quarantines, inspections, use of pathogen-free plant materials, certification of seed stocks, and other means to exclude the pathogen.

Evasion

The use of healthy seed, planting and growing plants under environmental conditions unfavorable for disease development, selecting early (or late) planting and harvest dates, and maintaining the proper distance between rows and fields are all examples of methods for evading disease. These practices increase the chance that a host will remain healthy or go through its susceptible stage before a pathogen reaches it.

Eradication

Eradication is the elimination or destruction of a pathogen. Methods of eradication include temporary removal and destruction of host plants, chemical treatment of soil or seeds to kill a pathogen, and sanitation of equipment and storages. Flooding fields during the fallow period may also reduce the incidence of some diseases caused by soil borne organisms. Growers routinely practice crop rotation by growing a non-host plant to reduce the amount of inoculum present to acceptable levels.

Resistance

Resistance is the growing of plants not susceptible to a disease. Resistant cultivars are usually developed through special breeding and selection programs. Immunity or total resistance is often unobtainable, and many varieties have partial resistance that allows a plant to grow in spite of contact with a pathogen.

See Chapter 16, *Pruning.*

Environmental modification

Creating conditions unfavorable for infection and disease development is a practical disease management method used by some growers (Table 1). Proper spacing of plants in a field or greenhouse will aid in reducing the humidity that favors development of some diseases. Good soil drainage and proper irrigation practices are also important. Environmental modification by drying and/or refrigeration of harvested products is one of the most common methods used to slow growth of pathogens and reduce disease.

Protection

Infection of plants may be reduced through *prophylaxis* or protection. Although biological control agents are used in some instances to protect plants from infection, the most common method to directly or indirectly protect plants from pathogens is through the careful use of plant protection chemicals (plant medicines).

Chemical controls

Chemicals or *pesticides* are often used to help manage plant diseases. The correct timing of chemical applications as well as choosing the proper chemical is essential for good management. Labels are legal documents that provide application information, and these directions must be followed.

Fumigants and sterilants

These chemicals generally have a broad range of activity but are not applied to growing plants. Soil fumigation is commonly used to reduce nematode populations as well as other soil-borne pathogens and pests.

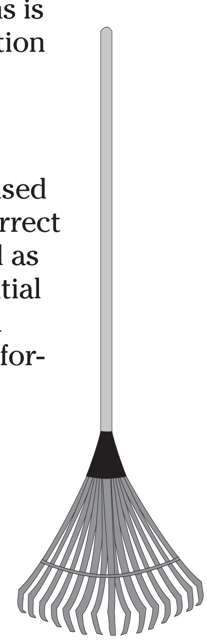


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Table 1.—Plant families for rotations.

Plant family	Some common genera	Common name of popular flowers and vegetables
Amaranthacea	*Celosia* spp.	Cockscomb
Apiaceae	*Apium* spp., *Coriandrum* spp., *Daucus* spp., *Foeniculum* spp., and *Pastinaca* spp.	Carrot, celery, cilantro, fennel, parsley, and parsnip
Apocynaceae	*Catharanthus* spp.	Madagascar periwinkle
Asteraceae	*Ageratum* spp., *Brachycome* spp., *Calendula* spp., *Callistephus* spp., *Centaurea* spp., *Coreopsis* spp., *Cosmos* spp., *Dimorphotheca* spp., *Gaillardia* spp., *Gomphrena* spp., *Helianthus* spp., *Helichrysum* spp., *Lactuca* spp., *Senecio* spp., *Tagetes* spp., *Taraxacum* spp., and *Zinnia* spp.	African daisy, calliopsis, China aster, chrysanthemum, cineraria, cornflower (bachelor's button), cosmos, dandelion, floss flower, globe amaranth, Jerusalem artichoke, lettuce, marigold, pot marigold, sunflower, strawflower, Swan River daisy, and zinnia
Balsaminaceae	*Impatiens*	Impatiens
Boraginaceae	*Myosotis* spp.	Forget-me-not
Brassicaceae	*Brassica* spp., *Lobularia* spp., and *Matthiola* spp.	Broccoli, brussels sprout, cabbage, candytuft, cauliflower, daikon, flowering kale, horseradish, kale, kohlrabi, mustard green, radish, rutabaga, stock, sweet alyssum, turnip, and watercress
Campanulaceae	*Campanula* spp. and *Lobelia* spp.	Bellflower, cardinal flower, and lobelia
Caryophyllaceae	*Dianthus* spp. and *Gypsophila* spp.	Dianthus and baby's breath
Chenopodiaceae	*Beta* spp. and *Spinacia* spp.	Beet, spinach, and Swiss chard
Convolvulaceae	*Convolvulus* spp. and *Ipomoea* spp.	Morning glory and sweet potato
Cucurbitaceae	*Citrullus* spp., *Cucumis* spp., and *Cucurbita* spp.	Cucumber, gourd, honeydew melon, muskmelon, pumpkin, squash, watermelon, and zucchini
Dioscoreaceae	*Dioscorea* spp.	Yam
Dipsacaceae	*Scabiosa* spp.	Pincushion flower
Fabaceae	*Glycine* spp., *Lathyrus* spp., *Phaseolus* spp., *Pisum* spp., and *Vigna* spp.	Lima bean, mung bean, pea, snap bean, soybean, and sweet pea
Lamiaceae	*Salvia* spp.	Sage
Liliaceae	*Allium* spp. and *Asparagus* spp.	Asparagus, chive, garlic, leek, onion, and shallot
Malvaceae	*Abelmoschus* spp. and *Lavatera* spp.	Mallow and okra
Papaveraceae	*Eschscholzia* spp. and *Papaver* spp.	California poppy and poppy
Plumbaginaceae	*Limonium* spp.	Sea lavender and statice
Poaceae	*Zea* spp.	Corn

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Table 1.—Plant families for rotations (continued).

Plant family	Some common genera	Common name of popular flowers and vegetables
Polygonaceae	*Rheum* spp.	Rhubarb
Primulaceae	*Primula* spp.	Primrose
Ranunculaceae	*Consolida* spp.	Annual delphinium and larkspur
Rosaceae	*Fragaria* spp.	Strawberry
Scrophulariaceae	*Antirrhinum* spp., *Diascia* spp., *Linaria* spp., *Mimulus* spp., and *Nemesia* spp.	Monkey flower, snapdragon, toadflax, and twinspur
Solanaceae	*Browallia* spp., *Capsicum* spp., *Lycopersicon* spp., *Nicotiana* spp., *Salpiglossis* spp., *Schizanthus* spp., and *Solanum* spp.	Amethyst flower, butterfly flower, eggplant, nicotiana, painted tongue, pepper, petunia, potato, and tomato
Tropaeolaceae	*Tropaeolum* spp.	Nasturtium
Verbenaceae	*Verbena* spp.	Verbena
Violaceae	*Viola* spp.	Pansy and violet

See Chapter 20, *Propagation.*

Total eradication of pathogens and pests is generally not possible. Fumigants are typically expensive, difficult to apply, highly toxic, and nonselective in their activity. Therefore, beneficial microorganisms and insects are affected as well.

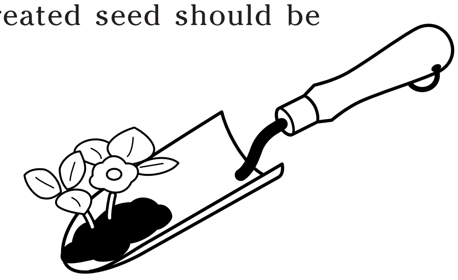
Proper soil preparation, soil moisture (approximately 70 percent field capacity), and soil temperature (55-85º F) are critical for achieving uniform chemical distribution and effective disease management. Methyl bromide and chloropicrin are highly volatile fumigants, and plastic sheeting is required to seal the soil surface during their application. In contrast, metham sodium is less volatile, and water can be used to seal the soil surface. Label directions will give precise directions on the soil conditions required and suitable application methods.

Nematicides

Fumigants are considered nematicides. However, other liquid and granular chemical formulations in addition to fumigants are available for nematode control. These products have low volatility and can be applied before and after planting many particularly nonfood crops. Nematicides kill nematodes that come in contact with the chemical and may kill some insects as well. Nematicides are generally highly toxic and may contaminate ground water when not used properly.

Seed treatments

Seed treatments are typically fungicides that protect a seed and germinating seedling from early infection and/or decay. Pathogens can be seed borne or soil borne. Some advantages of seed treatments are that small amounts of chemicals are required and that seedlings are able to get off to a strong start. Because treated seed is not to be used for feed, food, or processing, dyes are used to color treat seed, and treated seed should be



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How to discourage plant diseases in a garden

- **Select a suitable location for planting.** Some plants like sunny locations; others prefer more shade. Avoid extremely wet and/or cold soils because they favor many root disorders. If it is necessary to plant in such areas, select plants that tolerate these conditions.
- **Practice annual rotation.** If possible, change the planting location of specific plant families each year (see Table 1) to help prevent the buildup of disease-causing organisms.
- **Select disease-resistant varieties** if they are available and adapted to the growing conditions.
- **Use only disease-free seed and transplants.** Many disease-causing organisms are carried to gardens on seeds and transplants. Buy from a reputable source. Throw away any rotted or poorly growing plants or plant parts.
- **Maintain correct soil fertility and pH** through careful use of fertilizers, lime, soil amendments, compost, etc. Plants that are too weak or too vigorous as a result of improper fertilization are more subject to diseases.
- **Do not crowd plants.** High humidity beneath a plant canopy may favor certain diseases. Thin plants to permit free air movement.
- **Water properly.** Try to maintain an even water supply and avoid dry-wet fluctuations in the soil environment. Drip systems and soaker hoses are preferred to overhead sprinklers. To encourage quick drying of foliage, water early in the morning instead of in the evening, especially if using an overhead system.
- **Control insect pests.** Some insects spread certain viral and bacterial diseases.
- **Destroy and remove diseased plants or diseased plant parts** as soon as they are observed. They may be a source of pathogens that can spread to other plants.
- **Spade under or compost crop refuse** as soon as possible after harvesting a garden. This practice not only recycles organic matter to the soil but also reduces the possibility of disease-causing organisms overwintering in a garden. Add diseased plant parts to the compost pile only if “hot” composting. Generally, if plant parts have decayed sufficiently so that they are no longer recognizable, most pathogens will have been released and will not survive.
- **Be alert to leaf diseases** that occur annually on certain plants. Take care of them early before damage becomes so severe that a plant is lost.

See Chapter 2, *Soils and Fertilizers.*

See Chapter 3, *Entomology,* and Chapter 14, *IPM.*

See Chapter 15, *Composting.*

properly labeled. An exception is the treatment of high moisture grains with acetic or propionic acid. Acid-treated grain is commonly used for livestock feed.

Protectants

These chemicals are usually applied to the seed or foliage of a growing crop so that a protective chemical barrier over a host surface prevents an initial infection. These products must not be toxic to a host.

See Chapter 19, *Pesticides.*

Systemics

These are applied to a seed or growing crop and are often absorbed and transmitted systemically within a plant. These substances may kill or suppress a pathogen growing within host tissue and, therefore, may have a curative or therapeutic effect. Some systemics have very selective activity and, through repeated use, become ineffective due to selection for insensitive pathogen isolates.

Integrated methods

Frequently, a number of management methods are *integrated* or used simultaneously to reduce the economic loss of plant diseases. Relying on a single method for disease management frequently results in failure. Integrated methods can reduce costs associated with more expensive management methods and decrease the risk associated with dependence on a single method of management. An added benefit of integrated methods is that disease management is generally greater than for each method used individually (Figure 6).

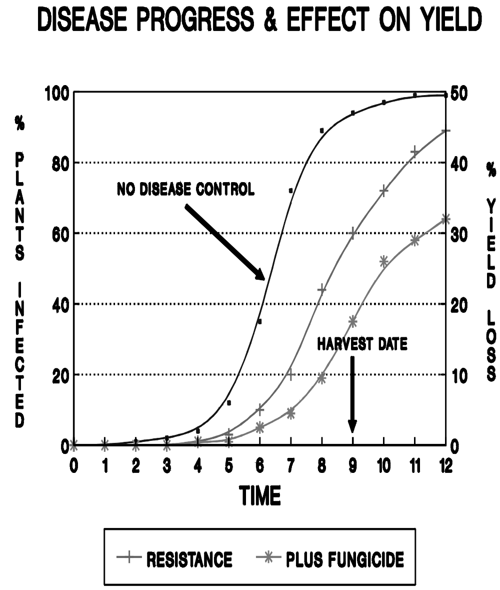


Figure 6. Integrated control methods (resistance plus fungicide curve) are often more effective for disease control than relying on a single method (resistance).

Fungicides for home gardeners

Many fungicides are registered for use on plants, but only a few are readily available to gardeners. Although many others are neither highly toxic nor restricted in use, they may be difficult to obtain in small quantities.

Some fungicides such as sulfur and copper products are allowed under organic growing guidelines. Others such as captan, triforine, and chlorothalonil are not considered organic.

The label is the law. Always follow the label directions. To do otherwise is illegal.

There are, however, a few exceptions. For example, if a label says to use a certain amount of product, do not use more. However, if experts recommend using less, that is acceptable. Never use a product on a plant that is not listed on the label. However, if an expert recommends using the product for a disease that is not on the label, it is acceptable to do so as long as the plant is on the label.

One needs to understand a pathogen's disease cycle and host susceptibility to get good control using fungicides. Proper timing, coverage, and selection of fungicides are also important.

Many fungicides work by protecting healthy plant tissues. Captan, copper, chlorothalonil (Daconil), and sulfurs must be present before fungi arrive. Although some fungicides are locally *systemic* (they move inside the plant), they must be applied soon after (or before) infection for maximum benefit. None of these fungicides can revive heavily diseased plants or make diseased plants appear healthy.

Some fungicides work better when a *spreader sticker* is mixed with the solution. This material helps the fungicide stay on a plant longer or spread over a leaf surface better. Most wettable powder formulations benefit from the addition of a spreader sticker. Liquid formulations usually already contain such compounds.

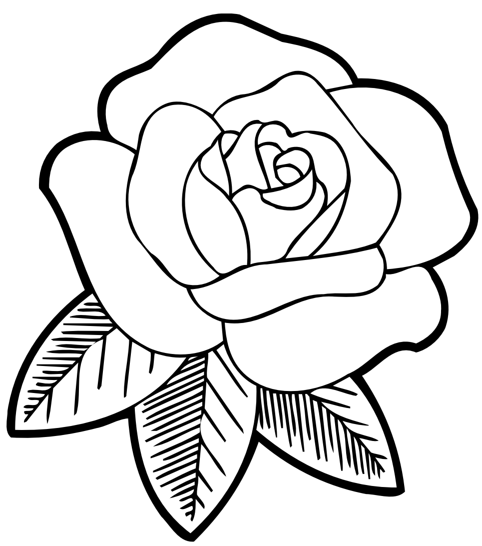
For more information

University of Wyoming Cooperative Extension Service publications

Snow Molds of Turfgrass (B-868)
Backyard Composting: Simple, Small-Scale Methods (B-974R)
Landscape Pests: Integrated Pest Management Strategies for Controlling the Dastardly Dozen (B-1035)
Bacterial Diseases of Beans (B-1056)
Iron Deficiency Chlorosis on Woody Landscape Plants in Wyoming (B-1097)
Dwarf Mistletoes Affecting Pines and Firs of Wyoming (B-1083)

Other references

Insects and Diseases of Woody Plants of the Central Rockies (Colorado State University Cooperative Extension Bulletin 506A, 2000), 283 pp.
Sunset Western Garden Problem Solver (Sunset Books, Inc., Menlo Park, CA, 1998), 320 pp.



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Weed Management

5

Many things grow in the garden that were never sowed there.
Thomas Fuller, *Gnomologia,* 1732

Every garden has weeds, and every gardener wonders what to do about them. This chapter will explore the origin of weeds, their adaptations and impacts, and the techniques one can use to manage weeds in a landscape.

Topics in this chapter

- Why are weeds a problem?
- Why do gardeners all have weeds?
- Weed identification
- Weed life cycles
- Weed competition
- Managing weeds

Why are weeds a problem?

The plants called weeds are aggressive, pushy, in-your-face plants. There are no shrinking violets in this group. This is not to say that they don't have some redeeming qualities because many weeds have a substantial set of virtues. However, these virtues often are overwhelmed by their "weedy" attributes.

The most useful definition of a weed is quite simply "a plant out of place." This clearly makes how one categorizes weeds to be dependent upon personal perspectives and management goals for given situation. A more formal definition is "any plant that is objectionable or interferes with the activities or welfare of humans." A plant may be defined as a weed in some cases and not in others. Clover can be a valuable addition to a pasture and is viewed with tolerance in many lawns. But a park manager faced with reducing liability due to bee stings may feel compelled to remove clover in some parts of the park. Millet seeds from a bird feeder that sprout in a perennial flower bed are weeds in that context, but millet is an important crop in Wyoming.

Weeds can cause a range of problems in a garden or community. They can:

- Compete with desirable crops
- Reduce the aesthetic qualities of a landscape
- Obstruct sight lines on roadways
- Interfere with water drainage from roads and low-lying communities

By Chip Bubl, Extension agent, Columbia County, Oregon State University. Adapted for Wyoming by Stephen Enloe, Cooperative Extension Service weed specialist and Tom Whitson, retired Cooperative Extension Service weed specialist, University of Wyoming.

- Create a fire hazard along railways and next to power substations, homes, and other structures
- Present allergy or poison hazards for humans or animals (through skin contact, ingestion, or inhalation)
- Harbor diseases, rodents, and insect pests
- Impart off flavors to water, milk, and some crops.

Why do gardeners all 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 their food, fiber, and medicinal characteristics. Yet the very practices that favored growth of the earliest crops inadvertently encouraged other plants that were also favored on plowed soil. Many of these plants became very aggressive competitors on farms and in gardens.

As agricultural practices and products spread to distant parts of the earth, plants now called weeds extended their range. In each area, native plants that liked tilled ground were added to the weed inventory and moved well beyond their original habitat. It is amazing how many of "our" weeds are equally well known in Asia, Europe, Africa, and South America. Table 1 shows the original home of some of the most common weeds in the western U.S.

Many weeds traveled the world in feed and seed, on equipment, in ships' ballasts, as mattress filler, or in the bellies of domesticated animals. In addition, many plants that once had value as food, fiber, medicine, or ornamentals stayed around to become a nuisance long after their usefulness had diminished. Once weeds get a foothold in a new area, they may spread rapidly by way of wind, water, animals, trade goods, equipment, seed hay, mulch, or gravel.

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 may be leaving their natural enemies behind. Saltcedar was imported for windbreaks and ornamental plantings. It now grows rampant along Wyoming waterways, choking out native vegetation. Purple loosestrife was planted as a pond ornamental. 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 remove them completely. Instead, gardeners must live with them and work to lessen their negative impacts. Fortunately, new techniques offer a range of options to achieve that goal.

Table 1.—Origin of Wyoming weeds.

Weed species	**Origin**
Horsetail	Native
Spotted knapweed	Eurasia
Canada thistle	Eurasia
Pigweed	Tropical Americas
Dalmatian toadflax	Europe
Field bindweed	Europe
Purslane	India
Smartweed	Europe
Common chickweed	Europe
Dandelion	Europe
Kochia	Eurasia
Downy brome grass	Europe
Quackgrass	Mediterranean
Barnyardgrass	Eurasia
Crabgrass	Europe
Poison-ivy	Native

Weed identification

Accurately identifying a plant that is causing problems in a landscape is the first step toward a good management plan. Fortunately, the list of weeds that cause most problems is surprisingly short. Often, a little time spent with a good reference (such as *Weeds of the West*) will help put a name to some of the challenging plants that can be encountered. It might be helpful to give some of the worst weeds specific nonsense names prior to establishing a more accurate identification. Then it is easy to mesh new knowledge with an old identification.

Weed books usually classify plants first into two groups and a miscellaneous category:

- *Monocots* (Figure 1) include grasses, lilies, and the like.
- *Dicots* (Figure 2) are broadleaf species.
- "Other" weeds include mosses, horsetails, and ferns (Figure 3).

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, *species*.

Scientific (botanical) names are in Latin and list 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. When common names are used they should be standardized with the Weed Science Society of America to avoid confusion.

One doesn'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 a plant is known, one can gather important details about its life cycle and how it spreads within the landscape or garden. With practice, one can learn to distinguish weed seedlings from planted vegetables and flowers.

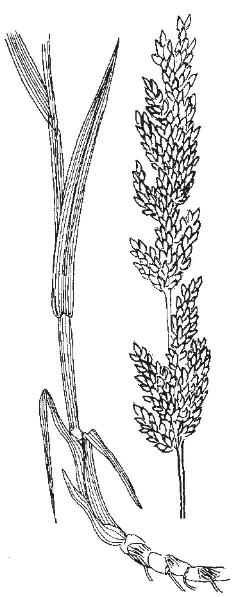


Figure 1.—Reed canarygrass (Phalaris arundinacea)*, an example of a monocot.*

Figure 2.—Little bittercress (Cardamine oligosperma)*, an example of a dicot.*

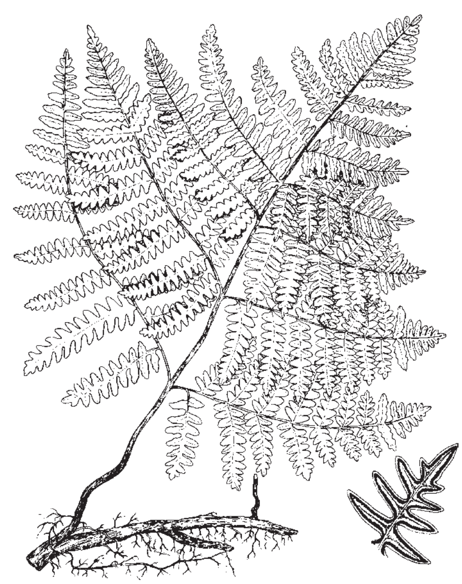


Figure 3.—Western bracken fern (Pteridium aquilinum).

Table 2.—Weeds classified by life cycle.

Common name	Botanical name	Common name	Botanical name
Annual weeds		**Perennial weeds**	
Grass weeds		***Grass weeds***	
Annual bluegrass	*Poa annua*	Quackgrass	*Elytrigia repens*
Barnyardgrass	*Echinochloa crus-galli*	Bermudagrass	*Cynodon dactylon*
Downy brome	*Bromus tectorum*	***Broadleaf weeds***	
Crabgrass	*Digitaria sanguinalis*	Blue flowering lettuce	*Lactuca pulchella*
Witchgrass	*Panicum capillare*	Buckhorn plantain	*Plantago lanceolata*
Broadleaf weeds		Canada thistle	*Cirsium arvense*
Common chickweed	*Stellaria media*	Creeping buttercup	*Ranunculus repens*
Common groundsel	*Senecio vulgaris*	Curly dock	*Rumex crispus*
Common lambsquarters	*Chenopodium album*	Dalmatian toadflax	*Linaria dalmatica*
Common mallow (Cheese plant)	*Malva neglecta*	Dandelion	*Taraxacum officinale*
Common purslane	*Portulaca oleracea*	Field bindweed (Field morningglory)	*Convolvulus arvensis*
Mayweed chamomile (Dog fennel)	*Anthemis cotula*	Leafy spurge	*Euphorbia esula*
Kochia	*Kochia scoparia*	Poison-oak	*Rhus diversiloba*
Ladysthumb	*Polygonum persicaria*	Red sorrel	*Rumex acetosella*
Pineapple weed	*Matricaria matricarioides*	Russian knapweed	*Acroptilon repens*
Prostrate knotweed	*Polygonum aviculare*	Spotted knapweed	*Centaurea maculosa*
Redroot pigweed	*Amaranthus retroflexus*	St. Johnswort	*Hypericum perforatum*
Redstem filaree	*Erodium cicutarium*	**Other weeds**	
Russian thistle	*Salsola kali*	Horsetail	*Equisetum arvense*
Shepherdspurse	*Capsella bursa-pastoris*	Yellow nutsedge	*Cyperus esculentus*
Biennial broadleaf weeds			
Houndstongue	*Cynoglossum officinale*		
Musk thistle	*Carduus nutans*		
Bull thistle	*Cirsium vulgare*		
Common mullein	*Verbascum thapsus*		
Wild carrot (Queen Anne's lace)	*Daucus carota*		

Note: This list is not exclusive. It does include many of the most common weeds that gardeners should recognize.

Weed life cycles

Most gardens have a mix of annual and perennial weeds, with a few biennials thrown in to keep things interesting. By understanding the life cycle of troublesome weeds, one can begin to make intelligent decisions about control strategies. Later sections of this chapter examine some of the management strategies that can make gardening easier.

Table 2 lists some of our worst weeds by common and botanical name. It also shows their life cycles.

Annuals

Annuals go from seed to seed in less than one year, often in periods as short as 45 days. Once they have shed their usually prodigious quantities of seed, the plants die. As one might suspect, there are lots of annual weeds since their growth habit parallels the agricultural cropping pattern.

Annual weeds can be found throughout the gardening year. There are both winter annuals and summer annuals.

Winter annuals germinate in late fall through early spring and go to seed in spring/early summer. Some common examples include mustards, downy brome, annual bluegrass, and common chickweed (Figure 4).

Summer annuals get started in the spring and summer and go to seed in the summer and fall. Many of the most annoying weeds are in this group, including crabgrass, pigweed, purslane, puncture-vine, and lambsquarter. 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.

Figure 4.—Common chickweed, an example of an annual weed.

Figure 5.—Tansy ragwort (Senecio jacobaea)*, an example of a biennial weed.*

Biennials

Biennial species are less common (Figure 5). They take more than one year but less than two to complete their life cycle. Most start from seed in the 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 the livestock-poisoning weed houndstongue.

Perennials

These weeds are often 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 seeds and often from roots, tubers,

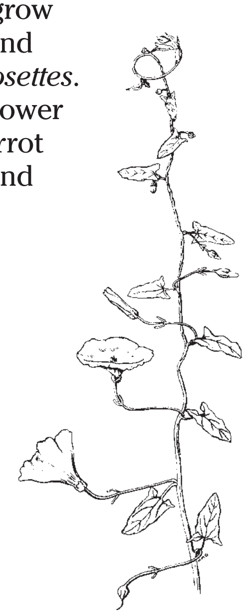


Figure 6.—Field bindweed (Convolvulus arvensis)*, an example of a perennial weed.*

bulbs, and rhizomes as well. Tilling perennial weeds often spreads them, and mulches may have little impact. Weeds in this group include quackgrass, poison-oak, Canada thistle, field bindweed (Figure 6), and horsetail (Figure 7).

Weed competition

Gardeners work to create landscapes that provide food and are a source of beauty. Weeds can disturb the appearance of a landscape and supress desirable plants. A vegetable garden is supposed to produce lots of good vegetables. This can be difficult when weeds gain the upper hand.

Most garden soils contain a lot more weed seeds than vegetable or flower seeds. Studies on commercial vegetable farms show that viable weed seed populations in the top 6 inches of soil average 900 per square foot, with some fields having in excess of 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 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.

Weeds compete directly with garden plants for light, nutrients, and water. A successful weed grows aggressively to capture whichever resource is in the 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 give some eye-opening results (Table 3).

Table 3.—Vegetable yields in weeded and unweeded plots.*

	Yield	
Crop	**Weedy**	**Nonweedy**
Carrots	27.9 lb	503.3 lb
Beets	45.9 lb	240.3 lb
Cabbage	129.1 lb	233.6 lb
Onions	3.6 lb	67.7 lb
Tomatoes	23.2 lb	164.2 lb
Potatoes	52.7 lb	148.3 lb

*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.

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 at least a certain leaf area to produce a marketable crop while others (e.g., potatoes and artichokes) can send up new shoots and recover to produce a near-normal yield if weed competition is removed early enough.

Some characteristics that help weeds compete include:

- 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 rapidly germinate with the onset of favorable conditions
- Ability to thrive in disturbed or bare soil

Rapid root and top growth

Weeds grow quickly to capture sunlight, water, space, and nutrients. They can often alter their branching pattern, leaf size, and leaf orientation to win the battle for light. Weed root growth can stunt crop roots in moisture-short soil.

Sophisticated reproductive strategies

Gardeners know that weeds can produce tremendous numbers of seeds. Weeds 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 be able to germinate. Lotus seed in Manchurian lakebeds has germinated 1,000 years after the seed was produced. Common lambsquarter seed dug from ancient Egyptian tombs has germinated. Table 4 shows weed seed production and survival rates under optimal conditions. Most weed seeds are long gone before they reach these ages. Nevertheless, as the saying goes, one year of weeds leads to seven years of hoeing.

Chemical warfare between plants

Some weeds, especially some herbaceous perennials, 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 Russian and spotted knapweeds, quackgrass, Canada thistle, pigweed, kochia, purslane, and smartweed.

Table 4.—Weed seed production and seed survival in soil.

Weed species	Number of seeds per plant	Seed survival (years)
Spotted knapweed	1,100	17
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.

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 one's personal gardening philosophy.

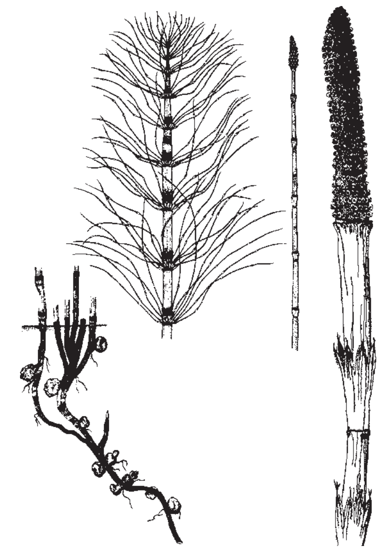


Figure 7.—Field horsetail (Equisetum arvense).

In the broadest sense, weed management strategies have three objectives:

- To prevent the introduction of new weeds
- To discourage weeds so they can't compete with desired plants
- To stop weeds from going to seed, thus reducing over time the weed seed burden in the soil

Prevention

While most garden soils already have many weeds present and other weed seeds can be blown in, the alert gardener can take some steps to prevent the introduction of new weeds. Check any soil to be hauled in. Look for signs of field bindweed, which will cause years of agony if it finds the landscape.

Watch container plants from nurseries, garden exchanges, or 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 the landscape.

See Chapter 10, *Vegetables*.

Finally, cultivate a relationship with neighbors that allows for a coordinated approach to managing creeping perennial weeds such as spotted knapweed, Dalmatian toadflax, field bindweed, and Canada thistle.

Cultural and mechanical control

The alert gardener looks for opportunities to reduce the impact and spread of weeds. This section looks at ways to achieve those goals without herbicides.

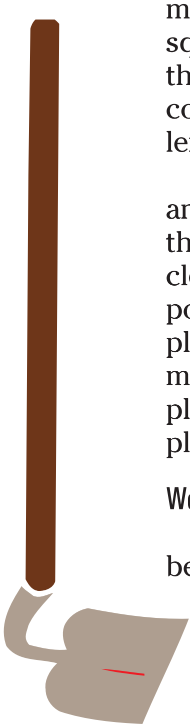
Gardening involves lots of small decisions that can have a cumulative effect on weed problems. Working from the premise that weeds thrive in disturbed ground, one can manipulate the landscape in ways that reduce weed success. These techniques are called cultural control methods. Several are discussed below.

Rotation

Rotating a vegetable garden 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 clean up 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 raises the soil temperature, killing many weed roots and seeds. Leave the plastic on through August. The area can be planted in the fall or next spring.

Weeding



Cultivating soil to control weeds has been practiced for thousands of years. Agricultural yields improved tremendously when cultivating equipment became widely available.

Advantages: A germinating weed is very vulnerable to root disturbance from hoeing, hand pulling, or rototilling. A secondary benefit of tilling is that it helps break up soil crusts that may limit vegetable or flower seedling growth. Tilling and hand pulling are normally gardeners' first weapons in the weed wars. A sharpened hoe makes for more effective weeding.

Recent technology has improved the quality of flame equipment used for weed control. These tools work well on small annual weeds but are less effective on established perennial plants. Be careful when using open flame in a yard.

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. Also, tilling brings new weed seeds to the surface. In addition, excessive cultivation destroys soil tilth and causes compaction, a result of weight applied by equipment, etc. Some plant compounds are toxic to the skin, so one should wear gloves when hand weeding.

When tilling, take care not to damage desirable plants' roots.

Bed planting

In this method of garden arrangement, planted areas are designed with untilled sections between them. Soil tillage is reduced, and mulches are used extensively. Flower or vegetable crops are often planted close together to compete against weeds. Shading is effective in preventing some weed species from germinating. Transplants are used extensively.

Advantages: The reduction in tillage reduces the number of weed seeds brought to the surface. Leaving untilled areas (either in sod or heavily mulched) reduces the area that needs to be managed for weeds.

Disadvantages: Most of the work (tillage and weeding) must be done by hand. Some gardeners plant too thickly and stunt their crops much as weed competition would have done.

Using transplants

Vegetables or flowers can be started in a cold frame or greenhouse and set out into a freshly worked garden.

Advantages: The transplant has a head start against germinating weed seeds and, if managed well in the transplanting process, should effectively compete against many weeds. This can be one of the best weed management strategies.

Disadvantages: It takes time and planning to produce transplants or money to purchase them. Also, not all plants transplant well.

Mulches

Mulching may help suppress weeds. 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 during both winter and summer for year-round weed control. Mulch materials may be home generated or purchased; however, purchased materials can be somewhat expensive.

Advantages: If used effectively, mulches reduce weed-pulling time significantly. When bare soil is covered, many weed seeds either won't germinate or can't grow through mulch. Also, when mulching is used instead of hoeing or rototilling, fewer weed seeds are brought to the surface. Done correctly, mulching can also cool the soil and conserve soil moisture.

Disadvantages: Mulches are not without problems. If organic mulches are applied too thickly, they may produce acids that can hurt plants.

In general, plastic mulch is not the best choice for woody landscape beds. Around most woody plants, the inability of plastic mulches to "breathe" can create a zone of lifeless soil that often leads to root disease problems.

Synthetic mulches are generally covered with an organic mulch to improve their appearance. However, over time weed seeds blow in and often germinate in the organic material on top of the weed barrier, thus reducing weed control. In addition, both plastic and landscape fabrics can give shelter to vertebrate pests.

Mulches for woody landscapes

Annual 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 spring weed problems.

Landscape fabrics are better than plastic mulches in a woody landscape bed since water and air can pass through them. Although more expensive, laminated fabrics are porous, allowing water to pass through and preventing roots from penetrating. When choosing a fabric, make sure it cannot be broken or stretched. Easily perforated fabrics are not effective.

Mulches for annual gardens

Plastic mulch does have a place in annual vegetable and flower gardens. It is usually used with drip irrigation and bed planting. Make slits in the plastic and place transplants next to the water source. Add fertilizer to the soil prior to transplanting or later through the irrigation system. Dispose of the plastic after the growing season.

Be sure to stretch the plastic tightly over the soil surface to get the benefits of soil warming as well as weed control. Black plastic is preferred for weed control because it reduces light to the soil, thus preventing weed growth. Clear plastic is sometimes used where there are few weeds.

Landscape fabrics can be used in the same way, but since they allow moisture to pass through, they don't require a drip irrigation system. However, they are thicker than plastic and tend to cool the soil instead of warming it. This can be a problem for crops such as tomatoes, peppers, and melons, which require very warm soil.

Organic mulches

For most vegetable and flower garden situations, organic mulches are the best choice. Organic mulches tend to improve the soil as they break down. Winter mulches can be pulled back or tilled in before planting in the spring. A few types of leaves such as walnut can inhibit the growth of some plants and seeds. 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. Organic mulches can cause nitrogen deficiency as they decompose.

Water management

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 those with drip irrigation, much of the garden stays dry. In those drier areas, weed problems are much reduced. Drip systems are often combined with bed planting and/or plastic mulches in vegetable and annual flower plots.

Advantages: Drip systems are excellent tools for reducing weed growth and are fairly easy to set up.

Disadvantages: Despite improvements and reduced costs in modern systems, drip systems can still be costly to install and complicated to maintain. In some cases, they might not provide an adequate zone of moisture for desirable plants.

Competitive plantings

In permanent landscape areas, it is often best to eliminate bare areas underneath 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 can now choose mixes that include certain broadleaves (e.g., clover) with good lawn character. These mixes tend to repel some of the weedier broadleaf species.

Advantages: The landscape can be more visually interesting, and over time the need for weeding is reduced.

Disadvantages: There is a cost to establishing plants. Also, if a woody landscape area is underplanted with herbaceous perennials, one can't use certain herbicides (such as Casoron). Herbaceous perennial weeds such as Canada thistle, bindweed, and quackgrass can cause problems. Finally, some shallow-rooted plants, such as iris, don't like aggressive understory plantings.

Lawns planted in both grass and broadleaf species do not look exactly like traditional lawns and prevent the use of herbicides usually recommended to get rid of undesirable plants.

Cover crops

Cover crops are generally grown in the winter on annual vegetable and flower beds. The cover crop may be a winter-hardy grain, a legume, or a combination of the two.

Advantages: The cover crop smothers much winter weed growth. Fast-growing crops such as winter wheat are the most competitive. Cover crops also capture excess fertilizer, improve soil tilth, and increase organic matter when turned under. They are generally very inexpensive. In warm areas, some cover crops can be cut and left on the surface as a weed-suppressing mulch, and crops such as tomatoes can be transplanted through the residue. Crop residue left on the soil surface enhances the environment for beneficial soil insects.

See Chapter 2, *Soils and Fertilizers*.

Disadvantages: The only major disadvantage is that gardeners in most areas have to till in the cover crop before they can plant a spring/summer garden. In a wet spring, this can delay planting. Wheat grain used as a cover crop might reduce the germination of some small-seeded vegetables such as lettuce. Cover crops are by no means 100 percent successful in weed suppression, so there may be some weeds to contend with. Also, slugs may prosper if the residue isn't turned under.

Chemical control (herbicides)

Herbicides are another tool for managing weeds. The extent to which one chooses to use them depends on personal philosophy, garden objectives, and the particular weed problems in a garden. Herbicides may have a place in a garden, but always understand what one is trying to achieve, what the alternatives are, and what decisions make the most sense given the situation.

All herbicides have detailed label instructions on mixing, application timing, target weed species, hazard to desirable plants, and other significant issues concerning their safe and effective use. It is crucial that one reads these instructions before purchasing a product and follows them when mixing and applying. The label is the legal document that defines the use of a product and the responsibilities of consumers.

Herbicides control weeds by interfering with critical plant functions, thus resulting in the death of a plant. Not all herbicides act in the same manner.

One needs to understand some important terms and concepts before purchasing and applying herbicides.

A *selective* herbicide controls certain plants and not others. For example, most lawn herbicides control broadleaf plants such as common chickweed without damaging grasses. A few products control some (though not all) annual weed 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 controls grasses without damaging broadleaf species.

If a herbicide is selective, the label will give extensive information about which plants it is safe to use around and which weeds and plants it is likely to affect. In addition, there will be instructions on when to use the herbicide to get the desired results and avoid problems.

See Chapter 19, *Pesticides*.

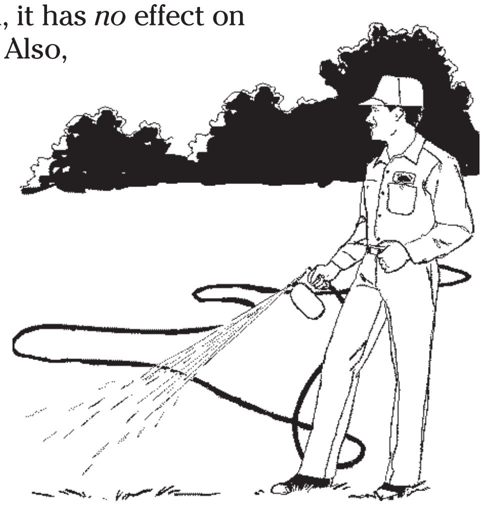
Nonselective herbicides can potentially damage any type of plant. Some last a long time (have residual effect in soil); others do not. The label details how the herbicide acts.

It is important to remember that some products may be selective at certain rates but lose that selectivity as the amount applied increases. These products are not recommended for use in home landscapes.

Most herbicides are *systemic*, which means they move from the point of initial absorption to other parts of the plant. They may be sprayed on the leaves and move to the roots or vice versa. These products move through the plant to have their effect.

Nonsystemic or *contact* herbicides affect only the part of the plant they touch. When a contact product is sprayed on leaves, it kills those leaves but does not travel to the root system. Thus, contact herbicides may control young annual or biennial weeds, but established perennial weeds that lose leaves due to a contact herbicide application will resprout. Very few contact products are available to home gardeners.

Herbicides are also 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, on the other hand, 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 than the other. Again, the label will describe how to apply the herbicide.

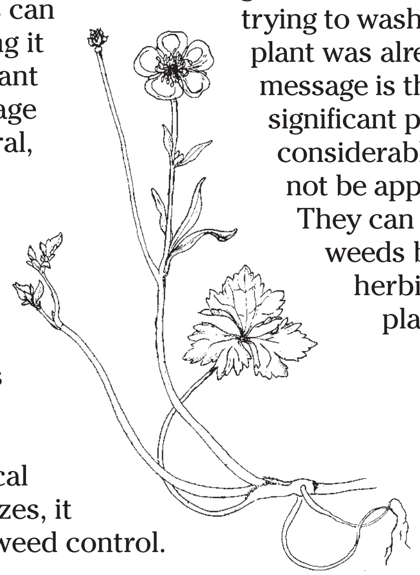
Finally, it is important to know when to use herbicide relative to the growth of the weeds and the crop. A *pre-emergent* herbicide is put on before weeds sprout. The desirable plants (landscape trees and shrubs, vegetables, flowers, bulbs, etc.) may or may not be present. Careful label reading is important.

A *postemergent* product is used after weeds are up. Selectivity of postemergent herbicides may depend on crop age, presence of bark, rate applied, 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 thick, waxy leaf surface (such as poison oak) or a very hairy leaf (such as stinging nettle) may not absorb a herbicide as well as does a plant with a smooth leaf. Likewise, a plant with narrow, upright leaves may be hard to cover adequately with spray mixture. Sometimes a weed's growing point is 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 faster. However, some herbicides can become volatile (gaseous) at temperatures above 85°F. Dichlobenil (Casoron) tends to become volatile when temperatures exceed 55°F. While this particular chemical does little harm as it volatilizes, it also doesn't provide much weed control.



On the other hand, some formulations of 2,4-D and some of its relatives can volatize in the same manner as dichlobenil and can have harmful effects on plants down wind if temperatures climb into the mid 80s. Since small amounts of this herbicide can visibly injure sensitive plants, high temperature combined with a little wind can cause serious problems in gardens.

Wind drift by itself can be a problem when using herbicides. As a sprayer is pumped, 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 it is supposed to land. Again, this drift can cause unintended consequences and neighborhood problems.

Moisture in modest quantities is needed to move soil-applied herbicides into the soil. Dichlobenil works in this way. However, if a downpour occurs shortly after the material is applied, the chemical may wash downslope instead of entering the soil. This runoff can damage lawns or other plants in its path.

When using foliar chemicals, there must be enough time between application and rain to allow a plant to absorb the herbicide. Normally, eight hours of dry weather is enough. However, there are many stories of gardeners misapplying herbicides and then trying to wash them off only to find that the plant was already damaged. The take-home message is that while eight hours is ideal, significant plant damage can occur in considerably less time. Herbicides should not be applied with a hose-type sprayer. They can be washed off the target weeds by the spray force, and the herbicide may damage desirable plants.

Sometimes herbicides work poorly in dry weather. Plants that are drought stressed 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 moisture stressed.

Specific herbicides

Note: Trade-name products are mentioned as illustrations only. This does not mean that the participating extension services endorse these products or intend to discriminate against other products.

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] and dichlorprop [2,4-DP]) to broaden the spectrum of weed control.

Dicamba

Dicamba has the same effect on plants as 2,4-D. It is also systemic, postemergent, and foliage applied. Dicamba is very active against broadleaves, especially some of the harder-to-control lawn weeds. It is used in some lawn herbicide mixtures such as Trimec. It is more dangerous to woody plants than 2,4-D and can be absorbed through roots. It is not uncommon to see landscape tree and shrub injury when dicamba is used extensively on lawns surrounded by woody plants. Dicamba is also sold under many trade names. Normally it is mixed with other herbicides at very low rates.

Dichlobenil

A systemic, pre-emergent, soil-applied herbicide, dichlobenil is available in a granular form. It controls annual, biennial, and perennial broadleaves and grasses but generally does not damage woody plants. It is used in landscape beds where there are no underplantings of herbaceous flowers or bulbs. Dichlobenil is best used before weeds emerge. It needs light rain and cold temperatures to move into the soil. If temperatures are too warm when it is applied, it becomes volatile and does not provide much weed control. If it rains too much just after it is applied, it may travel downslope and damage nontarget plants. Generally, it is best applied from November until February but should not be applied to frozen soil. Dichlobenil persists in soil for six to nine months or more, depending on rainfall, soil conditions, and application rate. Its use may limit later planting options. It is sold under the trade names Casoron and Norosac for home use.

Glyphosate

Glyphosate is a systemic, nonselective, foliar-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. There is little chance that it can be picked up by roots unless they are exposed in some manner.

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 going) 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 to control most grasses almost any time they are green and on annuals when they are actively growing. It works more quickly (seven to 10 days) in warm weather. It can also be effective in colder weather although the results might not be evident for a month or more. It is sold under the name Roundup and several other brands.

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 is mixed with 2,4-D in the product Crossbow and is sold alone in other "brush killer" and lawn formulations. Read the label carefully to see whether the formulation is an ester or an amine. Avoid applying esters in hot weather to reduce potential volatility and drift.

Benefin, oryzalin, trifluralin, and pendimethalin

These pre-emergent compounds act on germinating seeds. There is a fairly complex list of weeds (some but not all grasses and broadleaves) that they control and plants around which they can be used. They are most effective on annuals when they are germinating.

It is very important to read the labels carefully. These products differ in their need for mixing into the soil, the weeds they control, and the plants around which they can be used. Trifluralin is sold as Preen, Treflan, and several other names. Oryzalin is marketed as Surflan and Lilly-Miller Grass and Weed Preventer. Pendimethalin is commonly sold as Halts Crabgrass Preventer. While these herbicides are effective for controlling crabgrass with pre-emergent applications, it is important to note that they are not effective on established quackgrass or smooth brome. Both are common turf weeds throughout Wyoming that some homeowners have mistakenly assumed to be crabgrass. Be sure to correctly identify that a weed problem is crabgrass before applying these herbicides. Additionally there are specific plantback intervals that must be followed when using these herbicides. Always consult the label for this information.

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 under the name of Ortho Grass-B-Gone 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.

Corn gluten meal

Corn gluten meal (CGM) is a natural byproduct of the corn milling process. It has been used as livestock feed for many years. CGM has pre-emergent herbicidal activity; it inhibits root growth of susceptible germinating seeds. It affects a variety of annual and perennial broadleaf and grass seedlings. It is not effective on established perennial weeds. CGM has been used on existing turf and around established plants, transplants, or deeply seeded vegetables in vegetable and flower gardens. It is usually surface applied and lightly worked in. If worked in too deeply, it might damage nontarget plants. Read the label for cautions, use rates, and application techniques.

Weed management for specific situations

Lawns

Choose grass species suited for an area. A vigorous lawn reduces weed invasion. Good fertility, watering, mowing, and aeration programs will keep turf in top condition. Plan an annual program of overseeding weak areas, especially those in shade. Work to reduce insect damage to a lawn; weakened areas offer little competition to encroaching weeds.

See Chapter 8, *Lawns*.

New lawn blends that contain grass–broadleaf combinations may provide a stable plant community that resists invasion by more weedy species. These lawns do not have the feel of pure grass, however, and some people find them unacceptable.

By mowing high (3 inches or so), the shade cast by the grass will inhibit many broadleaf weeds. Use a fertilizer low in phosphorus to avoid stimulating clover (assuming clover is not wanted in a lawn). Some broadleaf weeds can be managed by hand pulling, but smaller species may be hard to control this way.

Weedy perennial grasses such as quackgrass can be very invasive. There are few options short of complete renovation once these plants get established. Some gardeners spot spray the patches with glyphosate and then overseed them.

Some herbicides are helpful against crabgrass. Many homeowners think they have crabgrass when they really have other grass weeds that are not affected by anticrabgrass products.

Annual bluegrass, a winter annual, is common in lawns. Some herbicides are available to help manage this species.

Usually, lawns are weakest in shady areas and where drainage is a problem. In shady areas, overseed lawns annually to maintain a viable turf.

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 to apply herbicides over the entire lawn each time it is fertilized.

Herbicide-treated lawn clippings should be used cautiously as mulch or in compost. Unintended damage to nontarget plants can occur. Of particular concern are lawns that have been commercially treated with clopyralid-containing products (such as Lontrel). This herbicide can persist for more than a year in compost and may injure nontarget plants. Washington has restricted the use of clopyralid in home landscapes.

If young children or pets use the lawn, be very cautious with herbicides.

Renovation

Lawn renovation is often done to reestablish turf grasses 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. Repeated tillage over three to four weeks can give acceptable control in dry weather.

Some homeowners use glyphosate to kill small patches of weedy lawn. They then dethatch, aerate, and overseed. Rototilling is not used 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

See Chapter 7, *Woody Plants*.

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 the first line of defense against weeds. They reduce the germination of weed seeds and protect the soil. Organic mulches such as bark are probably the most effective and cause the least problems. Hoeing in mulch is very easy and disrupts most annual weeds. Landscape fabrics are fine in many cases, but black plastic can cause root problems around some plants in the heavy soils of Wyoming. Perennial weeds are generally not deterred by organic mulches and may defeat landscape fabrics as well.

Drip irrigation places water around desirable plants but doesn't water everything. The potential for weed growth in the dry areas is greatly reduced.

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 get established. This can be a great reason to buy more plants. It does help to have a plan and to know which species work best in this role. In some cases, competitive plantings may limit herbicide choices.

The herbicides most commonly used in woody landscapes are dichlobenil, oryzalin, trifluralin, and spot application of glyphosate. Be sure to understand how these products work to avoid damaging desirable plants.

See Chapter 10, *Vegetables*, and Chapter 6, *Herbaceous Ornamentals.*

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, vigorous plants (including extensive use of transplants) that shade the ground as they mature, drip irrigation, mulches, and relentless attention that keeps weeds from going to seed. Winter weeds can be managed by mulches or cover crops.

Some gardeners use glyphosate before the first spring cultivation to control persistent perennial weeds, especially quackgrass. Corn gluten meal may also be useful. 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 very carefully and follow instructions if using these products.

For more information

UW Cooperative Extension Service publications

Weed Control in Garden and Lawn (B-909R)

Other references

Whitson, T.D. ed. *Weeds of the West* (Western Society of Weed Science, Newark, California, 2000). 628 pp.

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Figures 1–7 and the illustration on page 398 were reprinted by permission from *Gilkey's Weeds of the Pacific Northwest,* La Rea Dennis.

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Herbaceous Ornamental Plants

6

It's hard to 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 specialists. Annuals, biennials, and herbaceous perennials offer variety and interest to gardens of all styles.

Not so long ago, flowers were often 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. 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 frequently 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 also 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.

Topics in this chapter

- Types of herbaceous ornamental plants
- Using herbaceous perennials in garden design
- Selecting plants
- Soil preparation
- Propagation
- Flower garden maintenance
- Pest management
- Bulbs, corms, rhizomes, tubers, and tuberous roots
- Specialized herbaceous flower gardens

By Mary Robson, Cooperative Extension agent, King and Pierce counties, Washington State University. Adapted for Wyoming by Karen L. Panter, Extension horticulture specialist, University of Wyoming.

See Chapter 1, *Botany*.

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 this characteristic is desirable depends on one's garden style. Informally designed cottage-style gardens gain from self-seeded plants. 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.

In milder areas of Wyoming, hardy winter annuals such as pansies (*Viola wittrockiana* var., "Universal," and others) and ornamental kale (*Brassica* spp.) can be planted in fall to replace summer annuals in containers, window boxes, and gardens. Hardy annuals tolerate frost and give nearly year-round color in mild areas of Wyoming.

Table 1 lists the height and bloom color of several 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. Foxgloves (*Digitalis purpurea*), forget-me-nots (*Mysotis 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.

Perennials

Unlike annuals and biennials, perennial plants live year after year. Trees and shrubs are *woody perennials*. Mature garden, park, and arboretum landscapes are often composed mostly of woody perennial plants.

Many familiar garden flowers such as peonies (*Paeonia* spp.), delphiniums (*Delphinium elatum),* and Shasta daisies (*Chrysanthemum maximum*) are perennials.

These plants are called *herbaceous* because they do not form permanent woody branch structures as shrubs and trees do.

Hardy perennials live through winter in the ground, reviving from their crowns in spring. They send up new shoots, often

Table 1.—Height and bloom color of common annuals.

Plant (*Latin name*)	**Height (inches)**	**Bloom color**
African daisy (*Osteospermum*)	6–12	White, yellow, salmon
Ageratum (*Ageratum*)	4–24	Blue, white
Amaranthus (*Amaranthus*)	48–96	Red, red and green
Arctotis (*Arctotis*)	24	White with bluish eye
Aster (*Callistephus chinensis*)	18	Yellow, pinkish red, blue, white, lavender
Balsam (*Impatiens balsamina*)	12–18	Rose, purple, white
Basil, purple (*Ocimum basilicum*, foliage)	15	Red-purple foliage
Browallia (*Browallia*)	8–12	Blue, violet, white
Calendula (*Calendula officinalis*)	12–24	Yellow, gold, orange
California poppy (*Eschscholzia californica*)	12	Red to yellow
Cabbage (*Brassica*, flowering)	8–14	Red to white
Calibrachoa (*Calibrachoa*)	6-12	White, pink, rose, violet
Candytuft (*Iberis*)	12–16	Pink, lilac, white
Chrysanthemum (*Chrysanthemum*)	36	Yellow, purple, orange
Cineraria (*Senecio* x *hybridus*)	10–14	Violet, pink, blue, white
Clarkia (*Clarkia*, *Godetia*)	18	White, pink, red, pink and red
Cockscomb (*Celosia*)	18–36	Blue, red, yellow, orange
Cornflower (*Centaurea cyanus*)	36	Pink, blue, white
Coleus (*Coleus* x *hybridus*, foliage)	8–20	Variegated foliage
Cosmos (*Cosmos bipinnatus*)	36–72	Lilac, red, yellow, white
Dusty miller (*Artemisia stellerana*)	24	Silvery foliage, yellow flowers
Forget-me-not (*Myosotis*)	12	Blue, pink
Four o'clock (*Mirabilis*)	24	Pink, white, yellow
Gaillardia (*Gaillardia pulchella*)	15–24	Yellow, orange, red
Geranium (*Pelargonium* x *hortorum*)	12-24	Pink, orange, red, violet, white
Gomphrena (*Gomphrena*)	15–30	White, pink, purple
Heliotrope (*Heliotropium*)	10	Rose
Impatiens (*Impatiens wallerana*)	8–24	Red, pink, white, orange
Larkspur (*Delphinium*)	18–36	Blue, pink, white
Lobelia (*Lobelia*)	4–18	Blue, violet, white, pink
Lupine (*Lupinus*)	24–36	Pink to purple
Marigold (*Tagetes*)	8–48	Yellow, orange to reddish-brown
Mimulus (*Mimulus*)	12–30	Yellow, red
Morning glory (*Ipomoea*)	48+ (vine)	Blue, lavender, pink, red, white
Nicotiana (*Nicotiana*)	24–48	Red, pink, white
Nigella (*Nigella damascena*)	12–15	White, blue, violet
Pansy (*Viola* x *wittrockiana*)	8–12	Blue, purple, white, yellow
Petunia (*Petunia* x *hybrida*)	6–12	White to rose, purple
Phlox (*Phlox drummondii*)	6–18	White, rose, purple
Poppy (*Papaver*)	Varies	Red, pink, blue, orange
Portulaca (*Portulaca*)	8	Yellow, white, rose, orange
Salvia (*Salvia splendens*)	18–36	Blue, red, white
Scaevola (*Scaevola*)	6-12	Lavender blue
Snapdragon (*Antirrhinum*)	6–18	Blue, purple, yellow, orange, red
Statice (*Limonium*)	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 pea (*Lathyrus*)	48+ (vine)	Orange, yellow, rose, purple, white
Torenia (*Torenia fournieri*)	12	White, blue, violet
Verbena (*Verbena* x *hybrida*)	8–24	White, pink, blue, red
Zinnia (*Zinnia elegans*)	6–36	Red, pink, yellow, orange, white

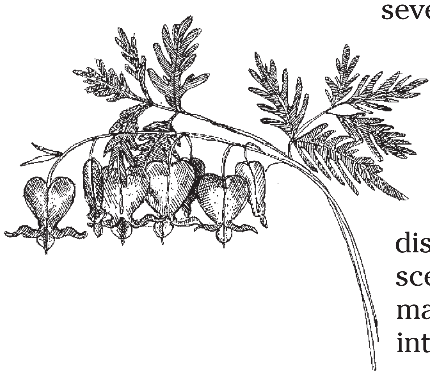
through the remains of the previous year's dead stems, leaves, and flowers. Some hardy perennials such as delphinium (*Delphinium* spp.) live only a few years before requiring replacement. Others such as peonies (*Paeonia* spp.) may survive for decades long outliving the gardener who planted them.

Tender perennials won't survive outdoor winter conditions even with protection. They must be lifted before frost occurs, stored, and replanted after the danger of freezing weather passes. Dahlias, gladiolus, some salvias, tuberous begonias, and geraniums (*Pelargonium* spp.) are tender perennials in most western climates.

Tender perennials differ from annuals because they do not complete their life cycle in one year. They have perennial characteristics such as energy storage in roots and the capacity to revive for successive seasons in appropriate growing conditions. Thus, although the definition of an herbaceous perennial is constant from one climate area to another, which plants are hardy in a particular region depends on the area's winter temperatures.

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.

Successful flower gardening depends, as does any other aspect of gardening, on understanding a 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 a garden's environment before selecting herbaceous plants. Analyze the hours of daylight, soil texture, drainage, water availability, and winter frost conditions. Choose plants whose cultural needs match the garden situation.

See Chapter 22, *Landscape Design*.

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, based on harmonious color patterns, bloom throughout the seasons, and intriguing year-round texture, depends entirely on each gardener's taste. Because herbaceous plants are used intensively in modern gardens, many books give excellent suggestions on how to design with them. Visiting gardens and nurseries and keeping an idea notebook will also help develop design confidence and improve garden choices.

Table 2 lists perennials by their season of bloom and gives their height and bloom color. Figure 1 illustrates how plants can be arranged according to height while Figure 2 shows the arrangement by season of bloom. Figure 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, producing pink flowers, orange/purple combinations, 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

Following some sensible basic steps when installing a new garden will produce 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. This practice increases the air and nutrients available to roots and can produce a fine garden site capable of sustaining plants for many years.)

Spread 3 to 4 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,

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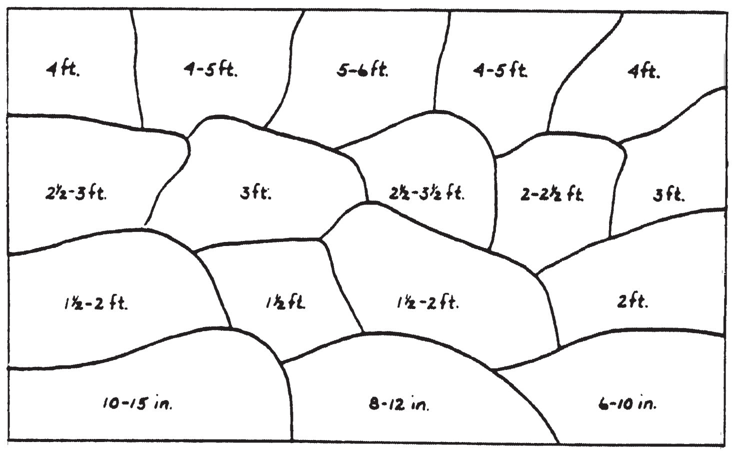

Figure 1.—Flower border divided into bold plant groupings according to height. Background: large groups of tall plants. Foreground: shallower, wider groupings of small plants.

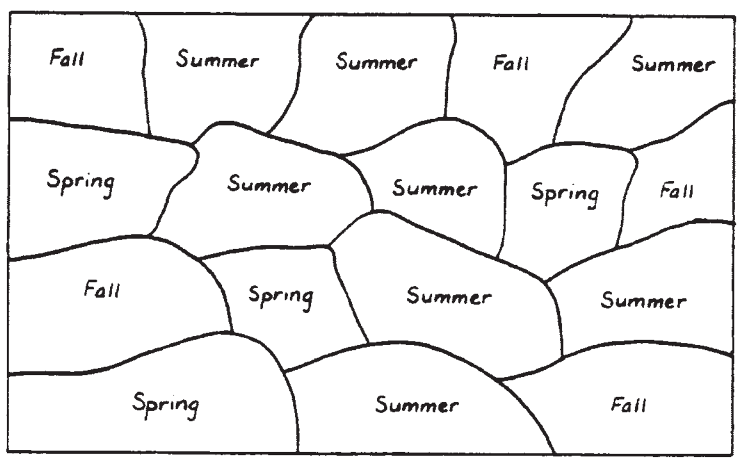

Figure 2.—Flower border designed for continuous bloom from spring through fall.

Table 2.—Bloom season, height, and bloom color of common perennials.

Botanical name	Common name	Height (inches)	Color
Late winter			
Chionodoxa luciliae	Glory-of-the-snow	4	Blue
Crocus vernus	Dutch crocus	4	Various
Eranthis hyemalis	Winter aconite	3	Yellow
Galanthus nivalis	Common snowdrop	6	White
Helleborus niger	Christmas rose	12	White
Iberis sempervirens	Edging candytuft	12	White
Sanguinaria canadensis	Bloodroot	8	White
Scilla siberica	Siberian squill	6	Blue
Early spring			
Adonis amurensis	Amur adonis	12	Yellow
Anemone pulsatilla	Pasqueflower	9	Purple
Aquilegia canadensis	American columbine	18	Red-yellow
Arabis alpina	Alpine rockcress	12	White
Aubrieta deltoidea	Common aubrieta	6	Purple
Bergenia cordifolia	Heartleaf saxifrage	12	Purple
Dicentra spectabilis	Bleeding heart	10	White
Hyacinthus orientalis	Hyacinth	8	Various
Leucojum vernum	Spring snowflake	12	White
Muscari botryoides	Common grape hyacinth	8	Blue
Narcissus (various)	Narcissus	12	Yellow
Pulmonaria angustifolia	Cowslip lungwort	12	Blue
Trollius europaeus	Globe flower	24	Yellow
Tulipa (early)	Tulip	12	Various
Late spring			
Ajuga reptans	Carpet bugle	6	Purple
Aquilegia chrysantha	Golden columbine	24	Yellow
Aurinia saxatilis	Goldentuft	18	Yellow
Brunnera macrophylla	Siberian bugloss	12	Blue
Cerastium tomentosum	Snow-in-summer	6	White
Chrysanthemum coccineum	Painted daisy	24	Various
Convallaria majalis	Lily-of-the-valley	12	White
Dicentra spectabilis	Bleeding heart	36	Pink
Doronicum cordatum	Caucasian leopardbane	24	Yellow
Euphorbia epithymoides	Cushion spurge	24	Yellow
Gaillardia aristata	Common gaillardia	15	Red-orange
Galium odoratum	Sweet woodruff	8	Yellow
Hemerocallis	Lemon daylily	36	Yellow
Iris germanica	Iris	18–36	Various

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Table 2.—Bloom season, height, and bloom color of common perennials (continued).

Botanical name	Common name	Height (inches)	Color
Late spring (continued)			
Nepeta mussinii	Mussini mint	12	Blue
Paeonia officinalis	Common peony	30	Various
Phlox divaricata	Blue phlox	12	Lavender
Phlox subulata	Moss phlox	6	Pink
Polemonium reptans	Creeping polemonium	6	Blue
Primula	Primrose	6	Various
Pulmonaria officinalis	Pulmonaria	6–12	Purple
Silene quadrifida	Alpine catchfly	6	White
Trollius europaeus	Common globeflower	24	Yellow
Tulipa gesnerana	Darwin tulip	18	Various
Veronica prostrata	Rock speedwell	4	Blue
Early summer			
Achillea millefolium	Common yarrow	18	Rose
Achillea ptarmica	Sneezewort	24	White
Aconitum napellus	Aconite	24	Blue-white
Anchusa azurea	Italian bugloss	36	Blue
Astilbe 'Davidii'	David astilbe	60	Rose
Astilbe japonica	Japanese astilbe	12	White
Baptisia australis	Blue wild-indigo	24	Blue
Campanula carpatica	Tussock bellflower	8	Blue
Campanula medium	Canterbury bells	24	Blue
Chrysanthemum maximum	Shasta daisy	24	White
Delphinium hybrids	Larkspur	24–60	Various
Dianthus barbatus	Sweet William	18	Various
Dianthus deltoides	Maiden pink	9	Pink
Dianthus plumarius	Grass pink	12	Various
Digitalis purpurea	Common foxglove	48	Purple
Lilium candidum	Madonna lily	36	White
Lilium pumilum	Coral lily	23	Red
Linum perenne	Perennial flax	18	Blue
Lupinus	Lupine	36	Various
Lychnis viscaria	German catchfly	12	Purple
Oenothera fruticosa	Common sundrop	18	Yellow
Papaver nudicaule	Iceland poppy	12	Various
Papaver orientale	Oriental poppy	36	Red-pink
Penstemon barbatus	Penstemon	36	Scarlet
Platycodon grandiflorus	Balloonflower	24	Blue-violet
Veronica spicata	Spike speedwell	12	Purple
Midsummer			
Asclepias tuberosa	Butterflyweed	24	Orange
Cimicifuga racemosa	Cohosh bugbane	48	White
Echinops ritro	Steel globe thistle	36	Blue
Heliopsis helianthoides	Pitcher heliopsis	36	Orange

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Table 2.—Bloom season, height, and bloom color of common perennials (continued).

Botanical name	Common name	Height (inches)	Color
Midsummer (continued)			
Heuchera sanguinea	Coralbells	18	Crimson
Lilium tigrinum	Tiger lily	24–60	Orange
Lychnis chalcedonica	Maltese cross	24	Scarlet
Lychnis x *haageana*	Haage campion	12	Orange-scarlet
Macleaya cordata	Pink plum poppy	72–96	Cream
Monarda didyma	Oswego beebalm	36	Scarlet
Phlox paniculata	Perennial phlox	24	Various
Physostegia virginiana	Obedience plant	36	Pink
Veronica incana	Woolly speedwell	12	Rosy-purple
Late summer and early fall			
Aconitum carmichaelii	Violet monkshood	48–60	Blue
Anemone hupehensis (*Anemone* x *hybrida*)	Japanese anemone	12–36	Various
Aster novae-angliae	New England aster	36–48	Various
Aster novi-belgii	New York aster	36–60	Blue
Aster tataricus	Tartarian aster	60–72	Violet-blue
Campanula pyramidalis	Chimney bellflower	72	Blue
Colchicum autumnale	Common autumn crocus	3–4	Purple
Echinacea purpurea	Purple coneflower	36	Purple
Eupatorium purpureum	Joe-pye-weed	72	Purple
Helenium autumnale	Common sneezeweed	36–48	Yellow
Hosta plantaginea	White plantainlily	12–18	White
Hosta sieboldiana	Plantain lily	12-24	Lilac, white
Kniphofia uvaria	Common torchfly, red-hot poker	36	Orange
Liatris pycnostachya	Cattail gayfeather	48	Purple
Liatris spicata	Spike gayfeather	24	Purple
Lilium speciosum	Speciosum lily	24–48	Pink
Lilium superbum	American Turk's cap lily	24–36	Orange-red
Limonium latifolium	Bigleaf sea-lavender	20	Lavender
Rudbeckia fulgida	Showy coneflower	36	Golden
Salvia azurea grandiflora	Great azure sage	48	Blue
Salvia officinalis	Gentian sage	12–24	Blue
Sedum spectabile	Showy stonecrop	18	Crimson
Solidago canadensis	Canada goldenrod	36	Yellow
Stokesia laevis	Stokesia, stokes aster	12–24	Lavender-white
Veronica longifolia subsessilis	Clump speedwell	24–36	Blue-purple

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. In this situation, improve drainage or choose plants suitable for damp conditions.

See Chapter 2, *Soils and Fertilizers*.

Soil testing is helpful when starting a garden on an unfamiliar site or when expanding an existing garden. Many soils in Wyoming are very alkaline, with a pH well above 7 or 8. Some plants that grow well in alkaline soils include baby's breath (*Gypsophila paniculata*), daylilies (*Hemerocallis* spp.), and lupine (*Lupinus* spp.).

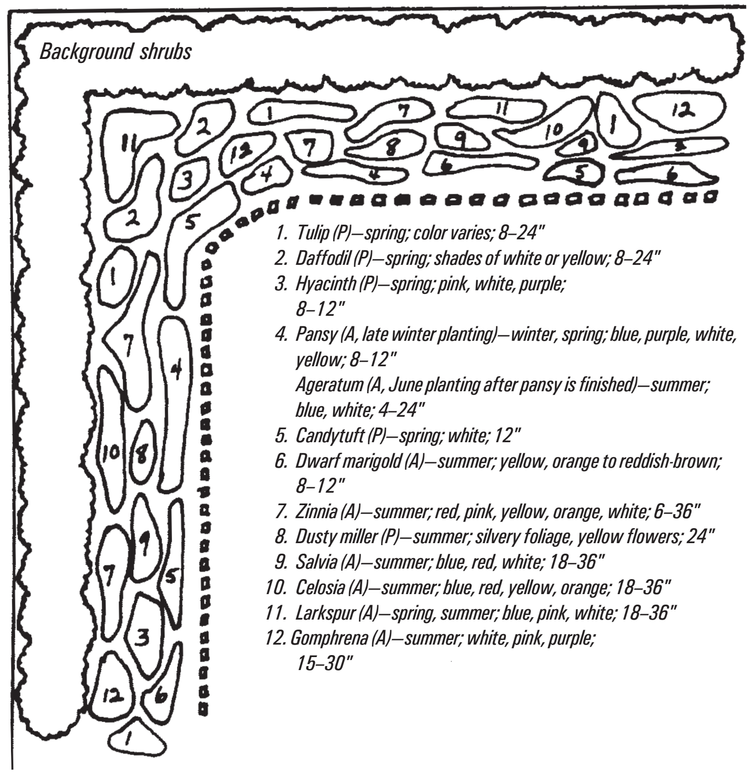


Figure 3.—Sample perennial/annual bed with a mix of bloom seasons, flower colors, and heights. In spring, blocks 1, 2, 3, 4, and 5 will bloom. In summer, blocks 4, 6, 7, 8, 9, 10, 11, and 12 will bloom. A=Annual; P=Perennial.

Propagation

Annuals and biennials

These flowers are generally started from seed or purchased as small plants. Some 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 minus*) 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 a 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 and impatiens. Unless you have excellent propagation facilities, these plants are difficult to grow from seed.

Perennials

Perennials grow more slowly than annuals, and many do not bloom the first year although some will. 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.

See Chapter 20, *Propagation*.

Division

As herbaceous perennials develop established root systems, they spread into large clumps. Thus, many can be propagated by division.

Divide perennials as part of 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.

Divide perennials when they are dormant. Time the division to allow for root development before the plant normally blooms. 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 2 to 6-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 each 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. Without these systems, rooting will be slower and require more care but you can still 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 will 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 4-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 benefit from regular fertilizing. Well-prepared soil and organic mulch help make nutrients available to plants, but annuals grow so rapidly that supplemental fertilizer may be beneficial. Slow release fertilizers work well. One application at planting will usually be sufficient for the growing season. Many types of liquid, granular, and powder fertilizers are available. Follow label directions closely and avoid over fertilizing. Be sure to water before and after fertilizing.

When planting a new *perennial* garden, slow-release fertilizers can be dug in thoroughly before planting. Fertilize established herbaceous perennials as they start growth each year. Again, slow-release types can be applied in spring for the growing season, and other fertilizer types are available. Read and follow label instructions. 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.

Soil tests results will reveal whether fertilizing is necessary for any herbaceous plants.

See Chapter 2, *Soils and Fertilizers*.

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.

Herbicides are not recommended in herbaceous plantings.

It's best to remove weeds at the seedling stage by hoeing lightly, avoiding the roots of desired plants.

Watering

Most annuals need regular water because they don't make deep root systems. However, some annuals such as cosmos (*Cosmos bipinnatus*) tolerate dry conditions.

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,* 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 watering, 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 each year are helpful. Apply 2 to 3 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.

See Chapter 5, *Weeds,* and Chapter 19, *Pesticides.*

Do not cover a perennial plant's crown (the central growing area above the roots) with winter mulch but bring it up to the edge of the crown. In cold locations, cover the entire plant after the soil freezes or after several freezing nights. If plants are covered 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. Delphiniums may reach 6 feet tall with heavy stalks of bloom; lilies as well as some chrysanthemums and dahlias 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 can also 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 one also can improvise supports from bamboo stakes, twigs, or branches. Choose staking material that is about 6 inches shorter than the plants' ultimate height.

Whatever method is used, put support systems in place while plants are small and tie plants loosely to the stakes as they grow (Figure 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, one can extend the bloom period on many plants, such as pansies, marigolds, and petunias.

Deadheading can prolong the bloom period and improve a garden's appearance. Some early summer-blooming perennials such as 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 a garden show. Poppies, for example, can be grown for their 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.

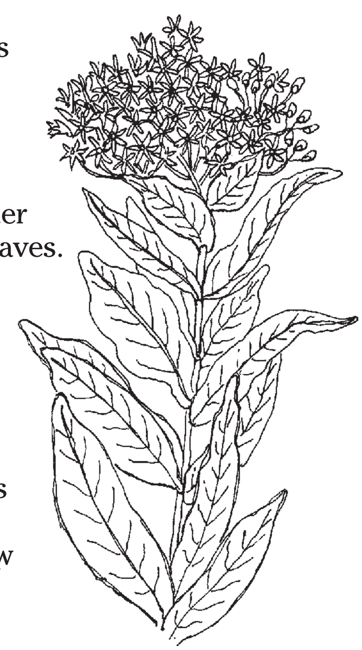
Fall cleanup

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 do. The following practices 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.
- Control weeds.



Several diseases commonly affect annuals, bulbs, and herbaceous perennials. Powdery mildew

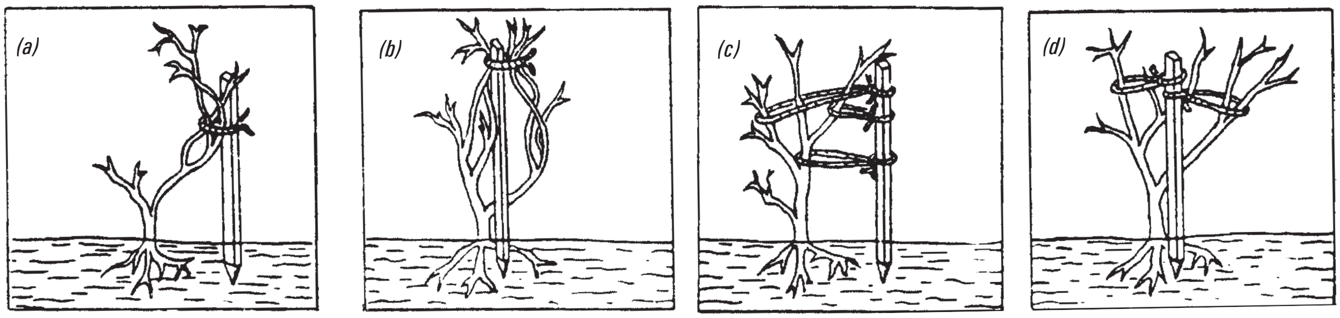


Figure 4.—Staking plants: (a) and (b) Plants are tied too tightly. (c) and (d) It is better to tie the principal branches loosely.

(a fungus) attacks delphinium, 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 diseased plant parts can help with control.

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 and use broad-spectrum insecticides as little as possible to protect beneficial predators. Aphids, for example, have many natural enemies including lady beetles, lacewings, wasps, and birds.

Slugs, fairly common in Wyoming, attack tender shoots of bulbs, lilies, and young transplants. Hand picking and selective use of baits can help manage slugs. Place baits in traps rather than broadcasting them.

Consult relevant publications and experts for specific controls. Properly identify 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 plants. Many, such as hyacinths, tulips, and crocuses, can survive for a while without soil around their roots which enables them to be stored and shipped easily. Figure 5 illustrates flowers of several types of bulbs and corms.

See Chapter 3, *Entomology*, Chapter 4, *Disease,* Chapter 13, *Diagnosing Problems,* and Chapter 14, *IPM.*

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. A homogenous mass exists inside. Roots form at the base. Some examples of plants that form corms are crocuses and gladioluses.

Tubers are swollen, modified, underground stems. They don't have basal plates where 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 irises, lillies-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 mid summer, may be planted in fall or early spring.

See Chapter 1, *Botany.*

Tender bulbs, tubers, and corms generally bloom in mid to late summer. Examples are dahlias, gloxinias, tuberous begonias, and gladioluses. Plant them when the ground warms after the last frost. They don’t survive severe winter cold, so they must be dug in the fall. Store them in a frost-free location.

Selection and storage

Choose solid, healthy plants. With lilies, tulips, and narcissuses, 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.

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 bulbs can't be planted 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 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.

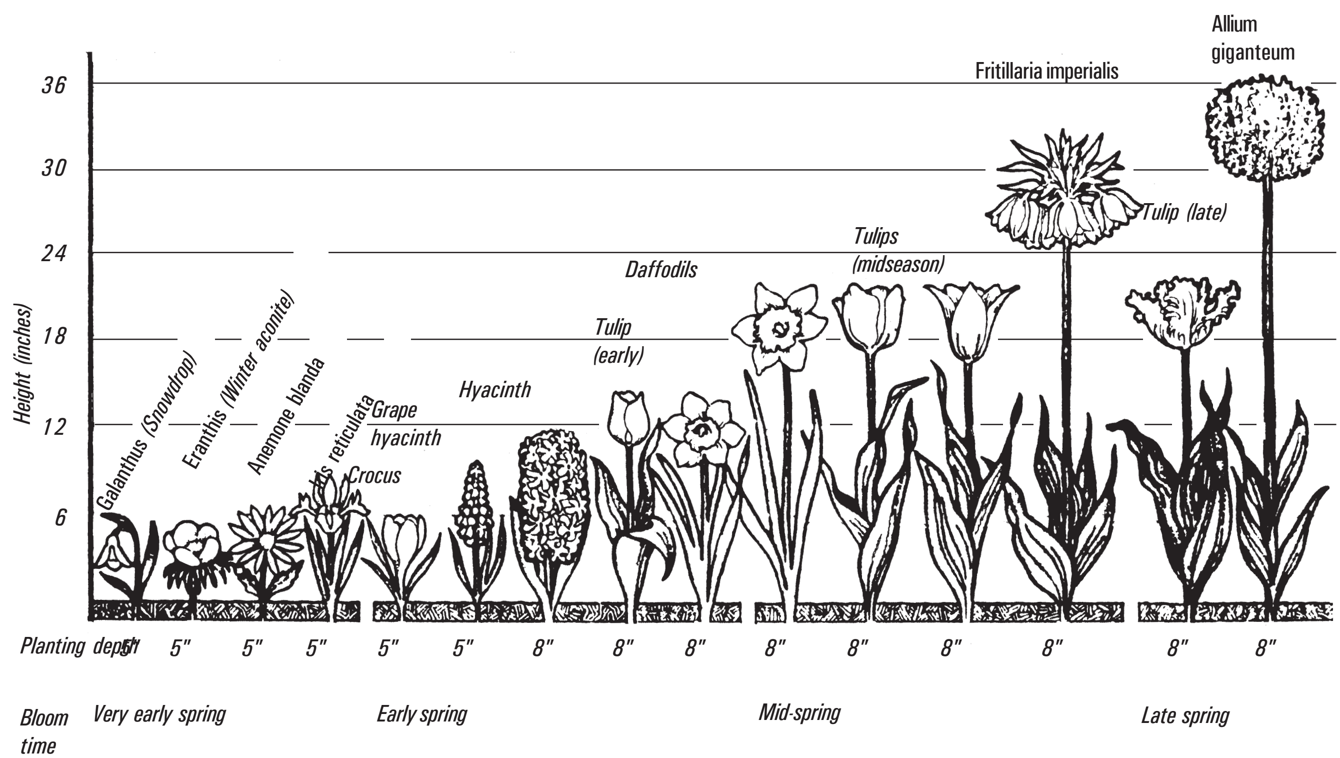


Figure 5.—Bulbs and corms offer a variety of blossoms. (Source: Netherlands Flower-Bulb Institute.)

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, narcissuses, tulips, and lilies must have excellent drainage. If a 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 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. Local nurseries or a local Cooperative Extension Service office can give specific ideas. Many growers suggest planting about three times the depth of a bulb. Shallow-planted bulbs may frost heave and can easily be dug out by rodents. To prevent squirrels and other rodents from digging out and munching on bulbs, plant them in a hardware cloth "cage."

Mulch hardy bulb and corm plantings lightly with 2 to 4 inches of composted leaves, shredded bark, or composted sawdust. Keep mulches open and light enough to allow shoots to emerge in spring.

Watering and fertilizing

Supplemental irrigation is essential all year in Wyoming and encourages root growth. Roots continue to grow slowly through the winter.

Fertilize spring bloomers when they are about an inch tall, using a granular formula or a liquid fertilizer. Let the leaves wither naturally and don't remove them until they are brown. Move spring-blooming bulbs and corms only after all foliage has ripened (usually in late summer).

Specialized herbaceous flower 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 greatly to the success of container plants. Plant roots must get sufficient air. If the soil is too dense, it packs down, thus contributing to root rot or other difficulties. Be sure to use a potting material that contains sufficient gritty particles in the form of pumice or perlite. Garden soil doesn't work well in containers because watering packs it and reduces available oxygen.

Choose a container suited to a plant's eventual size and make sure it has sufficient drainage holes in the bottom. Scrub pots well. Soak new clay pots before planting. 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.

One 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.

Plants in containers need regular fertilizer. Many potting mixes contain few, if any, plant nutrients, and watering leaches what nutrients there are. Be consistent; fertilize about every three weeks. Liquid fertilizers are simpler to use with containers than are granular types.

Avoid using too much nitrogen on plants being grown for bloom. Some commonly available fertilizers contain 20 percent nitrogen or more. If overused, they can reduce blooming.

Water regularly. Hanging baskets may need water daily during summer. Be sure a pot drains well and remove any attached saucers or decorative wrappers that might trap water against a plant's roots. Overwatering can rot plants so water only when needed and in moderation.

Bog gardens 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.

See Chapter 9, *Interior plants.*

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

University of Wyoming Cooperative Extension Service publications

Landscaping: Water-Wise Wyoming Gardens (B-1143)
Landscaping: Herbaceous Perennials for Wyoming (B-1152)

Washington State University Cooperative Extension publications

Arranging Flowers (PNW0013)
Diseases of Bulbous Iris (EB0710)
Diseases of Narcissus (EB0709)
Diseases of Tulips (EB0711)
Fertilizer Guide for Vegetable and Flower Gardens, Except Irrigated Central Washington (FG0050)
Insect and Mite Control in the Landscape (EB0826)

Oregon State University Extension publications

Dahlia Culture (FS 95)
Deer-resistant Ornamental Plants (EC 1440)
Fertilizing Your Garden: *Vegetables, Fruits, and Ornamentals* (EC 1503)
Plant Materials for Landscaping: A List of Plants for the Pacific Northwest (PNW 500)
Plant Selection for Sustainable Landscapes (EC 1534)
Preparing Winter Storage for Fuchsias, Geraniums, and Tuberous Plants (FS 1)
Producing Transplants at Home (FS 225)
Water-efficient Landscape Plants (EC 1546)

Books

Armitage, A.M. *Herbaceous Perennial Plants: A Treatise on Their Identification, Culture, and Garden Attributes*, 2nd edition (Prentice Hall, Englewood Cliffs, NJ, 1993).

Bloom, A. *Alan Bloom's Hardy Perennials* (Batsford, London, 1991).
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Phillips, R., and M. Rix. *The Random House Book of Perennials,* 2 volumes (Random House, New York, 1991).
Raven, S. *The Cutting Garden: Growing and Arranging Garden Flowers* (Reader's Digest Association, Pleasantville, NY, 1996).
Rice, G. *Hardy Perennials* (Viking, London, 1995).
Rix, M. *Growing Bulbs* (Timber Press, Portland, OR, 1986).
Thomas, G.S. *Perennial Garden Plants or the Modern Florilegium,* 3rd edition, revised (Sagapress, with Timber Press, Portland, OR, 1990).
Wilson, J.W. *Landscaping with Container Plants* (Houghton Mifflin, Boston, 1990).

Periodicals

Fine Gardening
Garden Design
Gardens Illustrated
Horticulture
Sunset

Divider goes here

Woody Landscape Plants

7

Woody ornamental plants are key components of a well-designed landscape. Landscape plantings divide and define areas, add aesthetic qualities, and increase a property's environmental and economic value.

See Chapter 22, *Landscape Design*.

There are many woody plants available for use in landscaping, so select carefully. Choose plants based on their ability to fulfill needs and grow well in a property's environment.

Install landscape plantings according to a plan, keeping two factors in mind:

- Use the right plants in each area to create the desired design effect.
- Place plants in the right environment with proper sun exposure, soil pH, drainage, and water.

Landscape plants last for many years. Giving them proper growing conditions and care will ensure that they remain a healthy and aesthetically pleasing part of a landscape.

Planting trees and shrubs

One can purchase trees and shrubs in a variety of ways (Figure 1):

- *Bare-root* (BR) plants have little or no soil around the roots. This is common among deciduous plants and small evergreens.
- *Balled and burlapped* (B&B) plants are dug with soil. The root ball is enclosed with burlap or a synthetic material.
- *Container* plants are grown and sold in containers.
- *Field-potted* plants are grown in a field and dug with or without soil. They then are potted into containers filled with organic media, field soil, or a combination of the two.

Topics in this chapter

- Planting trees and shrubs
- Transplanting established plants
- Fertilizing
- Watering
- Woody landscape plant problems
- Winter injury
- Construction damage

By Ray Maleike, Extension horticulture specialist, Washington State University. Revised for Wyoming by Mark Hughes, Community Forestry Coordinator, State of Wyoming, and Karen L. Panter, Cooperative Extension Service horticulture specialist, University of Wyoming.

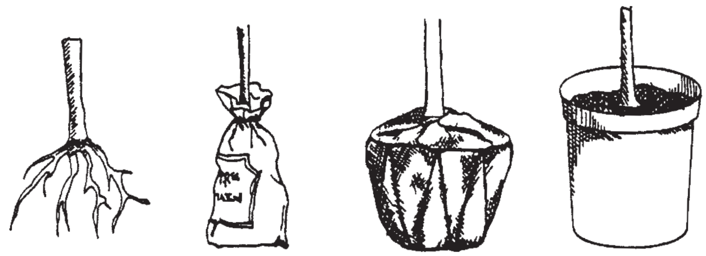


Figure 1.—Types of nursery plants.

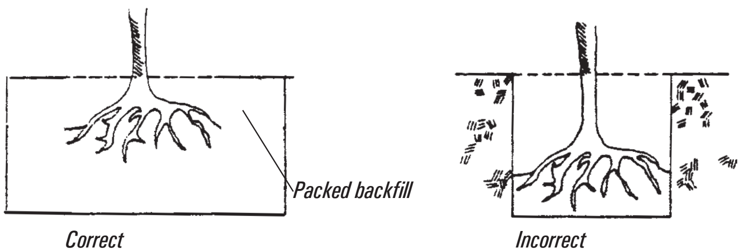


Figure 2.—Planting depth for a bare-root tree or shrub.

Overcoming drainage problems

Preparing well-drained soil before planting is the key to creating good conditions for plant growth. Many problems are caused by poorly drained soil that becomes waterlogged during the rainy season. To prepare the soil, follow these suggestions:

- Till in organic matter—the deeper the better.
- Break through hard soil layers to allow water to percolate.
- Install drainage tile or perforated plastic drain pipes to carry away excess water. (This option can be expensive.)
- Put the plant partially or wholly above the grade and fill in (create a berm) with good soil.
- Slope soil away from the plant so water runs away from the trunk.

Planting

Proper planting procedures are crucial to establishing a healthy plant. Planting procedures depend on which type of plant one chooses (e.g., bare root, balled and burlapped, etc.). Instructions for the common types are given below.

Bare root

1. Cut back damaged roots, making a clean cut. Then soak the roots in water for one to two hours.
2. Dig a hole wider but not deeper than the root system.
3. Put the plant in the hole to the level where it was growing in the nursery (Figure 2). Put a cone of soil under the plant for support. Spread the roots.
4. Backfill with native, *not amended*, soil. Tamp down the soil to remove air pockets.
5. Water thoroughly.

Balled and burlapped

1. Dig a hole wider but not deeper than the root ball (Figure 3).
2. Remove the wire basket, burlap, or synthetic material around the ball along with all rope, string, or twine tying materials.
3. Clean-cut all damaged roots.

Figure 3.—For B&B and container plants, the hole should be wide enough to allow for thoroughly tamping down the soil around the root system—about 6 to 12 inches on both sides of the root ball.

4. Place the ball in the planting hole with the top of the ball even with the soil surface or slightly higher.
5. Backfill with native, *not amended*, soil. Tamp down the soil to remove air pockets.
6. Water thoroughly.

Container plants

1. Dig a hole larger than the spread-out root system.
2. *Remove every kind of container*, even papier-mâche and peat pots.
3. Prepare the roots:
   a. If roots are not circling (pot bound), carefully spread the exterior roots away from the soil mass.
   b. If roots are circling, make six to eight vertical slashes in the root ball and spread the roots out. If the roots are very woody and circling, lay the ball on its side and use a spade or shovel to slice all the way through the bottom half of the root ball. Also slash the top half of the root system with six to eight vertical cuts. Spread the two flaps out (Figure 4).
4. Place the prepared root ball in the planting hole with the surface of the container media level with the soil surface or slightly higher.
5. Backfill with native, *not amended*, soil. Tamp down the soil to remove air pockets.
6. Water thoroughly.

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 when it is planted. However, light pruning may be helpful. Follow these steps:

See Chapter 16, *Pruning*.

1. Remove dead or injured branches.
2. Remove interfering, rubbing, or crossed branches.

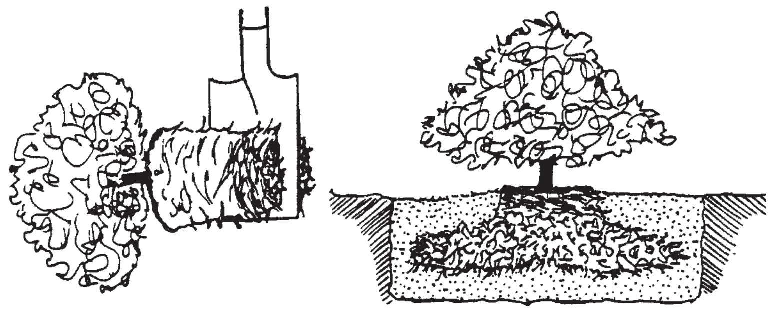


Figure 4.—Splitting a root ball.

3. Remove one branch from 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 may be taller and thinner and have deformed xylem and less root growth. It may not be able to stand by itself.

If staking is not needed, don't do it. If a plant needs to be staked in a windy area, follow these steps (Figure 5):

1. Drive two stakes into firm ground outside of the root ball. The line formed by the two stakes and the tree trunk should be perpendicular (at a right angle) to the prevailing wind.
2. Secure the two stakes to the trunk as low as possible. Use a material that will not chafe or damage the bark.
3. Remove stakes as soon as possible after the roots are established and the plant is stabilized, typically after one growing season.

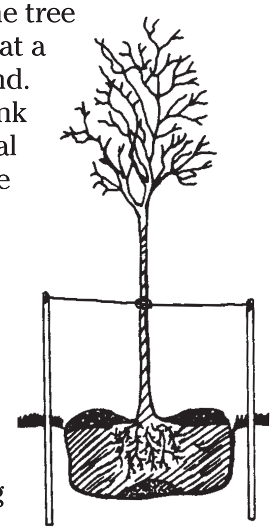


Figure 5.—Staking a newly planted tree.

Fertilizing

Do not put fertilizers into planting holes. Roots that come into contact with fertilizer particles may be damaged (burned).

Watering

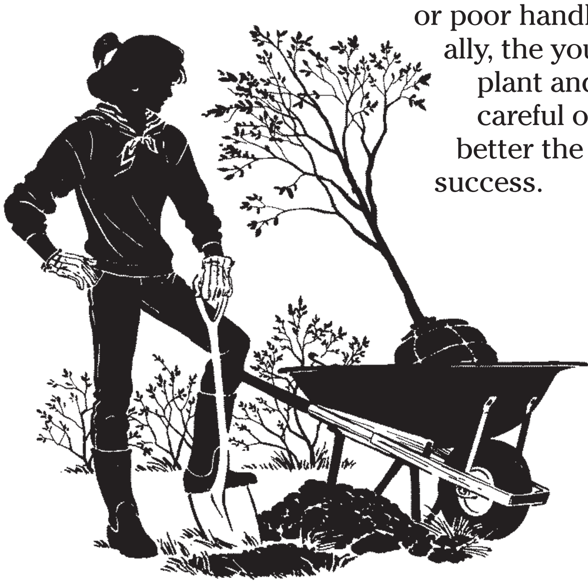
A recently transplanted plant needs special attention through its first growing summer. The nursery soil around a potted or B&B plant may be radically different from the soil where it is planted, and water may not move readily between the two. Therefore, it is important to apply water to both the nursery 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, in particular, 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 over water.

Mulching newly established shrubs and trees helps prevent moisture loss. Apply no more than 2 to 3 inches of mulch.

Transplanting established plants

Careful selection and placement of a plant should make transplanting unnecessary. Occasionally, however, it may become necessary 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 one is, the better the chance of success.



Timing

The best time to move evergreens is 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 it. The fall before the plant is to be moved, 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 that will eventually be dug.) New roots will grow at the cut edges. The following spring, prune the remaining segments. When digging the plant for transplanting, make the root ball larger than the root-pruned area to retain the maximum number of new roots.

See Chapter 16, *Pruning*.

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 the root-pruning cuts). Cut through woody roots but leave fibrous roots intact if possible. Use a 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 to work a sheet of plastic or burlap under it. Tip the ball from side to side carefully 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. Unwrap the ball and plant it like 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. Fertilizers can be expensive, and many are manufactured using non-renewable fossil fuels. If leaching and erosion occur, they can enter water supplies. Thus, remember these important tips:

- Fertilize woody plants only when necessary.
- Apply the correct amount of fertilizer at the right time of the year.
- Place fertilizers where they will be available to a plant's roots.

Determining the need for fertilizer

Whether there should be a yearly fertilizer program for landscape plants should depend on the inherent fertility of the soil, how well the plants are growing, and whether nutrients are recycled (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. 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 the cause of the problem is determined. Some possible indicators of a need for fertilization are:

- Smaller than normal leaves
- Light green or yellowish leaves (if the plant's leaves are normally dark green)
- Shorter than normal annual shoot growth
- Dead twigs and branch tips

However, these symptoms may also 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.

Research indicates that nitrogen may be the only nutrient that improves growth of woody landscape plants. In most cases, potassium and phosphorus reserves are sufficient for woody plants. Having the soil tested by a reputable laboratory can help determine the levels of phosphorus and potassium. Very low readings of these two minerals may indicate the need to add these nutrients to the fertility program.

See Chapter 2, *Soils and Fertilizers*.

See Chapter 13, *Diagnosing Problems*.

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), 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 1 to 3 pounds of actual nitrogen per 1,000 square feet. If the soil is very poor or plants are not growing well, consider using the higher amount. If plants are growing well and 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 2 pounds of actual nitrogen per 1,000 square feet. Too much nitrogen may stimulate shoot growth at the expense of flowers.

Once it is known how much actual nitrogen is needed, it's easy to calculate the amount of fertilizer to use. For example, to apply 3 pounds of actual nitrogen per 1,000 square feet using a 21-7-14 fertilizer, divide the desired amount of nitrogen (3 pounds per 1,000 square feet) by the percent of nitrogen in the formulation (21 percent, or 0.21). Thus:

3 ÷ 0.21 = 14 pounds

Fourteen pounds of 21-7-14 gives 3 pounds of nitrogen for a 1,000-square-foot area. See Table 1 for amounts based on other formulations.

The area beneath a tree is usually 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 6). 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. This number is the amount of fertilizer needed for the tree.

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 someone needs 3 pounds of actual nitrogen per 1,000 square feet and wants to use a 21-4-4 fertilizer, 14 pounds of fertilizer per 1,000 square feet are needed (from Table 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 feet x 20 feet = 400 square feet
400 sqare feet ÷ 1,000 square feet = 0.4
3 pounds N ÷ 0.21 = 14 pounds (or read from Table 1)
14 pounds N x 0.4 = 5.6 pounds fertilizer

Calculating by plant size

One 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 6 inches (measured at 36 inches above ground) should receive from 1/8 to ¼ pound of nitrogen per inch of trunk diameter. Trees greater than 6 inches in diameter can receive ¼ to ½ pound of nitrogen per inch of trunk diameter.

Table 1.—Approximate amounts of fertilizer needed to provide 3 or 6 pounds of actual nitrogen per 1,000 square feet.

	Amount of fertilizer to apply	
Type of fertilizer*	**1 lb N per 1,000 sq ft**	**3 lb N per 1,000 sq ft**
10-6-4	10 lb	30 lb
12-3-6	8 lb	25 lb
16-8-8	6 lb	19 lb
21-0-0	5 lb	14 lb
21-4-4	5 lb	14 lb
24-4-8	4 lb	12½ lb
33-0-0	3 lb	9 lb
46-0-0	2 lb	6½ lb

*These are examples. Availability may vary from location to location.

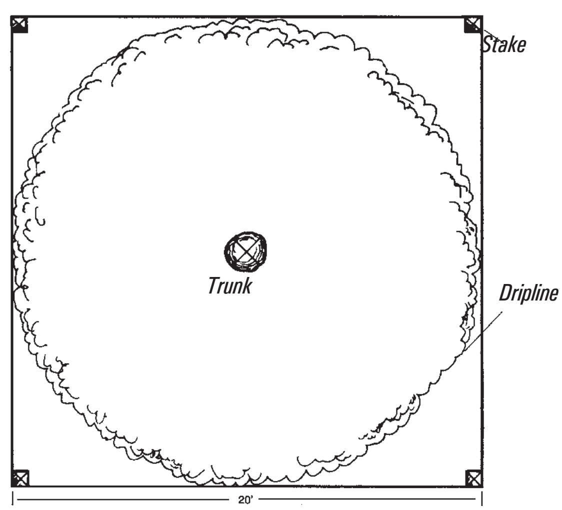


Figure 6.—Finding the area beneath a plant.

Flowering trees and large shrubs can receive from 1/8 to ¼ pound of nitrogen per inch of stem diameter. Shrubs are often fertilized according to their height or spread. Use 1/20 to 1/15 pound (about 1 to 1¼ ounces) of nitrogen per foot of height or spread.

Figure the amount of fertilizer to apply to an 8-inch diameter shade tree as follows. To apply ¼ pound of actual nitrogen per inch of trunk diameter, multiply the pounds of nitrogen needed (0.25) by the diameter of the trunk (8). Divide this number (2.4) by the percent of nitrogen expressed as a decimal (0.21 for 21-4-4 fertilizer). Thus:

0.25 pounds (0.3) pounds x 8 in = 2.0 pounds actual nitrogen

2.0 pounds ÷ 0.21 = 9.5 pounds of 21-4-4

Round off to 9 or 10 pounds.

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 6). Broadcast fertilizer over the soil surface and water it in immediately. However, inorganic nitrogen applied to the soil surface may damage grass or other plants growing under the tree. It also can be used by these plants before it reaches the tree's roots. To avoid these problems, put the fertilizer into 12 to 18-inch-deep holes spaced every 2 feet around the dripline and then irrigate.

When to fertilize

Although there is some controversy about the best time to fertilize woody plants, research indicates the most effective time for deciduous plants is in spring after growth begins. For trees or shrubs planted in turf areas, it may be better to split the amount into two applications to avoid burning the grass. Make the first application as growth begins, the second about four weeks later.

Fertilizing landscape plants with high-nitrogen fertilizer after July 1 is not recommended. It may stimulate growth that will not have time to harden off before fall; consequently, a plant may be damaged by winter freezes. Wait until plants are dormant or fertilize as they begin growth in the spring. However, if the soil is deficient in phosphorus and/or potassium, a midsummer application of these two minerals may increase flowering and hardiness for the next season.

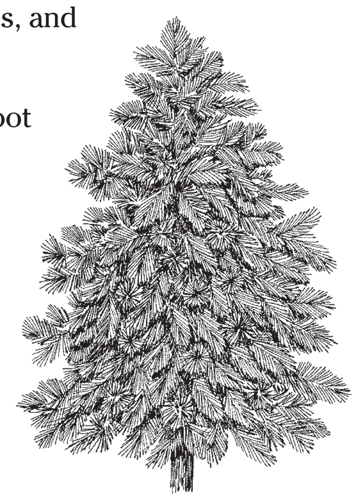
Fertilizing hints

- Never put any type of herbicide-containing fertilizer ("weed and feed") 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.

Watering

Watering landscape plants is one of the most misunderstood tasks facing gardeners. 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 the 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 the landscape. Check these areas and water them more often. For example:

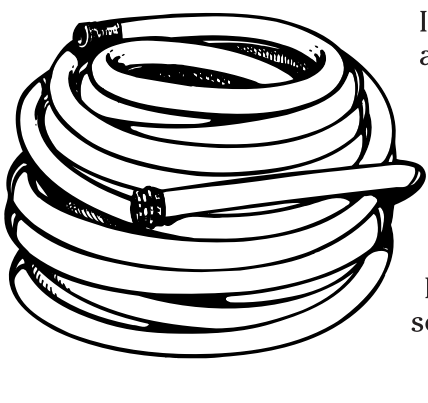
- Shrubs and groundcovers near house foundations, under eaves, or in hot afternoon exposures may receive little water from natural precipitation or may transpire water rapidly, so they may be stressed during hot summer days.
- Mounds or berms have much more soil surface exposed to evaporation than does the natural soil profile, so they dry out more quickly.
- Some plants demand more moisture or have shallow roots that dry out quickly during warm, sunny weather.

How to water

Water trees and shrubs just inside and outside their dripline or outer edge. For foundation or border plantings, water the entire area.

See Chapter 12, *Fruit Trees*.

Hoses, soaker hoses, and 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. During the rainy 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 media, exposure to sun or wind, temperature, 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 media surface feels dry. If a container completely dries out, one 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 once or twice a week is sufficient.

Be careful not to keep the root system soaking wet. Disease problems occur more often when soil is constantly wet.

Watering hints

- A quick, light watering does not wet a 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.
- Water any time of the day, but it is more efficient to water at night when evaporation losses are less.
- 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.

- Conserve water where possible. It is a valuable resource that is becoming scarce.

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 rot and foliage diseases. Insects also cause injury. However, most plant problems are due to adverse weather or cultural conditions that stress plants. These conditions include freezing, drought, over watering, and improper use of fertilizers. Construction activities such as grading also contribute to stress by compacting soil 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

Root systems of trees are closer to the soil surface than most people think. The vast majority grow horizontally, well beyond the drip line of the upper portion of a tree. Often they will extend two to three times the radius of the tree crown. Most roots are within the upper 2 feet or so of the soil profile. Root depth depends on many factors including tree species, soil texture, soil structure, and irrigation practices.

Poor irrigation practices which keep the soil too wet on the surface and too dry lower down (frequent shallow watering) will increase surface rooting, a serious problem around structures and concrete or asphalt. If inadequate drainage keeps the soil profile too wet (over watering), surface rooting can also become a problem. The presence or absence of mulch or other protective cover also affects rooting depth. If no mulch is present, the top 8 to 10 inches of the soil may be too hot for good root growth, and they will grow further down in the soil. If the area is mulched, however, most of the small absorbing roots will be concentrated in the upper 6 inches of the soil.

Watering to a depth of at least 12 inches is important. Then allow the tree to use the water supplied before watering again; deeply and infrequently are recommended.

The root systems of semi to fully mature trees and shrubs normally extend far beyond a 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 below. Keep in mind that these problems may show up in other plant parts, especially leaves.

Girdling (strangling) roots

Symptoms: This problem eventually limits water and nutrient transport, causing slow deterioration of a plant. The plant is stressed, and top growth diminishes.

See Chapter 13, *Diagnosing Problems*.

Causes: Impurities or trash such as sheetrock or lumber in the soil; twisting the plant during the planting process.

Remedies: Remove debris and foreign materials from the soil before planting. Chop off girdling roots and spread roots when planting.

Circling roots

Symptoms: General decline of plant vigor 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.

Kinked roots, one-sided root system

Symptoms: General decline of plant vigor over a period of time.

Causes: Improper production methods, jamming the plant in the pot or planting hole, dragging with a mechanical planter (J-shaped roots).

Remedy: Cut off kinked roots and carefully spread and straighten the remaining roots when planting.

Root rot

Symptoms: Soft brown, partially to totally decayed roots. The plant usually wilts and partially or totally dies.

Causes: Vary depending on susceptibility of the plant to disease organisms, poor soil aeration, amended backfill soil, inadequate drainage, and over watering.

Remedies: Increase downward and lateral drainage. Plant higher. Plant nonsusceptible species or resistant varieties. Do not amend backfill when planting. Monitor watering.

Suffocated roots

Symptoms: No buttressing or flaring out of the tree or shrub's base. Leaf and branch growth declines from the top down.

Cause: Fill or paving around the plant's base decreases the air supply to roots and changes water movement patterns. Susceptibility varies with species. Often due to planting too deeply.

Remedies: Provide drainage. Consult an arborist about whether an air well around the trunk base might help.

Cut roots

Symptoms: Death or decline in growth from the top of a plant downward.

Cause: Digging trenches within the plant's root zone.

Remedies: Avoid cutting large roots; tunnel under or over them where possible. Cut back damaged roots cleanly. Water the plant. Fertilization is of questionable benefit.

Compacted soil

Symptoms: A decline in growth from the top down.

Cause: Soil compaction or root damage from foot or machine traffic after a plant is in the ground.

Remedy: Buffer the area with a thick mulch. Direct traffic away from plants.

Plastic bag or other materials left on the plant

Symptoms: Wilting and eventual death.

Cause: Not taking a plant out of its pot before 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: Decay of heartwood or other internal portions of a trunk or branches.

Causes: Improper pruning, broken branches, storm damage, wounded stems, or root damage.

Remedies: Remove decayed wood but not down to sound wood. Filling cavities is of questionable value. If decay is in advanced stages, remove the tree for safety. Avoid problems by using proper pruning techniques.

Stem wounds, cankers, or girdling

Symptoms: Bark wounds.

Causes: Rope left on after planting, careless use of lawn mowers or weed trimmers, 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 injured 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

Causes: 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 cabling or cabling and bracing the competing limbs.

Bark scald or sunscald

Symptoms: Dead bark, usually on the south or southwest side of a trunk, especially on young, thin-barked trees.

Causes: Hot sun, alternate freezing and thawing of bark. Newly transplanted and young trees are susceptible.

Remedies: Shade the southwest side of the trunk, paint with white latex, or wrap. If wrapping a trunk, use wrap that is light-colored (to reflect sunlight) and woven (to allow air passage).

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: 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, blotch necrosis.

Cause: Plants exposed to hot sun.

Remedies: Shade the plants. Use tolerant plants. Periodically syringe leaves with water for temporary cooling.

Lack of roots

Symptoms: Wilting, early leaf drop, chlorosis, necrosis, poor growth, death.

Causes: Rot or decay (caused by poor drainage), trenching, transplanting, or insects (e.g., root weevils).

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 oxygen to roots, thereby reducing or stopping respiration.

Remedies: Improve drainage. Decrease water supply.

Plugged vascular system

Symptom: Wilting.

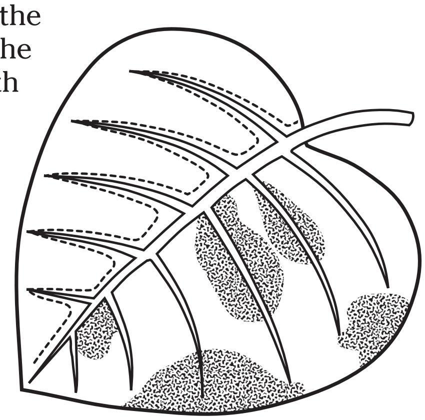
Cause: Diseases such as verticillium wilt.

Remedy: Determine the cause, take appropriate action (e.g., apply a registered fungicide or prune out the affected part of the plant).

Salt damage

Symptoms: Marginal to interveinal chlorosis or necrosis, rootlets 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



is also more common in arid areas than in regions where winter rain 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 2, *Soils and Fertilizers,* for more information.

Yellow (chlorotic) leaves

Nitrogen deficiency

Symptoms: Overall yellowing, *older leaves* first.

Cause: Not enough nitrogen available in the soil.

Remedy: Fertilize with a nitrogen fertilizer.

High pH

Symptoms: Interveinal chlorosis, *newer leaves* first. Chlorotic regions may die.

Cause: Alkaline soil may cause iron and/or manganese to become unavailable.

Remedies: Spray the plant or drench the root system with iron or manganese chelate as a temporary measure.

Other causes

Chlorosis may also be caused by drought, misuse of herbicides (see “Herbicide damage” below), bright sunlight, or natural leaf maturity. Some plants naturally have variegated or light green leaves.

Herbicide damage

Herbicides have specific toxicities to weeds but may also 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. The severity and type of damage depend on the type of herbicide, the amount applied, the plant species, and the stage of growth at the time of application.

Some herbicides act on plant hormones, causing twisted and distorted growth. Others inhibit photosynthesis and chlorophyll production, causing chlorosis. Table 2 lists some common herbicides and their possible effects.

Even if only part of a root system is affected by an herbicide, damage may spiral up the plant. Know where the root zones of 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 may 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

- 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 geographic area (*ecotype*)
- Differences in hardiness of different plant tissues
- How well a plant is established
- Condition of the plant: dormant or partly dormant; stressed 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, one sometimes can predict the type and extent of damage that might occur and take actions to protect plants.

Ultimate winter hardiness is controlled genetically and varies 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 on the West Coast.

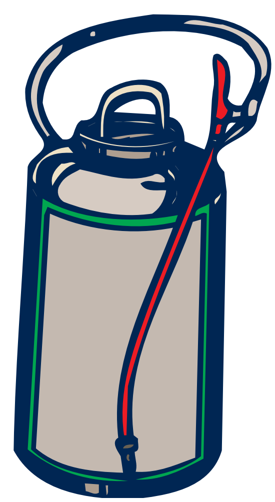
Plants native to a geographic region have evolved in response to the area's climate and weather patterns. The hardiest plants survive and produce offspring, passing on their genetic hardiness. Thus, native plants usually survive winter cold.

Many landscape plants are introduced (often called *exotics*). They may be adapted

See Chapter 19, *Pesticides*, and Chapter 5, *Weeds*.

Table 2.—Herbicide effects on plants.

Herbicide	**Damage symptoms**
Dichlobenil (e.g., 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 (e.g., 2,4-D, MCPP, triclopyr)	**Broadleaf plants**: Twisted, distorted leaves and stems. Grapes, *Mahonia,* and tomatoes are very sensitive. **Conifers**: Misshapen, distorted needles. *Note*: These herbicides are particularly susceptible to drift.
Dicamba (e.g., 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 (e.g., Roundup)	**Broadleaf plants**: Death of part or the entire plant, strap-shaped new leaves, purplish cast to plant. **Conifers**: None noted.
Triazines, atrazine (e.g., AAtrex), simazine (e.g., Princep)	**Broadleaf plants**: Chlorosis, leaf tip to margin to interveinal; may become necrotic. **Conifers**: Needle tip chlorosis.
Long-term residuals (chemical sterilants)	May cause plant damage or death if applied over the root system of desirable plants.



to a completely different environment than they encounter here. Exotic or introduced plants often respond differently to local climatic patterns than do 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.

Cold temperature damage may occur at any time depending on the severity of the cold and the stage of hardiness of the plant. It is most common in the following situations:

- *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 and lilacs are susceptible to damage from late 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. Thus, there may be fewer flowers or leaves than normal on these plants after a colder than normal winter.

Frozen roots

The media in an aboveground container may freeze, killing a potted plant's roots. In some 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 are usually brown or black and may be soft. Live roots may have a white growing tip.

One can reduce this type of damage by putting containerized plants in a protected area such as a cool garage or greenhouse during winter.

Sun and wind scald of leaves

During periods of severe cold combined with bright sunshine, as frequently happens in Wyoming, the leaves of some broadleaf evergreens deacclimate. Then, when the sun sets, the deacclimated leaf tissue freezes. Ice forms in the cells, rupturing their membranes and walls, and the cells die.

Damage is usually 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 frozen soil. Affected leaves or needles 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.

Sun and wind scald of bark

Bark 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. Sunscalded 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. Always remove the material during the growing season.

Bark splitting and frost cankers

Frozen bark is common on plants' lower trunks or crowns (where the roots and stem meet). It is caused by cold temperatures near the soil surface and often is a problem where there is no protective mulch or snow cover. Stem wounds may increase the chance of damage.

After thawing, the dead bark dries, splits, and separates from the wood. Sometimes, instead of splitting and loosening, bark adheres to the wood and forms a sunken area or canker as it dries. In either case, the plant can no longer transport food from its leaves to its roots, resulting in the death of the roots and eventually the entire plant. Leaves may even start to grow in the spring and then wither and die for no apparent reason.

Leaf droop and leaf rolling

The 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.

Limb and branch breakage

Branches may break because of heavy snow or ice. Prune the broken portion back to an undamaged branch or the main trunk. 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.

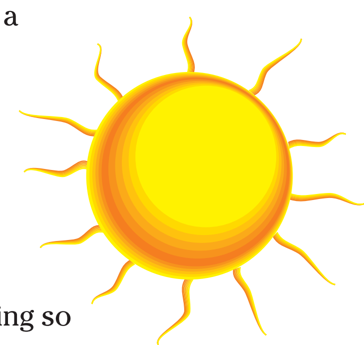
Graft unions may be sensitive to damage from cold. Only a portion of the graft may be injured. It may function for years until another kind of stress causes it to fail.

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, may be injured by cold. When damaged roots fail, the plant's top starts to die.

Preventing winter injury

- Select plants adapted to the local climate and soil conditions.
- If possible, place evergreen plants in areas that minimize their exposure to wind. Otherwise, provide a windbreak or shading during winter.
- In the fall, wrap the trunks of young, smooth-barked, 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 (Figure 7).
- Water landscape plants, especially evergreens, during fall and 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 are actually dead after growth begins. Sometimes, faded green branches begin to regrow and do not die. Even if leaves are dead, stems and vegetative buds may still 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 to find live tissue; older wood may be hardier than young wood.

Once the extent of the damage has been determined, do the following:

1. 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.
2. Water properly during the following growing season. Pay particular attention to plants beneath eaves.
3. If the soil lacks adequate amounts of basic plant nutrients, add fertilizer. If growth appears normal, fertilize only lightly if at all.
4. Use a loose, organic mulch to maintain soil moisture and protect the upper roots from temperature extremes.
5. 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 to 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 a property's aesthetic value. Often, however, these trees soon decline. They may exhibit stunted, brown leaves, twigs, or needles; thin foliage; and dead twigs and branches.

Causes

There may be a variety of causes, but damage is often the result of land-clearing and building activities.

Change of grade

When preparing a building site, developers often move soil, sometimes to level areas that were once sloping or to slope areas that were originally level. If trees are left standing, soil may be added over their roots, or the original soil level may be lowered. These changes can cause significant damage and even the 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 can also be detrimental. Most feeder roots, which supply the tree with water and nutrients, are located in the top 6 to 8 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 may also 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 the tree, the more difficult it is for it to recover.

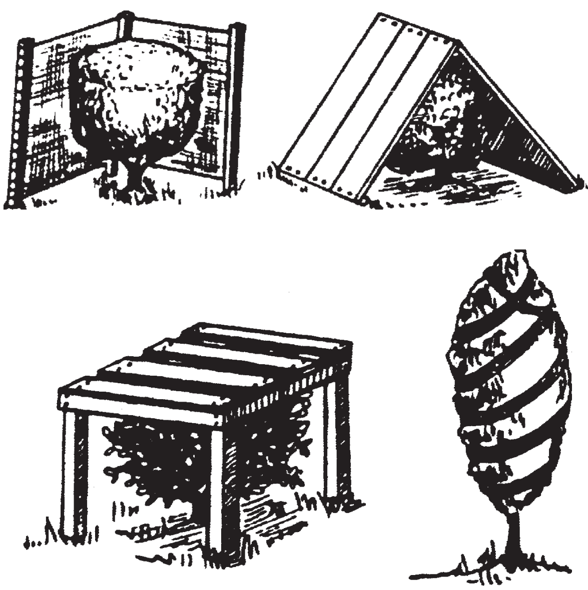


Figure 7.—Protecting shrubs from snow accumulation.

See Chapter 16, *Pruning*.

Soil compaction

Heavy equipment or repeated human 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 can eventually 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 and their 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. To raise the grade around a desired tree, construct a dry well around it. Consult a reputable tree specialist for advice.

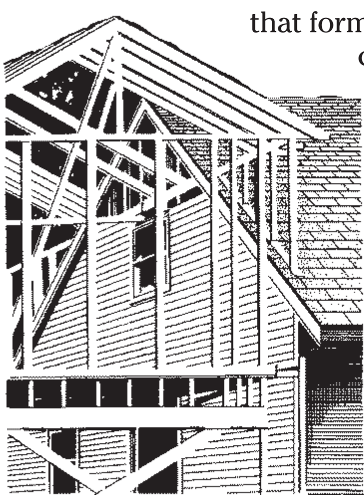
Care after construction

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, the 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 potentially damaged trees and shrubs properly. In this case, water is much more important than fertilizer. Use a complete fertilizer containing nitrogen and phosphorus in about equal proportions. See "Fertilizing" 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.

See Chapter 16, *Pruning*.

Remove dead trees. If live trees are a hazard, remove them or correct the hazard. Have professionals 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 the 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 eight to ten 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 in Wyoming. A wealth of information is available to help better understand specific plants or how to use them. Check with local bookstores or ask the university Cooperative Extension Service for publications about growing plants in the area.

University of Wyoming Cooperative Extension publications

Landscaping: Recommended Trees for Wyoming (B-1090)
Landscaping: Recommended Shrubs for Wyoming (B-1108)
Iron-Deficiency Chlorosis on Woody Plants in Wyoming (B-1097)
Landscaping: Water-Wise Gardening (B-1143)

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Hensley, D.L. *Professional Landscape Management* (Stipes Publishing, Champagne, IL, 1994). 343 pp.

Lily, S. *Arborists' Certification Study Guide* (International Society of Arboriculture, Urbana, IL, 1993). 170 pp.

Lloyd, J. *Plant Health Care for Woody Ornamentals* (International Society of Arboriculture, Urbana, IL, 1997). 223 pp.

Matheny, N., and J.R. Clark. *A Photographic Guide to the Evaluation of Hazardous Trees in Urban Areas* (International Society of Arboriculture, Urbana, IL, 1991). 72 pp.

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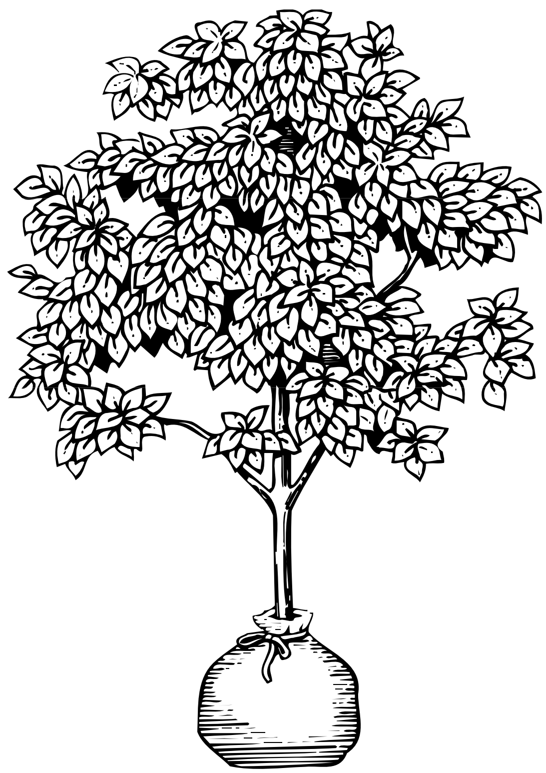
Watson, G.W., and E.B. Himelick. *Principles and Practices of Planting Trees and Shrubs* (International Society of Arboriculture, Urbana, IL, 1997). 200 pp.

Additional references

American Nursery and Landscape Association. *Resource Catalog.*
1250 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



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Lawns

8

The lawn has become one of the most important parts of the home landscape. It enhances a property's looks, a property's value, and its livability. It serves an aesthetic purpose and is also useful. A lawn is a ground cover intended to protect a home from the mud and dust of the outside world. Homeowners usually demand much more from their lawns than just covering. The home lawn can be a carpet for the outdoor living room, a cushion for children's play, a pasture for pets, an athletic field, a border for flower beds, or an arena for other outdoor activities. It should be attractive most of the year and vigorous enough to withstand a multitude of uses and abuses. Yet it should not be so vigorous as to require excessive maintenance.

A lawn consists of a large population of grass plants. To fulfill the various needs of the individuals in the home, the species of grasses used in a lawn should be selected with care. A good lawn begins with choosing the grasses which are best suited for the area and the uses for which a lawn is planted. The state of Wyoming contains large areas of native grasslands; however, few of these native grass species have much value as turfgrasses. There are others, however, that are adapted to Wyoming conditions.

Selecting the right turfgrass

The grass people sow will be the lawn they mow. No step in growing a permanent lawn is more vital to the final results than choosing a grass or mixture of grasses fitted for the job. If there were a large number of turfgrasses, this selection process might be quite complicated. In reality, there are only a few basic species suitable for planting in Wyoming.

Consider both intended use and climate when selecting the kind of grass for a lawn.

continues on page 146

Topics in this chapter

- Selecting the right turfgrass
- What about a low-maintenance lawn?
- Turfgrass species
- Soil preparation
- Maintaining the lawn
- Soils and fertilization

By Arthur L. Antonelli, Extension entomologist, Washington State University, and Gwen Stahnke, Extension turfgrass specialist, Washington State University. Adapted for Wyoming by Roger Hybner, former director Sheridan Research and Extension Center; Karen Panter, Cooperative Extension Service horticulture specialist, University of Wyoming; and Tony Koski, Extension turfgrass specialist, Colorado State University.

Turfgrass terminology

Vegetative parts of a grass plant (Figure 1) are useful for identifying a grass. Factors to look for include:

- Leaf blade
- Leaf sheath
- Vernation
- Collar
- Ligule
- Auricles
- Growth habit

Figures 2–8 illustrate each of these and give hints on what to look for when identifying a type of grass.

Always use more than one plant and identifying structure for identification since vegetative characteristics can vary depending on environmental conditions or cultivar.

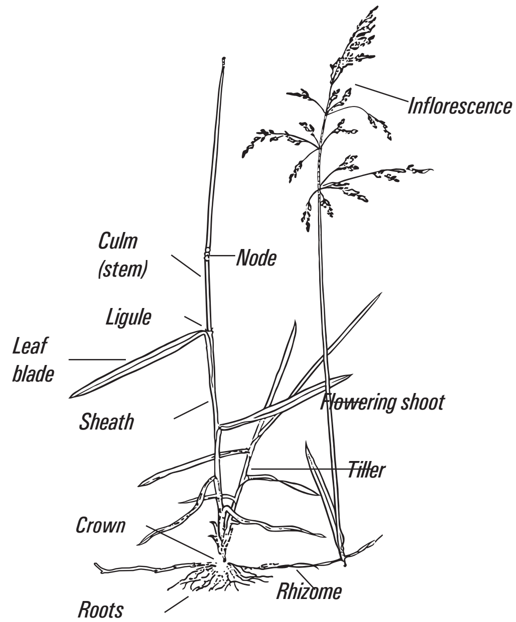

Figure 1.—A grass plant.

Leaf blade

The blade is the upper flattened portion of a turfgrass leaf (Figure 2).

- Is the leaf texture fine, medium, or coarse?
- Are veins prominent?
- What shade of green is the blade?
- Is the blade smooth (*glabrous*) or hairy (*pubescent*)?
- Is the tip of the blade sharply pointed, boat-shaped, or blunt and round?

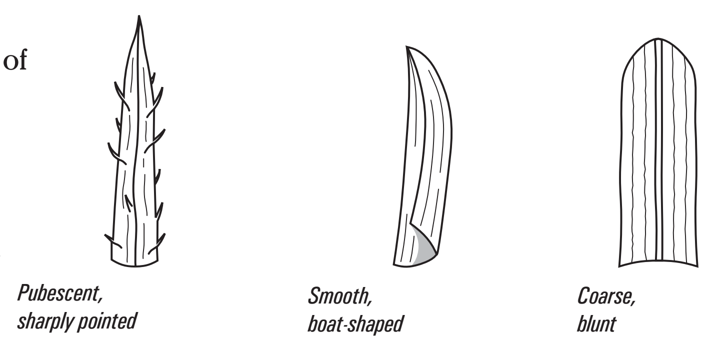

Figure 2.—Leaf blade shapes and textures.

Leaf sheath

The sheath is the lower portion of a leaf—the part that encircles the stem (Figure 3).

- Is the sheath cylindrical or compressed?
- Is the sheath closed or open or do the margins overlap?

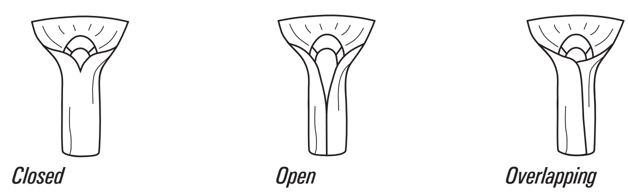

Figure 3.—Leaf sheath types.

Vernation

Vernation refers to the arrangement of new leaves within the older leaf sheath (Figure 4).

- Is the leaf folded or rolled when it emerges?

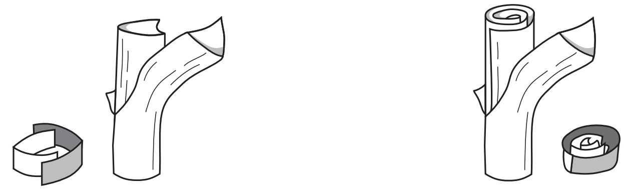

Figure 4.—Vernation types.

Collar

The collar is a band at the junction of the leaf blade and the leaf sheath (Figure 5).

- Is the collar divided, broad, or narrow?

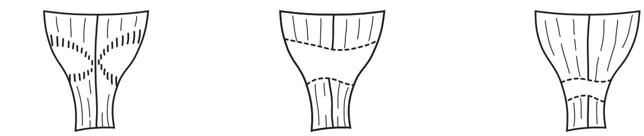

Figure 5.—Collar types.

Ligule

The ligule is an appendage on the inner side of a grass leaf at the junction of the blade and sheath (Figure 6).

- Is the ligule absent, membranous, or hairy?
- If present, what is the size and shape of the ligule?
- What does the upper edge of the ligule look like? Is it smooth, notched, or hairy (*ciliate*)?

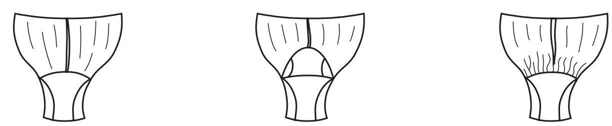

Figure 6.—Ligule types.

Auricles

Auricles are appendages occurring in pairs at the base of the blade (Figure 7).

- Are auricles present or absent?
- If present, are auricles small (rudimentary) or prominent (clawlike)?

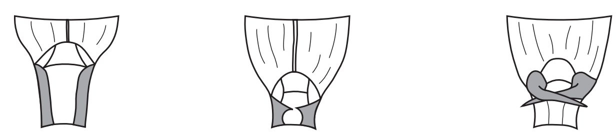

Figure 7.—Auricle types.

Growth habit

Growth habit refers to the orientation of shoots (Figure 8).

- Is the plant erect or lying down (*decumbent*)?
- Are there lateral shoots such as *rhizomes* (underground stems), *stolons* (aboveground stems), or *tillers* (shoots that arise from the crown)?

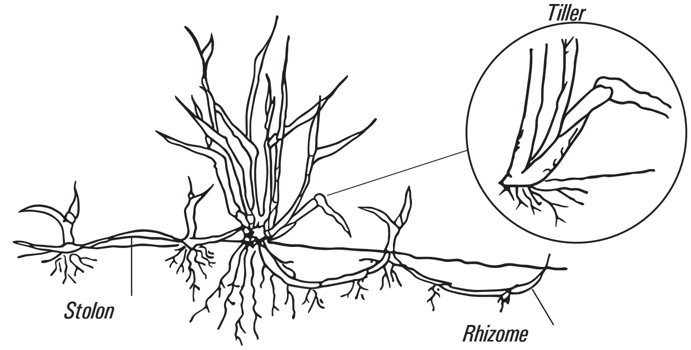

Figure 8.—Growth habits.

- Will it be planted for strictly aesthetic purposes or will it be used for play? If heavy traffic is expected, choose a cultivar (cultivated variety) that will tolerate lots of use.
- Will there be plenty of maintenance time available for the turfgrass or will minimal amounts of water and fertilizer and little or no pest management be the norm? If maintenance levels will be low, choose a turfgrass that requires little irrigation and fertilization.
- Is irrigation available? Most of Wyoming is semi-arid. When lawns can be irrigated, bluegrasses or fine fescues can be used. If no irrigation will be available, choose drought-resistant species.
- Is the water supply of good quality? If the water is high in salts or other contaminants, a turfgrass that tolerates salty or dry conditions should be chosen.
- Is the soil sandy or a heavy clay? Clay soils tend to drain poorly and may hold too much moisture for some types of turfgrasses.
- Is the lawn area in shade or sun? Most turfgrasses will not tolerate heavy shade conditions.
- What is the elevation? The higher the elevation, the harder it will be to select a turfgrass that will survive and thrive.
- How cold is the climate? Turfgrasses are divided into warm season and cool-season types. The long cold Wyoming winters virtually eliminate the use of warm season grasses such as Bermuda, Zoysia, and St. Augustine.

What about a low-maintenance lawn?

This means different things to different people. To some it means no maintenance with no irrigation, no fertilization, no or infrequent mowing, and little or no pest management. To most people, low maintenance simply means reduced levels of irrigation, fertilization, and pest management. The quality expectations of low-maintenance turf should not be high, however, since minimal inputs can only be expected to produce turf of minimal quality.

Table 1.—Turfgrass persistence under low maintenance (1 = best persistence; 10 = worst persistence).

Common name	**Latin name**	**Persistence ranking**
Buffalograss	*Buchloe dactyloides*	1 BEST
Blue grama	*Bouteloua gracilis*	1
Wheatgrass	*Agropyron* spp.	1
Smooth bromegrass	*Bromus inermis*	1-2
Hard fescue	*Festuca longifolia*	2-3
Sheep fescue	*Festuca ovina*	2-3
Creeping fescues	*Festuca rubra* spp. *rubra/trichophylla*	3-5
Chewings fescue	*Festuca rubra* spp. *commutata*	3-5
Tall fescue	*Festuca arundinacea*	5-6
Common Kentucky bluegrass	*Poa pratensis*	6
Improved Kentucky bluegrass	*Poa pratensis*	8
Perennial ryegrass	*Lolium perenne*	9-10 WORST

Proper selection of species and/or cultivars is very important since some species do not persist under low maintenance or neglect. Table 1 outlines various species of turfgrasses and their ability to withstand low maintenance.

Turfgrass species

Few people ask the preceding questions before deciding on which turfgrass to use. The basic assumption, sometimes erroneous, is that Kentucky bluegrass must be planted, and little attention is given to alternative turfgrass species. Here are some descriptions of turfgrasses that can be planted in Wyoming:

Kentucky bluegrass (*Poa pratensis*)

Kentucky bluegrass is the most popular turfgrass in Wyoming. Bluegrass is not native to North America and presumably was brought here by early colonists. This highly adaptable species has naturalized over much of the continent.

Common Kentucky bluegrass is not genetically pure but contains thousands of variations within the species. This genetic variability allows bluegrass to adapt itself to a wide range of climatic conditions and different soils (Table 2). Blends of cultivars may also provide these benefits. In recent years, many selections of bluegrass plants have been made, propagated, and introduced under various cultivar and brand names. These selections are genetically pure strains of selected Kentucky bluegrass clones.

Some cultivars of Kentucky bluegrass will tolerate shade, some require high maintenance,and others perform well with low maintenance (Table 3). Kentucky bluegrass should be seeded at a rate of 3 to 5 pounds per 1000 square feet of area. Blends of at least two different cultivars of Kentucky bluegrass seed are frequently sold.

Turf-type tall fescue (*Festuca arundinacea*)

Tall fescues are coarse-bladed bunchgrasses which generally do not mix well with other turfgrasses. They are often valuable in high traffic areas or where low maintenance will be provided. Tall fescues produce strong, deep, fibrous root systems and thus tolerate drought conditions. Seed distributors will often sell turf-type tall fescue blends that are combinations of several different cultivars of tall fescue. These blends are ideal for home lawn use and are generally less expensive than buying a single cultivar. Turf-type fescues should be seeded at 6 to 8 pounds per 1,000 square feet.

Fine fescues (*Festuca* spp.)

Fine fescues are sod-forming grasses that make excellent turf by themselves or in mixtures with other grasses such as bluegrass. Creeping red fescue spreads slowly by short rhizomes and establishes easily from seed. Most fescues tend to grow best in moderately fertile soils but will handle poor soils as well (Table 6). Fine fescues are compatible with bluegrasses. Fescue should be seeded at a rate of 5 pounds per 1,000 square feet. Some suggested cultivars are listed Table 7.

Blue grama (*Bouteloua gracilis*)

Blue grama is another warm-season grass that is actually native to Wyoming. Some suggested cultivars include Hachita, Lovington, and Common (or unnamed). The suggested seeding rate is 1 to 3 pounds per 1,000 square feet.

Crested wheatgrass (*Agropyron* spp.)

Crested wheatgrass is a long-lived, hardy, drought-resistant grass which can be used for dryland lawns throughout Wyoming. It thrives in most soils of the

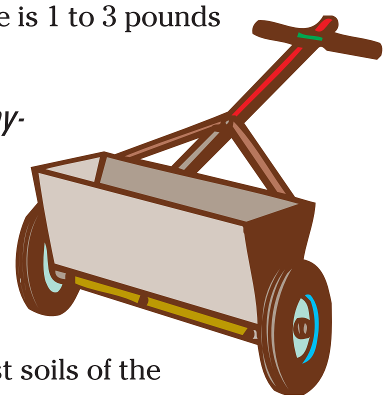

Table 2..—Advantages and disadvantages of Kentucky bluegrass.

Advantages	Disadvantages
sod forming - has underground rhizomes	thatch forming
high recuperative potential and rate	disease prone - leafspot, patch diseases, Aschochyta leaf blight
soft, easily mowed leaves	poor to fair shade tolerance
high quality - color, density	more frequent insect problems - billbugs, grubs, mites
readily available in sod form	higher nitrogen requirement than other grasses
excellent heat and cold tolerance	poor salt tolerance
good drought resistance - can go dormant and survive long periods without water	will invade flower and vegetable gardens

Table 3.—Kentucky bluegrass cultivars for various circumstances.

Shady areas
A-34, Alpine, Apex, America, Blacksburg, Bristol, Classic, Freedom, Georgetown, Glade, Limousine, Mystic, Nugget, Ram-I

High maintenance
P-104, Blacksburg, Midnight, Apex, Barcelona, Ascot, Broadway, Eclipse, Miracle, Shamrock, SR-2000, Platini, Bartitia, Touchdown

Low maintenance
Unique, ISI-21, Sophia, Voyager, Baronie, Livingston, SR-2000, Merion, Washington

Table 4—Advantages and disadvantages of turf-type tall fescue.

Advantages	Disadvantages
establishes quickly	seeding can produce poor results unless done very carefully
drought resistant - deep rooted	sod availability more limited compared to bluegrass
wear tolerant	leaf shredding more common when mower blade is dull
few disease problems	some varieties must be mowed more often than bluegrass
nice texture and deep green color	heavy use by children and/or pets can produce worn areas which may need overseeding
excellent heat and cold tolerance	if rooting is restricted by poor soil, may require the same amount of water as Kentucky bluegrass
slow thatch former	potentially short lived
does well in shade	
good salt tolerance	
slow to invade flower and vegetable gardens	

Table 5.—Turf-type tall fescue cultivars.

Adobe, Alamo, Apache II, Bonanza II, Bonsai Plus, Cochise, Coronado, Coyote, Crossfire II, Duke, Eldorado, Falcon II, Grande, Finelawn Petite, Guardian, Houndog V, Jaguar, Leprechaun, Lexus, Marksman, Mirage, Pixie, Pyramid, Rebel 3D, Rebel Jr., SR 8200, SR 8300, Safari, Shortstop, Silverado, Southern Choice, Starlet, Titan, Titan 2, Tomahawk, Vegas, Virtue
Note: The variety K-31 or Kentucky 31 is discouraged as it provides poor quality turf.

Table 6.—Advantages and disadvantages of fine fescues.

Advantages	**Disadvantages**
quick to establish	moderate to poor wear tolerance
fine leaf texture	moderate to poor recuperative potential
high density	can become thatchy
tolerates low fertility	may be difficult to mow due to tough leaves
tolerates poor soil conditions	not heat tolerant
drought resistant	susceptible to red thread, leafspot, dollarspot
moderate salt tolerance	
good shade tolerance	
cold tolerant	

Table 7.—Fine fescue cultivars.

Creeping red types Aruba, Barcrown, Boreal, Dawson, Flyer, Jasper, Seabreeze, Shademaster II **Chewings fescues** Banner II, Brittany, Bridgeport, Jamestown II, Koket, SR 5100, Shadow, Tiffany, Treazure, Victory
Hard fescues Aurora, Brigade, Discovery, ecostar, Reliant II, Scaldis, Spartan, SR 3100
Sheep fescue Quattro

Table 8.—Advantages and disadvantages of blue grama.

Advantages	**Disadvantages**
excellent cold, heat, and drought tolerance	warm season grass, becomes straw colored with first frost in fall, turns green in late spring
low fertility requirement	not traffic tolerant
requires infrequent mowing	not shade tolerant
few insect and disease problems	not a sod-forming grass
rapid germination and establishment	not adapted to elevations above 6,000 feet
native species	high seed cost
naturalizes well with spring bulbs	difficult to seed due to high percentage of inert components

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Table 9.—Advantages and disadvantages of crested wheatgrass.

Advantages	Disadvantages
excellent cold, heat, and drought tolerance	becomes dormant quickly under drought conditions
low fertility requirement	does not form a tight sod
recovers rapidly from dormancy (drought)	light green or blue-green color

Table 10.—Advantages and disadvantages of smooth bromegrass.

Advantages	Disadvantages
excellent cold, heat, and drought tolerance	turf lacks density
low fertility requirement	leaves are coarse
sod former	susceptible to leafspot
persists under neglect	can be invasive due to rhizome growth

Table 11.—Advantages and disadvantages of buffalograss.

Advantages	Disadvantages
excellent heat and drought resistance	warm-season grass, green only a few months during the growing season
excellent cold tolerance	poor to fair shade tolerance
few disease and insect problems	fair salt tolerance
sod former, aggressive stolons	not recommended for use at higher than 6,500 feet elevation
low fertility requirement	will not tolerate heavy, constant traffic
requires only infrequent mowing	aggressive stolons will invade flower beds, driveways, neighboring lawns
can be established from seed sod or plugs	becomes less aggressive and more prone to weeds if overfertilized and/or overwatered
a native species	
naturalizes well with spring bulbs	

Table 12.—Advantages and disadvantages of perennial ryegrass.

Advantages	Disadvantages
quick to establish	does not recuperate well from damage
wear tolerant	leaf shredding is common from dull mowers
good color and density	disease prone - rust, leafspot
does not form thatch	poor shade tolerance
compatible in color and texture with bluegrass	unavailable as pure sod
may contain endophytes	poor freezing tolerance if flooded or exposed to wind
can possess good drought resistance if deep rooted and in well-prepared soil	
moderate to good salt tolerance	

Table 13.—Perennial ryegrass cultivars.

Accent, Achiever, Advantage, Assure, Blazer III, Brightstar, Calypso II, Citation III, Cutter, Dancer, Divine, Edge, Elf, Excel, Express, Imagine, Laredo, Legacy II, Line Drive, Majesty, Manhattan 3, Morning Star, Navajo, Night Hawk, Nobility, Omega 3, Omni, Pegasus, Pennant II, Precision, Prizm, Quickstart, Riviera II, Roadrunner, SR 4010, SR 4200, SR 4400, Saturn II, Stallion Select, Top Hat, Vivid, Wind Star, Wizard

plains and intermountain regions (Table 9). Crested wheatgrass should be sown at a rate of 5 pounds per 1,000 square feet. Some suggested cultivars include Ephraim and RoadCrest.

Smooth bromegrass (*Bromus inermis*)

Smooth bromegrass is also adapted to Wyoming's climate (Table 10). One recommended cultivar exists - Lincoln. It should be seeded at a rate of 10 to 12 pounds per 1,000 square feet.

Buffalograss (*Buchloë dactyloides*)

Buffalograss is a fine-bladed perennial grass which spreads by above-ground stolons (Table 11). It is very drought resistant and is suited for dryland lawns in Wyoming. It can be established by seed or sod. It is slow to establish but eventually forms a very dense lawn. During the growing season it is gray-green but turns straw colored when growth stops in the fall. It is a warm-season grass and therefore browns out with the first hard fall frost and doesn't turn green until June or even later. Buffalograss should be seeded at a rate of 2 to 3 pounds per 1,000 square feet.

Perennial ryegrass (*Lolium perenne*)

Common perennial rye has the characteristics of quick germination and short life span (Table 12). It is a bunchgrass that typically has limited use in Wyoming. Rye seed is inexpensive and is often found in turf seed mixtures. Since it has a short life span, it may be useful to use on sloping areas to help prevent soil erosion while the lawn is becoming established. The suggested seeding rate for perennial ryegrass is 6 to 8 pounds per 1,000 square feet.

There are newer cultivars of perennial ryegrass that are more suited to lawn use than common rye. Table 13 lists some cultivars available.

Soil preparation

Before seeding or sodding, steps should be taken to prepare the soil. Extra time and energy spent before planting will go a long way toward minimizing problems in the future.

- Always choose grass species and cultivars that are adapted to the local area. Spend a little extra money to buy top quality certified seed or sod. It won't be regretted.
- A soil test is recommended on the area to be seeded or sodded. This is very important in determining fertilizer needs. Pay particular attention to iron levels in the soil. Contact a local University of Wyoming Cooperative Extension Service (UW CES) office for further information.
- Do some pre-plant weed management. This is particularly important when difficult perennial weed species are present. These tough weeds include Canada thistle, bindweed, quackgrass, bentgrass, and bermudagrass. Use a herbicide with no residual activity such as glyphosate (brand name Roundup). Allow enough time

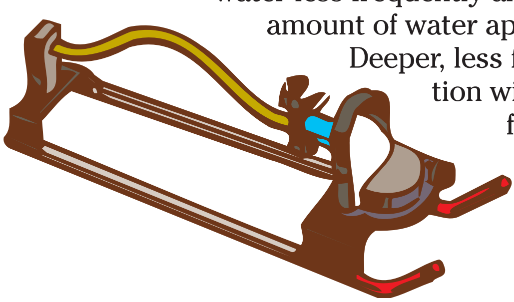
See Chapter 2, *Soils and Fertilizers*.

before planting for the herbicide to fully translocate.

- Use soil test results to determine how much fertilizer, if any, is needed. Incorporate fertilizers to a depth of 6 to 8 inches or as deeply as possible.
- If the organic matter content in the soil is less than 5 percent (and most Wyoming soils are), incorporate 3 to 5 cubic yards of good quality compost per 1,000 square feet to a depth of 4 to 8 inches. This should be enough to cover the soil with compost 1 inch deep before incorporation.

Before seeding:

- Prepare the area for seeding by smoothing and removing large rocks and other debris. Avoid overcultivating, though, because it will result in a fluffy seed bed that will be prone to compaction and crusting.
- If recommended by a soil test, apply up to 1 pound of nitrogen (N) per 1,000 square feet using urea, diammonium phosphate, or any quality starter fertilizer.
- Seed in two directions at right angles to each other with one-half of the seed in each direction. Using a seed drill or slit seeder is recommended. If the seed is broadcast, lightly rake or drag the seed into the soil. Slopes that may be prone to erosion should be mulched with clean straw, netting, or matting of some type.
- Irrigate lightly and frequently during germination to keep the soil surface moist. As the seedlings mature and form a deeper root system, gradually water less frequently and increase the amount of water applied each time. Deeper, less frequent irrigation will encourage the formation of a deeper root system.



- Avoid using pre-emergent herbicides in a newly seeded lawn (one exception is siduron, brand name Tupersan). Post-emergent broadleaf weed herbicides should not be used until the turf has been mowed two or three times.
- Seed cool-season grasses in mid to late August or early September and between late June and mid August in areas above 6,500 feet in altitude.

Before sodding:

- The soil should be prepared as for seeding, above.
- The soil should be slightly moist when the sod is laid.
- Water a newly sodded lawn frequently enough so that the underlying soil is always moist but isn't constantly saturated.

Maintaining the lawn

Irrigation

Water should be applied at a rate that allows the water to penetrate the soil and not run off. In fine-textured (clay) soils common in Wyoming, water won't penetrate as rapidly as it will in sandier soils. If the water is running off the turf surface, it is being applied too rapidly.

Enough water should be applied at each irrigation so that the soil is wet to a depth of about 12 inches. Wait to water again until an area of soil is dry. Shallow, frequent irrigations will encourage shallow root growth and undesirable soil conditions. They also wet the foliage more often, which can lead to disease problems.

A mature, healthy Kentucky bluegrass lawn will need up to 2 inches of water per week during the hottest, driest part of the summer. This should be applied in two or three irrigations per week.

It is also beneficial to water the lawn thoroughly in late fall before the ground freezes. This will help ensure that the grass roots will survive the winter. Low temperatures as well as Wyoming's radical temperature swings in winter can seriously damage grass roots if the soil is dry. Moist soil is "buffered" and takes longer to change temperature, thus helping to protect roots.

In winter, watering is also beneficial. If there is no snow cover and the ground is not frozen, the turf will benefit from watering every four to six weeks. Pay particular attention to exposed slopes, sites with shallow soils, and south or west-facing exposures.

Soils and fertilization

pH

The optimum soil pH range for most turf is 6.5 to 7.0. Most Wyoming soils are above that. Turfgrasses can be grown on soils with these higher pH levels if careful attention is paid to providing additional iron (Fe) and phosphorus (P). Phosphorus can be supplied by either leaving grass clippings on the lawn after mowing or by applying a balanced (complete) fertilizer. Iron deficiencies can be corrected by applying iron sulfate or iron chelate to the soil when symptoms develop. Trying to lower soil pH by using sulfur rarely works. This is because Wyoming soils are highly buffered and resist changes in pH.

Soil structure

The best way to improve soil structure is by adding good quality organic matter before seeding or sodding. This enhances soil structure and also improves water and nutrient-retention capabilities. The organic matter used must be free of pathogens and weed seeds and must be low in soluble salt content. Good sources of organic matter include well-aged manure, composted bark or sawdust, garden compost, and sphagnum peat moss (not mountain peat). Organic matter should be incorporated to a depth of 4 to 6 inches and as uniformly as possible.

Applying organic matter over the lawn surface is not recommended because a layering effect can occur. This layering effect can disrupt both upward and downward movement of water in the turf.

Balanced (complete) fertilizers

Most turf fertilizers contain nitrogen (N), phosphorus (P), and potassium (K) and sometimes iron (Fe) and sulfur (S). It helps to add these types of fertilizers if clippings are routinely removed from the lawn after mowing. Even if clippings are left, the use of a complete fertilizer is beneficial.

Winterizer fertilizers

These fertilizers usually contain higher percentages of phorphorus and/or potassium in addition to nitrogen. These fertilizers are often touted as enhancing winter hardiness of turf, but there is currently no evidence that suggests that extra P or K is beneficial for bluegrasses, ryegrasses, or fescues for winter hardiness. The most important nutrient for late-season (fall) fertilization of bluegrasses, ryegrasses, and fescues is still nitrogen. The use of winterizer fertilizers should not be discouraged, however, because it encourages homeowners to fertilize in late summer/fall, which is an excellent time.

Late-season fertilization

Late-season nitrogen fertilization has been applied by turf managers on Kentucky bluegrass for years. This practice involves applying much of the season's nitrogen during the late-season months of August through October (depending on location). This is not to be confused with dormant or winter

fertilization. Late-season fertilization requires that nitrogen be applied before the turf loses its green color in the fall. The advantages to late-season fertilization include:

- better fall and winter color
- earlier spring greening
- increased shoot density
- improved fall, winter, and spring root growth
- enhanced storage of energy reserves (carbohydrates) within the turf plant.

When fertilizing in the late season, use a fertilizer that does not depend heavily on warm temperatures or microbial activity to cause the nitrogen to be released. Good fertilizers to use are those that contain urea, sulfur-coated urea, IBDU (isobutylidine diurea), methylene ureas, and ammonium sulfate.

See Chapter 2, *Soils and Fertilizers*.

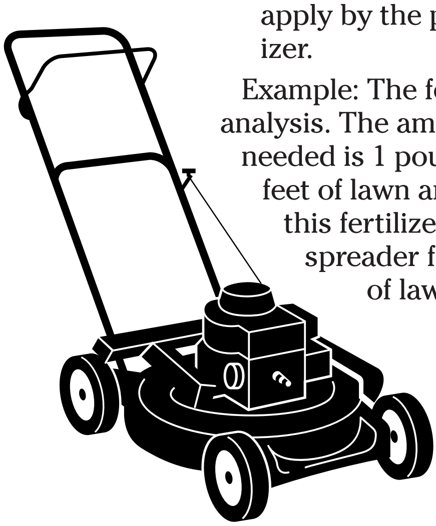
How much to apply

To calculate how much of a fertilizer source to apply, use the following steps:

1. Check the three numbers on the fertilizer bag. The first number is the percent of nitrogen (by weight), the second number is the percent of P_2O_5 (not actual P), and the third number is the percent of K_2O (not actual K).
2. Make note of the percent N in the fertilizer.
3. Divide the number of pounds of N to apply by the percent of N in the fertilizer.

Example: The fertilizer has a 20-5-10 analysis. The amount of this fertilizer needed is 1 pound of N to 1,000 square feet of lawn area. How many pounds of this fertilizer are needed in the spreader for each 1,000 square feet of lawn area?

1 pound N ÷ 0.20 N = 5 pounds of this fertilizer must be applied per 1,000 square feet of lawn (See Tables 14 and 15.)



Mowing

The two most important facets of mowing are mowing height and mowing frequency. Here are some tips:

- The preferred mowing height for all species is 2 ½ to 3 inches The minimum height that any lawn should be mowed to is 2 inches. Mowing to heights less than 2 inches results in decreased drought and heat tolerance plus higher incidences of insect, disease, and weed problems. Mow at the same height all year; there is no reason to mow shorter in the fall.
- Mow frequently enough that no more than one-third of the grass height is removed at any single mowing. If the mowing height is 2 inches, the grass should be mowed when it is 3 inches tall. If the mowing height is 3 inches, it should be mowed when it is about 4 inches tall. Bluegrass or fescue lawns may need mowing every three or four days during the spring but only once every seven to 10 days during periods of heat, drought, or cold. Buffalograss may only need mowing once every 10 to 20 days depending on the irrigation frequency.
- Grass clippings should be allowed to fall back onto the yard unless they are used for composting or mulching elsewhere in the landscape. Grass clippings decompose quickly and do not contribute to thatch accumulation. If herbicides have been applied to the lawn, clippings should not be used as compost or mulch but should stay on the lawn. Clippings recycle nutrients and organic matter back into the turf - an added benefit.
- Check mowing equipment frequently during the season for sharpness and adjustment. Ideally, rotary mower blades should be sharpened every fourth mowing. This is especially important when using rotary mowers on fescue or ryegrass lawns since a dull

Table 14.—Fertilizer application schedule for established Wyoming lawns.

Turfgrass species	Mid March to April	May to mid June	July to early August	Mid August to mid September (if grass is green)	Early October to early November
High-maintenance bluegrass, perennial ryegrass	1/2 to 1*	1	not required	1	1 (2)
Low-maintenance bluegrass	1 March through June		not required	1	(1)
Turf-type tall fescue	1/2	1/2 to 1	not required	1	(1)
Fine fescue	1/2	1/2 to 1	not required	1/2 to 1	not required
Buffalograss, blue grama	no N	1/2 to 1	1/2 to 1	no N	no N

*Nitrogen application rates are in pounds of actual nitrogen per 1,000 square feet of lawn area.

blade will shred and fray the leaf blades instead of cutting cleanly. The result is a brown-colored, unattractive lawn. Reel-type mowers should be checked for proper blade-to-bedknife adjustment before each mowing to avoid shredding and tearing grass leaves.

Thatch and compaction management

Thatch is a tight, brown, spongy organic layer of both living and dead grass roots and stems that accumulates above the soil surface. Interactions among environmental conditions, soil conditions, and management practices (irrigation, mowing, fertilization) influence the rate and extent of thatch accumulation. Thatch tends to be a problem on Kentucky bluegrass and fine fescue lawns. It is rarely an issue on tall fescue, wheatgrass, bromegrass, or buffalograss lawns.

Grass clippings do not contribute to thatch problems.

Measure the thatch layer by removing a small piece of turf, including the underlying soil. Beyond the one-half-inch thick point, thatch can be very difficult to manage. As the thatch layer thickens, it becomes the main rooting medium for the grass instead of the soil underneath. This predisposes the turf to drought stress and winterkill and also increases chances for insect, disease, and weed problems. Also, fertilizers and pesticides applied to a thatchy lawn aren't as effective.

Take measures to slow thatch accumulation when the thatch layer exceeds one-half inch. Measure the thatch layer by removing a small piece of turf, including the underlying soil. Beyond the one-half-inch thick point, thatch can be very difficult to manage. As the thatch layer thickens, it becomes the main rooting medium for the grass instead of the soil underneath. This predisposes the turf to drought stress and winterkill and also increases chances for insect, disease, and weed problems. Also, fertilizers and pesticides applied to a thatchy lawn aren't as effective.

Power raking and dethatching

Power raking has been used as a method of thatch removal for years. Light, shallow power raking can be beneficial if done frequently enough. However, deep power raking of a thatchy lawn can be very damaging and often removes a substantial portion of living turf. Used properly, power

Table 15.—Characteristics of some nitrogen fertilizers.

Fertilizer name	Analysis	N source	Residual N activity
Quickly available N fertilizers			
Ammonium nitrate	33-0-0	ammonium nitrate	4 to 6 weeks
Ammonium sulfate	21-0-0	ammonium sulfate	4 to 6 weeks
Ammonium phosphate	18-46-0	diammonium phosphate	4 to 6 weeks
Urea	46-0-0	urea	4 to 6 weeks
Slowly available fertilizers			
Slow-release sources			
Sulfur-coated urea	22 to 38% N	urea	10 to 15 weeks
ONCE	24 to 35% N	urea, nitrate, ammonium	15 to 36 weeks
Slowly soluble sources			
IBDU	31-0-0	isobutylidine diurea	10 to 16 weeks
Ureaform reaction fertilizers			
Nitroform	38-0-0	ureaformaldehyde	10 to 30 weeks
FLUF	18-0-0	urea/ureaformaldehyde	6 to 10 weeks
Nutralene	40-0-0	methylene ureas	7 to 12 weeks
Methylene urea	39-0-0	methylene ureas	7 to 9 weeks
Coron	28-0-0	urea/methylene ureas	7 to 9 weeks
N-Sure	28-0-0	triazone/urea	6 to 9 weeks
Natural organic fertilizers			
Ringers	6-1-3	blood, bone, seed meals	10 to 12 weeks
Sustane	5-2-4	composted turkey waste	10 to 12 weeks
Milorganite	6-2-0	activated sludge	10 to 12 weeks

raking wet, matted turf can help speed spring greening and encourage air movement into the root zone.

Core aerating/cultivating

See Chapter 5, *Weeds,* and Chapter 19, *Pesticides.*

This is a much more beneficial thatch management technique than power raking. The reasons are that core aerating/cultivating helps improve root zone by relieving soil compaction and also helps control thatch accumulation. In fact, soil compaction is one of the factors that contributes to thatch accumulation.

In core aeration, plugs of thatch and soil 2 to 3 inches long (the longer the better) are removed by the aerating machine and deposited on the lawn surface. A single aeration machine with one-half-inch diameter tines will remove about 10 percent of the thatch from a lawn if enough passes are made to result in an average 2-inch spacing between holes.

Leaving the cores on the lawn after core aerating is recommended. Over time the cores will disintegrate and filter back down into the lawn. The resultant mingling of soil and thatch hastens the decomposition of the remaining thatch. If leaving the cores on the turf is not an option, they can be raked and composted.

continues on page 160

Table 16.—Lawn diseases.

Disease/symptom	Conditions favorable for development	Management: Cultural	Management: Fungicidal*
Ascochyta leaf blight *(Ascochyta spp.)*			
Affected turf will be straw colored. Leaves die back from the tips.	Cool, moist. Winter drought. Dull mower blades.	Good turf management. Water in morning. Sharpen mower blades.	See labels
Dollar spot (*Sclerotinia homeocarpa*)			
Small, yellow-green blotches on grass blades. Turf becomes white, gradually becoming silver dollar size.	Summer drought. Low nitrogen. Warm days and cool nights.	Water deeply. Fertilize properly. Core aerate. Remove thatch. Minimize compaction.	See labels
Fairy ring (*Marasmius oreades*)			
Rings of dark green grass; sometimes dead zones, with or without tan mushrooms, 1–2" in diameter.	Mild, moist. Mushrooms appear mostly in spring and fall.	Open soil mechanically. Soak rings with water daily for one month. Spot water and fertilize.	flutolanil
Fusarium patch (*Microdochium nivale*). See also Pink snow mold.			
Browning and thinning of turf in large indefinite spots (1–8").	Cool, wet.	Promote air and soil drainage. Avoid excessive nitrogen. 2 pounds sulfur per 1,000 square feet per year may help.	fenarimol mancozeb triadimefon Use twice in spring and twice in fall.
Gray snow mold (*Typhula* spp.)			
Irregular, dead, bleached areas (2–24") with gray mold, usually under or near melting snow.	Cold, wet; worse under prolonged snow cover.	Avoid late fall, heavy nitrogen fertilization.	Apply before snowfall: chlorothalonil fenarimol triadimefon flutolanil
Helminthosporium diseases—*Bipolaris*, *Drechslera*, and *Exserohilum* species (*Helminthosporium* spp.)			
Root and crown rot; yellowing and thinning of turf or tan to purple spots on leaves.	Moist, cool = leaf spots. Moist, warm = root and crown rot. Shading, thatch, and mowing too short.	Water in morning, infrequently, and deeply. Pick up clippings. Do not let grass get matted. Moderate nitrogen. Reduce thatch. Mow as high as is practical.	chlorothalonil mancozeb

continues on next page

Table 16.—Lawn diseases (continued).

Disease/symptom	Conditions favorable for development	Management: Cultural	Management: Fungicidal*
Necrotic ring spot *(Leptosphaeria korrae)*			
Dead circles, arches, and patches several inches to several feet in diameter.	Heat, drought, compaction. Sodded lawns with cultural practices that favor thatch.	Promote deep-rooted turf and avoid thatch by proper fertilizer and water management.	fenarimol
Pink snow mold (*Microdochium nivale, Fusarium nivale*). See also Fusarium patch.			
Circular, light brown to dark brown patches (2–12"). Patches commonly bleached under snow and covered with pink fungus.	Cold, wet; worse under prolonged snow cover.	Avoid late, heavy nitrogen fertilization.	Apply before snowfall: fenarimol mancozeb triadimefon
Powdery mildew (*Erysiphe graminis*)			
White powdery spots on both surfaces of grass blades. Yellowish lesions may develop.	Cool, shaded areas. Stressed turf.	Shade tolerant varieties. Selectively prune trees/shrubs to increase light penetration and air circulation.	See labels.
Slime molds (various fungi)			
White to yellow slimy growth, usually turning to masses of small, dark, powdery "pin-heads" on large leaves; occasionally large, gray, powdery mounds (1–3") . Not parasitic.	Mild, moist.	Mow, rake, or wash off with water. Usually disappears after one–two weeks.	Common turf fungicides may prevent reappearance.
Summer patch *(Magnaporthe poae)*			
Small circular patches of slow-growing, thin turf, coalescing into larger patches of straw-colored turf with onset of hot weather.	Soil compaction. Hot, wet weather. Frequent, light waterings. Some herbicides and fungicides.	Alleviate stress. Promote deep root development.	See labels.

Table 16.—Lawn diseases (continued).

Disease/symptom	Conditions favorable for development	Management: Cultural	Management: Fungicidal*
Take-all patch (*Gaeumannomyces graminis* var. 'avenae')			
Thinning and/or dying of turf in circles (4–36") followed by invasion of weeds and annual bluegrass in center.	High moisture favors disease development, but symptoms do not show until turf is under moisture stress.	Use ammonium sulfate in balanced N-P-K nutrition program (3-1-2 ratio). Avoid high lime. 3 pounds of sulfur per 1,000 square feet per year may help.	fenarimol
Yellow patch (*Rhizoctonia cerealis*)			
Light brown to yellow patches and rings.	Prolonged moisture at 40–60°F.	Avoid excessive irrigation and fertilization to ensure deep rooting.	flutolanil

Table 17.—Common home lawn fungicides.

Note: Fungicide registrations vary by state. Not all products may be available in a given area. Before purchasing any fungicide, read the label to make certain it is labeled for the intended use. Then follow all label directions and precautions when applying the product.

Common name	Trade name	Registrant
chlorothalonil	Blackleaf Lawn and Garden Fungicide	Wilbur-Ellis Company
	Cooke Daconil	Cooke Laboratory Products, Chas. H. Lilly Company
	Green Thumb Lawn and Garden Fungicide	Cotter and Co.
	Ortho Multi-Purpose Fungicide	Solaris Corp.
fenarimol	Rubigan A.S.*	Dow Elanco Company
flutolanil	Prostar 50 WP*	AgrEvo Chemical Company
mancozeb	Fore Lawn Fungicide	Black Leaf Products Company
	Maneb Plus with Zinc	Green Light Company
	Broad Spectrum Mancozeb Spray	Green Light Company
triadimefon	Bayleton 25 Turf and Ornamental Fungicide	Miles Agricultural Chemical Division
	Fung-away	Green Light Company

*These fungicides may be registered for use by homeowners but are not commonly found in garden centers; check farm and feed stores. They are available only in large containers (1- to 4-pound bags, for example).

See Chapter 19, *Pesticides*.

For more information

UW Cooperative Extension Service publications

Landscaping: Turf in Wyoming (B-1129)

Low-Maintenance Grasses for Revegetating Disturbed Areas and Lawns (B-1070)

Snow Molds of Turfgrass (B-868)

Other publications

Christians, N. *Fundamentals of Turfgrass Management* (Ann Arbor Press, Chelsea, Michigan, 1998). 301 pp.

Divider Goes Here

Interior Plants

9

Cultivating plants inside a 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, one 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 a home.

A 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 is usually much higher in kitchens and bathrooms than in living rooms. Temperatures vary widely. The overall climate may range from humid subtropical to arid desert conditions in various locations.

The environmental factors of light, temperature, and humidity are to a large extent determined by how a home environment is managed for family comfort. Other environmental factors such as water and nutrient availability can be managed solely for the 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.

Topics in this chapter

- Managing light
- Managing temperature
- Managing humidity
- Managing water
- Managing nutrients
- Potting and repotting
- Houseplant problems

By George Pinyuh, Extension agent emeritus, King and Pierce counties; E. Blair Adams, Extension horticulturist (deceased); Arthur L. Antonelli, Extension entomologist; and S.J. Collman, Extension agent emeritus; all of Washington State University. Adapted for Wyoming by Karen L. Panter, Cooperative Extension Service horticulture specialist, University of Wyoming.

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 Cooperative Extension Service Master Gardeners, local garden club members, neighbors, houseplant books (there are hundreds, many available at libraries), garden encyclopedias (also available at libraries), and newspaper columns written by houseplant enthusiasts.

In general, a plant needs an environment as similar as possible to that where it grows naturally. Understory plants (those that live on the forest floor) can grow in diffuse light. Plants from deserts and 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 being grown 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.

Managing 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 located 1 foot away from a window may receive 100 foot candles of light. If it is moved 2 feet away from the window, it will receive only 25 foot candles of light, and at 3 feet it receives only 11 foot candles. Very few if any houseplants do well at such low-light intensities.

The most expedient method of adjusting light intensity is to move a plant closer to or farther from a light source such as a window. Unfortunately, this may place the plant in an inconvenient spot. Alternative ways to increase light intensity include:

- Moving the plant to a lighter room (southern versus northern exposure)
- Placing the plant near an electric light
- Providing separate artificial light for the plant
- Providing reflected light with a light-colored wall or mirror
- Keeping leaves free of dust and grime.

To reduce light intensity:

- 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).

Managing temperature

Home temperatures are adjusted for the comfort of people, but temperatures vary considerably in most homes. Bedrooms are usually cooler than bathrooms or living areas. Southern-exposure rooms are usually 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.

Managing humidity

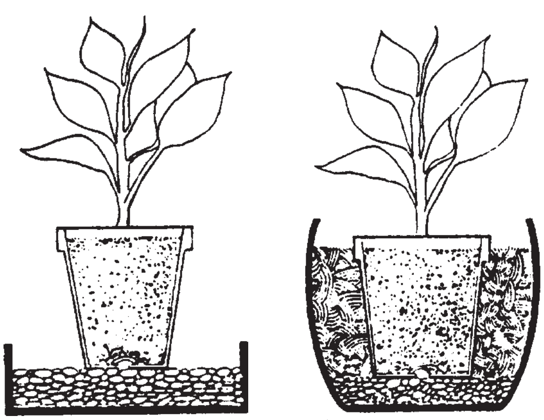
Many plants require a more humid climate than the average home. Ferns, ivies, and other humid-climate plants may grow best in bathrooms or kitchens, where the air is usually more humid. One can increase relative humidity around a plant by placing its pot on a shallow tray of moist gravel (Figure 1a). The gravel will evaporate water into the air around the plant.

Damp sphagnum moss packed between pots in planters also evaporates water into the air (Figure 1b). Moss has the added advantage of acting like a wick to draw up and dispose of excess water in the bottom of a planter box.

Grouping plants together in the same room raises the relative humidity for all. Plants transpire water continuously. The more plants being grown, the more water they transpire into the air.

A humidifier is another way to raise humidity. The higher relative humidity preferred by plants is also healthier for people.

Misting plants does not significantly increase humidity. It may, however, help keep leaves clean, which also is desirable.



(a) Gravel *(b) Sphagnum moss*

Figure 1.—Two ways to increase humidity around a plant: (a) A layer of moist gravel or pebbles in a tray beneath the pot; (b) a pot inside a large planter filled with moistened sphagnum peat moss.

Managing 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.

See Chapter 2, *Soils and Fertilizers*.

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.

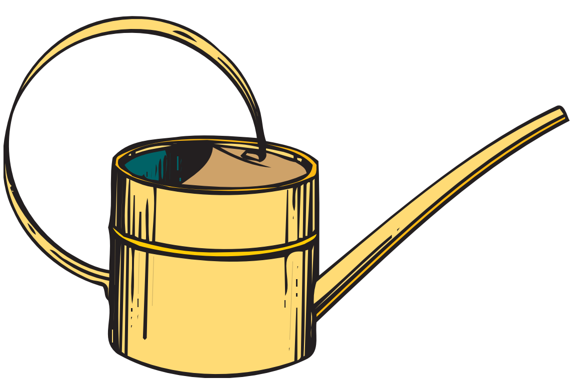
The following guidelines may help establish a satisfactory watering schedule:

- 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 technique usually assures that the available water supply is replenished and also reduces salt buildup.
- Do not allow pots to sit in excess water. Pour it away or raise pots on shims so they are always 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 watering 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 very 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, allowing water to run down and out the drainage holes without actually 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.
- Fluoride in tap water can damage sensitive plants. (See Table 1.)



- Room-temperature water is best. Plants such as African violets and their relatives may require even warmer water.

Managing 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 in 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 a watering can according to the label directions. Mix only enough solution to water plants once each time they are fertilized.

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 over fertilize. More is not better. Plants can be killed by 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. Repot mature houseplants on an annual basis or allow them to remain in containers until they have outgrown them or become pot bound (Figure 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 is already established in a container can be repotted. When first planting into pots, select small plants so that it is not necessary to remove many roots to fit the plant into the container. Pot rooted cuttings when the roots are about ½ inch long. Seedling plants transplant most readily as soon as the first true leaves have formed.

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 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 drain holes, pot the plants in drained pots that fit inside the other containers. 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 example, 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 conserves growing space, reduces the likelihood of over watering, 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. The quantity and type of soil mix determine how much water the pot retains for plant use.

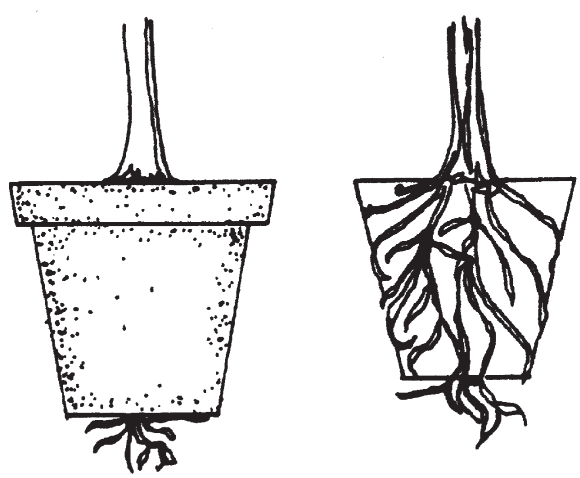


Figure 2.—If roots are growing out of the drainage hole, it's time to repot.

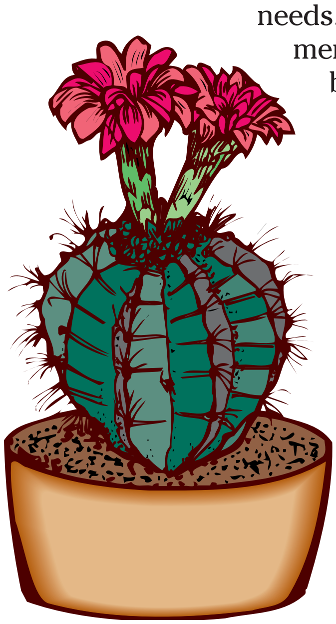
Potting soil mixtures

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 and 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.

See Chapter 2, *Soils and Fertilizers*.

Ready-to-use potting soil mixes are available in garden stores. Some of these commercially prepared potting soils are excellent but expensive. For only a few houseplants, prepared mixes are convenient and probably the most practical. However, if growing numerous houseplants, it may be more economical to prepare 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 must also contain sufficient mineral nutrients to supply a large part of a plant's 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 management techniques (watering and fertilizing) are adjusted to suit their different needs. Modify this general potting mixture with additional coarse mineral material or peat moss to satisfy specific plant requirements.
Instructions are given below.

General mixture

1 part garden soil (not clay)
1 part washed builder's sand, perlite, or pumice
1 part horticultural peat moss
1 quart steamed bonemeal per bushel (8 gallons) of mixture
1 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. When the mix is thoroughly blended, add sufficient water to moisten it. Then store it in a sheltered spot until ready to use. 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

1 part general potting mixture (above)
1 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

1 part general potting mixture (above)
1 part sand or coarse perlite

Cacti and other succulents grow best in a low-organic soil mixture 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.

Sterilizing soil

It is normally 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 soil treatment. Place slightly moist soil in a heat-resistant container, cover it, and bake it in a 250°F oven. 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, one can adjust the mixture for any type of plant. This arrangement requires only a minimal amount of storage space, and the 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 are also 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 repotting from another pot, gently remove the plant and crumble some of the old soil ball away (Figure 3).

If potting a new plant, trim the root system if necessary to fit the pot (Figure 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 5). Slap the sides of the container as the soil filters around the plant roots to help settle the medium. Thumping the bottom of the pot on the potting bench also aids in this process.

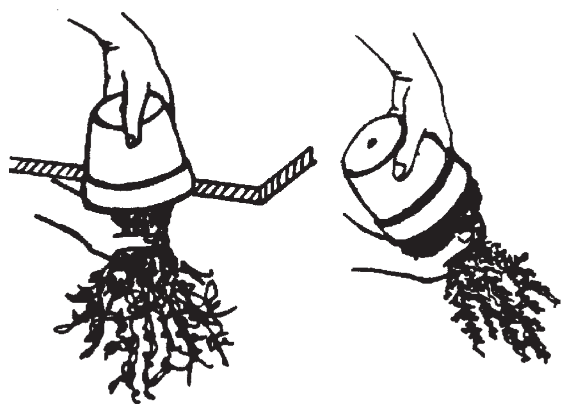


Figure 3.—Removing plants from pots.

Figure 4.—Trimming roots before repotting.

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 ½ 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 potting or repotting a plant is finished, fill the pot to the brim with water. Keep adding water until it comes out the drain hole to be sure the reservoir has been filled completely to the 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 Washington State University publications PNW0151, *Propagating Herbaceous Plants from Cuttings,* PNW0165*, Layering to Renew or Multiply Plants*, and PNW0170, *Propagating Plants from Seed.*

See Chapter 20, *Propagation*.

Houseplant problems

Most houseplant problems are related to cultural or environmental stress. Table 1 shows symptoms, possible causes, and treatments to help 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 proper conditions cannot be achieved for certain types of plants, it may be best to discard them and get varieties that grow successfully in the conditions provided.

See Chapter 3, *Entomology.*

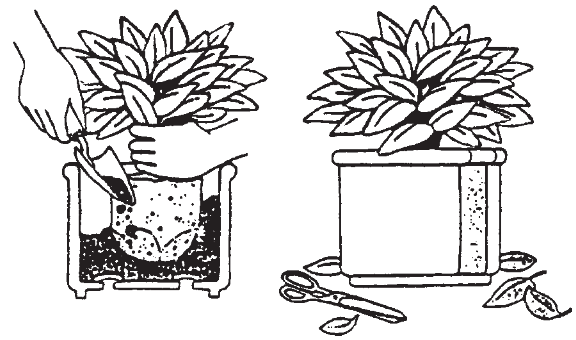


Figure 5.—Repotting a plant.

Other problems are caused by insects. Some of the more common ones are described below. Prevention is a key to managing houseplant pests. If 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 are normally 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.

Major pests

Aphids

Aphids are small insects about 1/16 to 1/8 inch long. They are six-legged, 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 a 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.

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Table 1.—Houseplant problem symptoms, possible causes, and treatments.

Symptoms (what is seen)	Possible causes	Treatment (corrective action)
Plants are spindly, 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 5 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.

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Table 1.—Houseplant problem symptoms, possible causes, and treatments (continued).

Symptoms (what is seen)	Possible causes	Treatment (corrective action)
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 (e.g., 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.

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 1/10 to 1/16 inch long that resemble tiny moths. Their bodies and wings are covered with a white, powdery substance. When at rest, they hold their wings roof-like 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 is often 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 as many as 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 are generally quite small, ranging from 1/16 to 1/8 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 (i.e., oystershell scale) while others look like turtle shells. The scale is actually 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 are often present. Severe plant injury or death may be the final result of poor control.

Chemical control of adults is often 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 3/16 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.

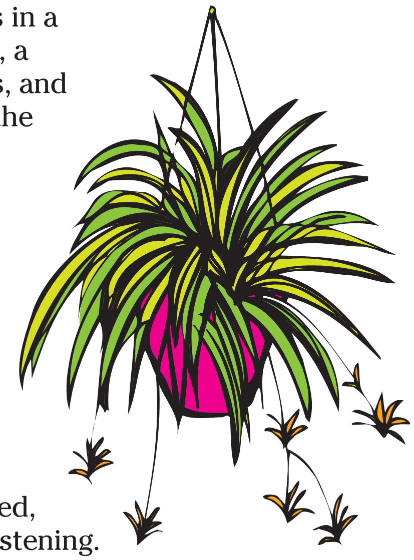
Mealybugs attack all plant parts. Damage is similar to that caused by aphids. Honeydew and sooty mold frequently occur on plants infested with mealybugs.

Spider mites

Mites are often 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 is often 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 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 can also be transferred to other plants by hands or clothing.

Damage consists of twisted, curled, and brittle leaves, deformed buds, and flowers that are often streaked with darker color. Blackening of leaves is also common.

Minor or less common pests

Leafminers

Many different insects are commonly 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 is rarely serious; it is usually 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, are most often 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 (1/8 inch or so) up to 1½ inches long. Coloring 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 may also have a series of false legs along the tail end.

Their presence is usually the result of an uninvited, fertile female moth who slips past a screen door and lays eggs inside. Caterpillars as well as other pests can also develop on plants that have been placed outdoors during the summer. Remove and destroy any eggs or caterpillars.

Beetles

Flea beetles and other leaf-feeding beetles are potential houseplant pests. These beetles have chewing mouth parts. 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 1/16 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 may also be noticeable, and some plants may have a silvery appearance. Flowers are also damaged.

Leafhoppers

Leafhoppers are small to moderate-sized sucking pests (1/16 to 1/4 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 (1/5 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 are often identified as such even by professionals.

Hand removal of slugs is usually all that is necessary. Look for them under mulch, pots, and pot rims. Placing shallow dishes of beer near plants is helpful because 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 1½ 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 (¼ to 2 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 avoid unhappy encounters with houseplant pests. When buying 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 new plants to 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 plants are put outside, treat them as newly purchased when they are brought 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; it may contain uninvited members of the soil fauna such as mites and slug eggs. Commercially prepared potting soil might be a better choice. With 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. In handling garden store plants or admiring a friend's collection, one can pick up scale crawlers or mites and bring them home to one's own plants. It is wise to be on the lookout for plant pests before handling strange plants.

See Chapter 20, *Propagation*.

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 used as 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 some smaller individuals were overlooked.

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 (e.g., 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.

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.

See Chapter 19, *Pesticides*.

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 may also 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 are generally 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.

For more information

University of Wyoming Cooperative Extension Service publications

Greenhouse Structures (B-1147)
Care of Flowering Potted Plants (B-1146)

Washington State University Cooperative Extension publications

Building Hobby Greenhouses (PNW0171)
Houseplant Pests (EB0695)
Houseplants (EB1354)
Interior Plantscape Pest Control (MISC0176)
Layering to Renew or Multiply Plants (PNW0165)
Propagating Herbaceous Plants from Cuttings (PNW0151)
Propagating Plants from Seed (PNW0170)

Oregon State University Extension publications

Care and Handling of Poinsettias (FS 162)

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Vegetable Gardening

10

The two major keys to a successful vegetable garden are planning and maintaining growth momentum. Planning will make a garden more productive and enjoyable. After a garden is planted, growth momentum can be maintained through proper fertilization, irrigation, and weed control. This chapter provides information on all these topics.

Selecting a garden site

- Select a level area that has loose, well-drained soil and receives at least eight hours of sun per day (12 hours is ideal). On sloped sites, use contour rows or terraces to reduce erosion. South-facing slopes are warmer and less subject to damaging frosts. However, perennials may be more likely to bloom too early and suffer damage from late spring frost on south-facing slopes.
- Avoid placing a garden in a low spot, at the base of a hill, or at the foot of a slope bordered by a solid fence. Such areas are slow to warm in the spring and, since cold air naturally drains into low areas, frost settles there. Also, if a creek is nearby, the water table may be very high or the area may be subject to flooding. Avoid windy locations. If planting in a windy spot, build or grow a windbreak.
- Locate a garden near a good, easily accessible water supply. Choose a spot near the house so it is convenient to work in the garden. Avoid planting near trees and shrubs because they compete for nutrients and water and may shade plants. Note that sites near buildings may not receive enough sunlight. Observe shading patterns through the growing season before starting a garden. To use a shaded area, plant shade-tolerant crops and increase effective light by reflecting light to the plants.

Topics in this chapter

By Pat Patterson, Extension program assistant, Lane County, Oregon State University. Adapted for Wyoming by Karen L. Panter, Cooperative Extension Service horticulture specialist, University of Wyoming.

- Try not to plant genetically related crops in the same location more than once every three years. Rotation prevents the buildup of some insects and most soil diseases. Chapter 4, *Plant Disease*, contains a list of related crops. Avoid locations near busy roads. Airborne pollutants (especially lead) from automobile exhaust can contaminate vegetables, especially leafy types. If planting in a lead-prone area, plant a hedge to trap airborne lead. Organic matter in the soil also helps bind lead. Avoid locating a garden on a site where buildings with lead paint have stood because as lead may be present in the soil in toxic amounts.

See Chapter 4, *Disease*.

Planning

Answering the following questions is a vital part of planning:

- *Who will do the work?* Will the garden be a group project, with family members or friends working willingly through the season? Or will one person be handling the hoe alone between camping and swimming? Remember, a small, weed-free garden produces more than a large, weedy mess.
- *What does a family like to eat?* Although vegetables in garden catalogs look delicious, there is no value in growing things no one eats. List the family's favorite vegetables in order of preference. Use this list when deciding how much to plant of each. Successive plantings of certain crops such as beans give a longer harvest and increase the yield.
- *How will the produce be used?* Canning, freezing, drying, or simply storing are factors not only in planning the size of a garden but also in selecting varieties. Some varieties keep much better than others. Make sure the selections are adapted to the intended use.
- *How much space is available?* Consider how much area can be converted into usable garden space, not simply how much empty ground is available.

Plan the garden on paper first as early as January or February. List recommended varieties and planting dates. Draw a map showing arrangement and spacing of crops. To keep a garden growing all season, a spring, summer, and fall garden plan may be needed. Using transparent overlays is an excellent way to plan and rotate a garden.

In the plan, place tall and trellised crops on the north side of the garden so they won't shade shorter vegetables. Also group plants by growing period. Plant spring crops together so later crops can be planted in these areas after the early crops mature. Consider length of harvest as well as time to maturity. Put perennial crops to the side of the garden so they will not be disturbed by annual tillage and replanting.

Order seeds at least two to four months before planting. Some plants can be started indoors as early as January. Start plants at the right time so they are not too mature or too fragile when it's time to plant.

Gardening equipment

Garden catalogs and stores are full of tools, many highly specialized. Some are very useful, others are nice but unnecessary, and some are gimmicks. The equipment needed depends on the size of a garden, one's strength and physical condition, and whether the job is to be done quickly or slowly. Oregon State University Extension publication EM 8504 describes how to modify tools for people with physical problems.

The minimum equipment needed by most gardeners includes a shovel or spade, a scuffle-type hoe, a rake, and a trowel. There is a wide selection of styles, and the choice is really one of personal preference and budget. One can get the best value for the price by considering each tool's uses and particular qualities when comparison shopping.

When purchasing tools, buy for quality rather than quantity. Tools will be used frequently. Cheap tools tend to break or dull easily and make a job unnecessarily difficult and frustrating. Quality tools last and keep their value if well kept. Tools should be lightweight for easy handling but heavy enough to do the job properly. Metal parts should be steel or hardened aluminum which stay sharp, keep their shape, and outlast softer metals.

Hand tools for cultivating

Various hand tools are illustrated in Figures 1 and 2. Shovels are earth movers with dish-shaped blades mounted to the handle at an angle. A garden shovel with a pointed blade is lighter and smaller than most other shovels and is well suited for garden use. Spades have a flat blade and are designed for cutting rather than lifting or moving soil. They are excellent for shaping straight-sided trenches and edging beds.

Shovels and spades come with long or short handles in standard or D-shaped styles. The choice of handle style depends on personal preference. For general-purpose digging, lifting, and moving, a long-handled shovel is ideal. Long handles offer greater leverage and are less tiring to use; short handles are often thicker and stronger. Choose a tool that fits one's height and strength.

A spading fork is useful for breaking and turning heavy soils and for loosening subsoil layers when double-digging a bed. Turning coarse compost, spreading mulches, and digging root crops are other jobs suitable for a spading fork. A hoe is essential for preparing a seedbed, removing weeds, and breaking up crusted soil. Several hoe styles are available. The lightweight Warren hoe has a heart-shaped blade and is useful for opening seed furrows and cultivating between plants. The hula or action hoe is a lightweight, maneuverable scuffle hoe. Pushing and pulling it just under the soil surface eliminates newly emerging weeds and breaks up crusted soil. This hoe works best on noncompacted soil since the blade is relatively thin and lacks the clod-breaking capabilities of a heavier hoe. It also is less effective where weeds have gotten a good start. Other types of scuffle hoes are somewhat sturdier and are used with a pushing motion rather than pushing and pulling.

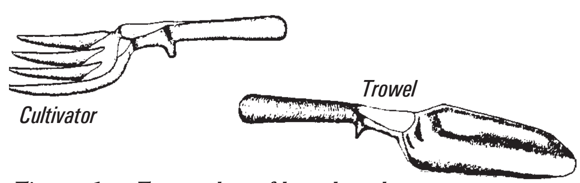


Figure 1.—Examples of hand tools.

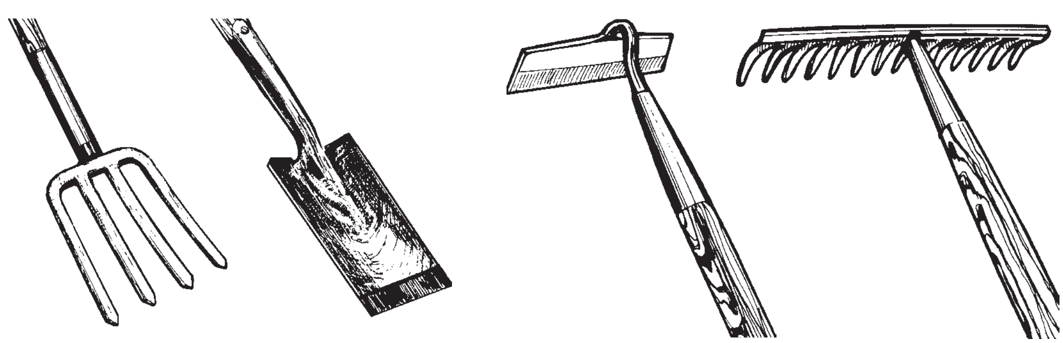


Figure 2.—Examples of cultivating tools. (Reprinted by permission from Home Gardens, *EB0422, Washington State University.)*

A sturdy rake is useful for clearing away rocks and debris, spreading mulches, and smoothing seedbeds. Choose a rake based on one's size, strength, and intended uses. As the number of tines increases, the weight also increases. Avoid choosing a rake so heavy it will cause quick tiring. The length of the rake handle is also important. The tip of the handle should come up to one's ear when the rake is standing upright. A handle that is too short will make the work harder and cause excess bending and back strain.

A trowel is used a lot, especially in spring, for digging jobs that don't require full-size tools. Trowels are perfect for transplanting seedlings and bulbs or digging shallow-rooted weeds. Small hand cultivators, often sold in sets with trowels, are good for weeding small areas and between closely spaced plants. Another useful digging tool is appropriately named a dandelion digger (also known as a weeder, cultivator, or asparagus knife). It is indispensable for digging weeds with long taproots such as dandelions or Queen Anne's lace or for prying out quack-grass rhizomes. It consists of a long (10 to 14 inches) solid metal rod with a two-pronged blade at one end and a handle at the other.

Other tools include pickaxes, mattocks, and wheel cultivators. Pickaxes break up extremely hard-packed or stony soil. Mattocks are used for the same purpose but have a cutting blade for removing large roots. A mattock can also chop debris for composting. A wheel cultivator has a number of attachments for soil preparation and weed control and may prove a good investment for large gardens. Tarps and 5-gallon buckets also are handy.

Power tools

The power rotary tiller is the power tool most commonly used by gardeners. Whether one needs a rototiller depends on the size of the garden, one's capabilities, and the intended uses of the tiller. Remember that overusing a tiller can destroy soil structure.

Both front and rear-tined tillers are available. Rear-tined tillers self propel on all but the rockiest soils. They travel straight and produce a footprint-free seedbed. There are optional attachments for a variety of uses such as hilling potatoes, making raised beds, and even plowing snow! The price of a rear-tined rototiller is considerably higher than that of a front-tined type. Consider the payback time necessary for such a large investment. Front-tined tillers are useful for lighter chores such as shallow cultivation or final seedbed preparation. They are even available in electric models.

Few other power tools are needed for a vegetable garden. A shredder is handy for a large garden with a lot of plant waste. Hand-operated shredders are slow but useful for small amounts of waste that is not too coarse. Gasoline shredders are quite expensive and should not be expected to chip branches and other large materials. They are best for shredding leaves, small branches, and other plant wastes. (Sunflower stalks, for example, would probably be too large.) A chipper, on the other hand, will chip large branches and other coarse material. A chipper shredder is a valuable aid for large gardens and/or serious composters.

Carts and wheelbarrows

A wheelbarrow or cart is handy in and around the garden. It should be easy to maneuver when full. Choose a size appropriate for one's physical abilities and garden needs. A wheelbarrow requires more strength and control than most garden carts.

Durable construction is well worth the price to ensure a long, useful life. Many small carts are made of relatively flimsy metal and, although inexpensive, are not particularly long lasting or suitable for heavy items such as rocks. To haul only light straw, leaves, sawdust, or similar materials, a small cart is adequate. For heavier jobs, use a wheelbarrow or investigate the newer garden carts, especially those with bicycle-size tires which make easy work of hauling. They are made of plywood and metal or of aluminum and are well balanced and easy to maneuver. Some are even collapsible.

Watering equipment

Watering is a must. Adequate water makes a big difference in garden yields. Determine whether cultural practices such as mulching, close plant spacing, shading, or wide-bed planting will meet the extra water needs. Then purchase watering equipment accordingly.

Overhead sprinklers waste water; drip irrigation systems are more efficient. Drip irrigation puts water right at the roots and doesn't wet plant leaves, thereby helping to control disease.

Timers allow automatic watering with drip and some other systems. However, they are relatively expensive and may be a nuisance because of maintenance and placement requirements.

Environmental monitoring equipment

Serious gardeners often invest in equipment that allows them to monitor the microclimate around their garden. These tools help tailor gardening practices to a particular site. For example:

- A rain gauge is an inexpensive device that tells how much rain has fallen.
- A maximum-minimum thermometer measures nighttime lows and daytime highs. It can be used to determine a site's microclimate.
- Soil thermometers measure soil temperature and the internal temperature of compost piles. They can help determine when to plant.

Trellises and cages

Trellises and cages for vining plants save space and keep fruits off the ground, thereby reducing plant damage and saving one's back.

Building one's own saves money and produce better quality for the price. One can even make a swing-down trellis to make it easier to harvest vegetables from vining plants. Use heavy-duty materials and sturdy design so the structure will withstand plant weight, rain, and wind. Use heavy-gauge wire and wood treated with a nontoxic material. Do not use wood treated with creosote or pentachlorophenol. Concrete reinforcing wire and PVC pipes also make excellent basic materials.

Tool maintenance

Thoughtfully selected and maintained, tools will give many years of service. The most important step in tool care is to put tools in their proper places. Tools left in the garden rust and break and can be a safety hazard. Some gardeners paint handles a bright color to make tools easy to spot.

Keeping a tool clean and sharp increases its usefulness and lengthens its life. Learn and practice the techniques of sharpening each tool. Professional gardeners often carry sharpening stones or files and sharpen tools after every hour or so of use.

Clean tools after each use. One effective method is to fill a 5-gallon bucket with sand and moisten the sand

thoroughly with oil. Keep the bucket in a tool shed and at the end of the gardening day remove clinging dirt from tools by plunging them into the oily sand several times. This practice keeps tools clean and oiled and prevents rusting.

Anyone with actual experience using a hoe knows there is a great difference between a sharp hoe and a dull one. While sharpening a hoe may seem like a lost art, it is easy to learn.

Hoes can be sharpened using an 8-inch mill file. Put the hoe blade in a vise or stand it up against a solid surface. File against the cutting edge, using enough pressure so that the file cuts instead of slides. Try to maintain the original angle of the bevel. Be careful not to get cut on the newly sharpened blade.

In fall, get tools ready for winter. Sharpen the tools, lightly oil metal parts, and rub wooden handles with linseed oil. Drain gasoline from power tools and obtain filters, mufflers, and tune-up parts so that a fall or late-winter tuning can get machines ready for early spring jobs. Have maintenance done during winter when demand is lowest.

Clean trellises, cages, traps, and other pest-control devices. Store them inside if possible. Repair cold frames and other season extenders and protect them from damage after their job is done. Oil and store wheeled tools such as cultivators, seeders, and carts.

Preparing the soil

The ideal vegetable garden soil is deep, easily worked, and well drained and contains at least 5 percent organic matter. Proper soil preparation provides the basis for good seed germination and subsequent crop growth. Careful use of soil amendments improves garden soil and provides the best possible start for crops. If soil is high in clay, using raised beds might be appropriate. If wind and drought are serious problems, consider sunken beds.

Soil testing

Check soil fertility and pH by having the soil analyzed before starting a garden. Recheck in 3 to 5 years if not having any problems. For best results, carefully follow instructions for taking a soil sample.

Soil tests measure the level of some nutrients as well as soil pH. They do not test for potential disease or contamination problems.

See Chapter 2, *Soils and Fertilizers*.

Soil pH measures the degree of acidity or alkalinity of the soil. Soil pH affects the availability of many plant nutrients. If it is too high or too low, poor crop growth will result. Vegetable requirements vary, but most crops do well with a pH of 6.2 to 6.8, which is slightly below neutral (slightly acid).

County Cooperative Extension Service offices can provide information for obtaining a soil test. The laboratory will mail results with recommendations for correcting any deficiencies that may exist. These reports and recommendations can be discussed with your local extension offices.

Tilling

To prepare a new garden, remove sod and put it upside down in a pile to compost. Plow, spade, or rototill the soil. Turn the soil again each year before planting.

Work only when soil moisture conditions are correct. Working excessively wet soils can destroy soil structure, which may take years to rebuild. Plowing wet soil with a tractor is especially damaging because it creates a compaction layer that inhibits root growth. Soils with adequate humus generally allow more leeway in when they can be worked because they have better structure.

To test soil moisture, take a handful of soil and squeeze it. If it stays in a mud ball, it is too wet. If it is powdery and clumped, it is too dry. If it crumbles freely, it is about right. If soil sticks to a shovel or the turned surface is shiny and smooth when spading, it is still too wet.

Working soil in the fall has several advantages over traditional spring plowing. It allows earlier planting because the basic soil preparation already is done when spring arrives. Turning under large amounts of organic matter in the fall is likely to result in better decomposition since autumn temperatures are higher than those of early spring and there is more time for the process to take place before planting. Harmful insects, disease organisms, and perennial weeds are killed, buried, or exposed to harsh winter weather.

Heavy clay soils improve with alternate freezing and thawing, which breaks up tightly aggregated particles. Snow is trapped in roughly plowed soil, so more moisture is retained than on flat, bare ground. Incorporating limestone or rock fertilizers in the fall allows them to integrate with the soil and influence spring plant growth.

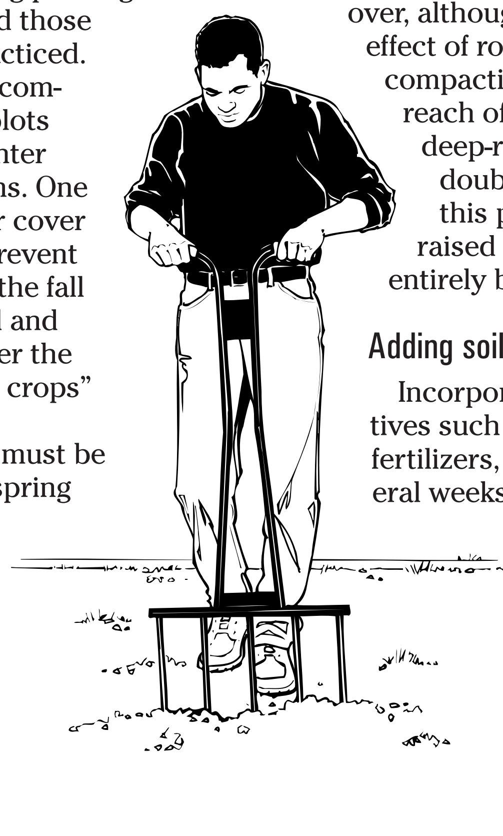
Note, however, that spring plowing is better for sandy soils and those where shallow tilling is practiced. Fall plowing alone is not recommended for steep garden plots since soil is exposed all winter and may erode when it rains. One solution is to grow a winter cover crop to improve soil and prevent erosion. In this case, till in the fall to prepare the soil for seed and again in spring to turn under the green manure. (See "Cover crops" later in this chapter.)

Generally, most gardens must be disked or rototilled in the spring to smooth the soil for planting. (Permanent raised beds are an exception.) Just before planting, break up large clods of soil and rake the bed level. Small-seeded vegetables germinate best in smooth, fine-surfaced soil.

Do not pulverize the soil. Over tilling destroys soil structure and promotes crusting, which inhibits water infiltration and increases erosion.

The equipment chosen to prepare a garden depends on the garden's size as well as on a person's physical ability, time, and budget. Options include hand-digging with a fork, spade, or shovel; tilling with a power rotary tiller; and using a small garden tractor or full-size farm tractor. If there are raised beds, the choices may be limited to small hand tools.

Turning the soil over completely can be detrimental; it may create soil compaction, upset the balance of microorganisms, and bury coarse organic matter so deeply that insects and microbes can't break it down. Rototilling, however, is acceptable for most home gardens as long as plant debris accumulation is not excessive. It has the benefit of mixing the upper layers of soil rather than completely turning them over, although one possible harmful effect of rototilling is to form a compaction layer just beyond the reach of the tines. Use of deep-rooted cover crops or double digging can alleviate this problem. Alternatively, raised beds can be worked entirely by hand.



Adding soil amendments

Incorporate slow-release additives such as aged manure, rock fertilizers, or green manure several weeks before planting. Add soluble fertilizers and finished compost just before planting.

When to plant

Regardless of whether one plants seeds directly in the garden, start one's own transplants, or purchase transplants, it's important to plant each crop at the correct time. Air and soil temperatures are critical to maintaining healthy plant growth, so planting too early or too late may deny vegetables the chance to grow and develop under good conditions.

For each type of plant, there is a minimum, optimum, maximum, and critical air temperature. Often, nighttime temperature is most critical, especially for fruit set on peppers, tomatoes, cucumbers, and melons. Temperature range often is more critical than the average temperature. Table 1 shows minimum, optimum, and maximum air temperatures for common vegetables.

Another aspect of temperature is *growing degree days* (GDD). This value measures the heat units usable by a plant for growing. For each crop, it is based on the temperature at which plants begin to grow (known as the *base temperature*). For cool-season crops, the base temperature is 40°F; for most warm-season crops, it's 50°F; and for peppers, eggplants, melons, and other tropicals, it's 60°F. Each crop requires a certain number of GDD to mature. For example, grapes require 1,000 to 1,600 GDD to sweeten and ripen. GDD are also used to predict pest emergence in order to time controls optimally.

To calculate a day's GDD, use the following equation:

$$\text{GDD} = \frac{\text{Max temp} + \text{Min temp}}{2} - \text{Base temp}$$

Add up the GDD since planting to calculate the accumulated GDD for a crop.

Soil temperature is as important as air temperature for plant growth. All seeds germinate best when soil temperature is about 70°F. Table 2 shows minimum (not optimum) soil temperatures for vegetable growth. The nitrogen cycle, which is important for making nutrients available to plants, is inactive below 40°F and most active between 80° and 90°F. Check the soil temperature at 9 a.m. at a 2-inch depth for seven consecutive days.

Starting from seed

Choosing and purchasing vegetable seeds is a most enjoyable gardening pastime. Thumbing through colorful catalogs and dreaming of the season's harvest make winter seem a little warmer. Make notes about the seeds chosen—their germination qualities, plant vigor, and insect and disease problems. From this information, one can determine whether a seed company

Table 1.—Air temperatures for vegetable growth.

Crop	Minimum (°F)	Optimum (°F)	Maximum (°F)
Bean, snap	50	80–90	100–110
Corn	50	85–90	100–115
Cucumber	48–50	75–80	95–105
Eggplant	60	70–85	95–100
Melon	59–65	86–98	110–120
Pepper	60	70–80	95–100
Pea	38–42	50–60	70–75
Potato	43–45	50–60	80–90
Tomato	50–55	60–80	85–95
(Night temperatures for fruit set)	55–56	59–68	72

meets the needs and whether the chosen varieties are suitable for the area and one's gardening style. For example, if powdery mildew is a big problem on squash family plants in the area, one may want to look for mildew-resistant varieties.

Planting depth

Various factors such as seed size, soil type, and season influence the depth to cover seeds. Some seeds require light to germinate and should not be covered at all. Read the packet directions. Instructions apply to seeds planted both indoors and out.

As a general rule, if soil is quite sandy or high in organic matter, plant seeds to a depth of four to five times their width, not their length. Seedlings emerge quite easily from sandy or organic soil.

If soil is heavy with a high silt and/or clay content, cover seeds only two to three times their diameter. Apply a band of sand, fine compost, or vermiculite 4 inches wide and ¼ inch thick along the row. These materials help retain soil moisture, reduce crusting, and make it easier for seedlings to push through.

When planting a fall garden in mid summer, the soil is warm and dry. Cover seeds six to eight times their diameter.

Starting seeds indoors

Adequate light is essential for starting seeds indoors. More home-grown seedlings are lost to inadequate light than to any other factor. Seedlings grown under low-light conditions are leggy and weak and topple over when they are 3 to 4 inches tall. Unless there is a sunny room or porch with a southern exposure, supplemental lights will be needed. A fluorescent shop light with two cool white bulbs suffices. Two bulbs illuminate a width of 12 inches along the length of the bulbs although light intensity falls off at both ends. Replace bulbs yearly.

Table 2.—Minimum soil temperatures for vegetable growth.

Crop	Temperature (°F)
Bean, snap	48–50
Cabbage	38–40
Carrot	39–41
Corn*	60–65
Eggplant	55–60
Melon	55–60
Onion	34–36
Pea	34–36
Pepper	55–60
Potato	39–41
Radish	48–50
Tomato	50–55

*Supersweet varieties are very sensitive to low temperatures.

A soilless or peat-lite mix is best for starting seedlings. Garden soil contains highly destructive disease organisms that can kill small plants. To use soil, pasteurize it first. To do so, place slightly moist soil in a heat-resistant container, cover it, and bake it in a 250°F oven. Use a candy or meat thermometer to ensure that the mix reaches 140°F for at least 30 minutes. This is a smelly process, but it works.

Peat-lite mix can be made with 50 percent perlite and 50 percent fine sphagnum peat. Pasteurized soil can also be added as one-third of the mix.

There are several options for seed-starting containers. Although expensive, preformed peat pellets or cubes require no additional soil mix. Soak them until thoroughly wet and plant seeds in the holes provided. Then plant the whole cube in the garden without disturbing the roots. Plant seeds in rows in flats or other large containers and grow seedlings until they have one or two sets of true leaves. At this time, transplant them into individual containers and grow them to transplant size. Economical options include pots, old cans, cut-off milk cartons, margarine tubs, or other throwaways.

See Chapter 20, *Propagation*.

Pop-out trays, available at garden centers, are easy to use and reusable. Peat pots are good, especially for large seeds and herbs. Sow one or two large seeds or several small seeds directly in each peat pot. Thin to one or two seedlings per pot. Plant peat pots directly into the garden. Remove one side and do not allow the edges to stick above the soil; they act as a wick and evaporate moisture from the exposed surface. Make paper pots or soil cubes with or without special equipment or purchase pot-making kits.

Regardless of the container used, fill it three-quarters full with a seed-starting mixture. Be sure there is adequate soil depth for the plant. Sow the seeds (Figure 3), cover them to the specified depth, and add water. If the home is dry, cover the containers with plastic wrap to maintain a consistent moisture level until the seeds germinate.

Seeds and seedlings are extremely sensitive to drying out. Do not keep them soaking wet, however, since constant moisture is conducive to damping-off, a fungal disease deadly to seedlings. Prevent or reduce damping-off by sprinkling milled sphagnum moss, which contains a natural fungicide, on top of the soil.

Planting seeds directly in the garden

Soil temperature affects the speed of seed germination (Table 2). In the spring, soil is cold, and many seeds rot before they have a chance to sprout. Presprouting is useful for planting in cold soils. To presprout seeds, place them between two layers of damp paper towels. Place the towels in a plastic bag and keep them in a warm place until the seeds germinate. Another method is to soak seeds for four hours. After presprouting seeds, plant them as usual. Handle sprouted seed very carefully to prevent damaging new roots.

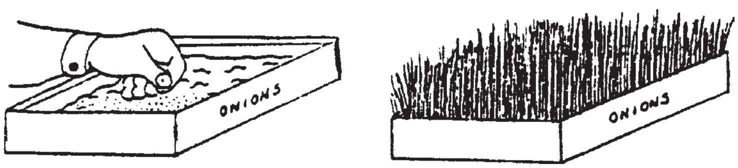


Figure 3.—Seeding onions.

When planting a fall garden in mid summer, it may may be necessary to water lightly each day to promote germination. Covering the row with a shallow mulch or board until seedlings emerge retains moisture. Check often and remove the board when the first seedlings appear. Shading the area keeps the soil cooler for germination. Seeds requiring a low germination temperature may benefit from two weeks of refrigeration before planting or presprouting.

For ease in planting, make seed tapes. To do so, lay out a strip of toilet tissue. Squeeze white glue into a lid, dip a toothpick in the glue, pick up a seed with the toothpick, and place it on the tissue. Be sure to space the seeds correctly for planting. Let the glue dry, roll the tissue, and label and store until needed. One can also place lines of gelatin (dissolve gelatin in water following package directions) on the tissue, lay the seeds in place, dry, and store.

Some seeds are difficult to germinate (e.g., parsley). To enhance germination, soak these seeds for four hours in a mixture of 1 teaspoon saltpeter to 1 quart of water (Saltpeter is the active ingredient in Stump Killer, which is available in most garden stores.)

Broadcast planting

Most crops can be sown in wide rows or beds instead of in long, single rows (Figure 4). Radishes, spinach, beans, peas, beets, lettuce, scallions, and carrots are especially suited to this type of culture. Sow seeds evenly, rake them in, and firm soil over them. Thin young plants to allow room for growth. This method of planting makes weeding challenging. *Quadruple-row planting* (leaving a space between blocks of four closely planted rows) allows for the use of a hoe for weeding.

Hill planting

Plant larger vegetables such as melons, squash, corn, and cucumbers in hills (Figure 4). A hill is not a mound but a grouping of seeds. Plant four or five seeds per hill and firm the soil well. Thin to three to five seedlings per hill.

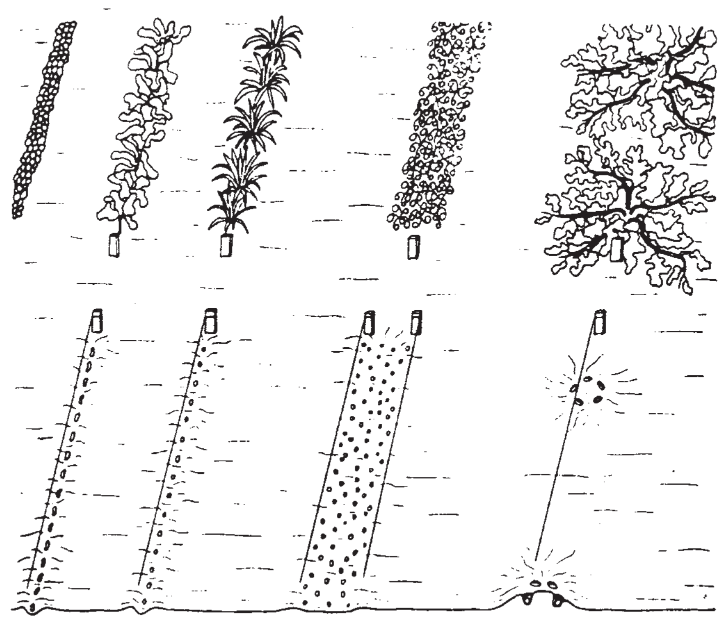


Figure 4.—Planting methods.

Saving seeds from your garden

Saving one's own seed can give a sense of self-sufficiency and save money. It can also maintain a variety not available commercially, which helps perpetuate a broad genetic base of plant material. Breeders search for old-time varieties when attempting to improve commercial plants; often heirloom varieties have inbred disease and pest resistance or cold hardiness. Participation in a seed-saver's exchange is rewarding. Extra seeds can be traded for unusual types not available through other sources.

Common self-pollinated annuals for seed saving include lettuce, beans, peas, herbs, and tomatoes. Save seeds only from open-pollinated varieties, since the offspring of hybrids are not likely to be the same as their parents. Some dealers have responded to the increased interest in seed saving by clearly marking open-pollinated varieties in their catalogs.

Do not keep seeds from a diseased crop. It is possible to carry seed-borne diseases into the next year's crop. Take care to prevent disease development during the seed-drying process. Frequent rain or high humidity hampers seed drying. In cool, rainy weather, dry seeds indoors.

Only skilled seed savers should save seeds from cross-pollinated crops. Typical problem crops come from the squash and carrot families. Saving squash seed in a season when more than one type of squash was planted produces some weird cross-pollination results.

Clearly mark the variety and date saved in permanent ink on seed-storage containers. Store seeds in the dark at less than 50 percent humidity and less than 50°F. An ideal way to prepare seed for long-term storage is to place seed packets in a jar, seal the jar tightly, and place it in a refrigerator or freezer. To help absorb moisture, place a small cloth bag filled with dry powdered milk beneath the seed packets in the bottom of the jar. Use about ½ cup of dry milk from a recently opened package. Seed viability is directly related to storage conditions. Table 3 shows typical viability of various vegetable seeds.

Test seeds for germination before planting as follows:

1. Moisten two or three layers of paper towels.
2. Place 25 to 50 seeds on the towels and roll the towels loosely. Place them in a plastic bag.
3. Keep the towels in a warm place such as on a kitchen counter or on top of a water heater.

Some seeds, such as radish, germinate in two or three days. Peppers can take 10 to 14 days. Observe the seed at two-day intervals to determine the speed and percentage of germination.

For more information on saving seeds, see the books *Growing Vegetables West of the Cascades* by Steve Solomon and *Saving Seeds* by Marc Rogers and the excellent information from the Seed Savers' Exchange, 3076 North Winn Road, Decorah, Iowa 52101.

Seeds easily saved

Tomato

Save seed from the fully ripe fruit of the desired tomato plant. Mash the tomato and drip the seeds into a jar of water. Let them ferment for two to four days, stirring two or three times each day. Good seeds will sink, and bad ones will float.

Rinse good seeds until clean. Squeeze them onto a paper towel or a piece of screen. Leave the seeds at room temperature until they are thoroughly dry.

Pepper

Select a mature pepper, preferably one turning red, and allow it to turn completely red before extracting the seeds. Place seeds on a towel or a piece of screen until they are thoroughly dry.

Eggplant

Separate seeds from the mature fruit and dry them thoroughly at room temperature.

Bean, pea, soybean

Leave pods on the plant until they are "rattle dry." Watch the pods carefully because some varieties split and scatter the seeds when they are dry. Pick dried pods and place them in a well-ventilated area at room temperature. When the pods are completely dry, remove the seeds. To control possible weevil infestation, place seeds in a freezer for 24 to 30 hours.

Lettuce

Lettuce seeds are more difficult to collect, but it is possible to save them. Leave a

Table 3.—Viability of vegetable seeds.

Vegetable	Years*	Vegetable	Years*
Asparagus	3		
Bean	3	Lettuce	5
Beet	4	Muskmelon	5
Broccoli	5	Onion	1
Brussels sprout	5	Parsnip	1
Cabbage	5	Pea	3
Carrot	3	Pepper	4
Cauliflower	5	Pumpkin	4
Corn, sweet	1	Radish	5
Cucumber	5	Rutabaga	5
Eggplant	5	Spinach	5
Kale	5	Tomato	4

*Average number of years seeds may be saved.

plant or two to produce a seed stalk.

After the plant blooms and the flower forms a miniature “dandelion head,” gather the seeds. Separate the seeds from the chaff by rubbing them.

Seeds difficult to save

Vine crops: cucumber, melon, squash, and pumpkin

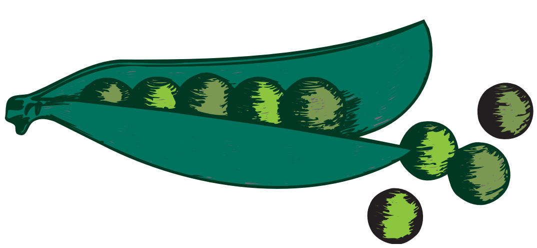
It usually doesn’t pay to save these seeds. Without controlled pollination, these crops cross with other varieties and sometimes other types. Muskmelons do not cross with cucumbers, however.

One can control pollination in a garden, but it requires careful attention. First, distinguish between male and female flowers. Male blossoms are on a longer stalk and do not have a miniature fruit at the base as do female blossoms.

With careful observation, note the blossoms that will open the following day. They have a light yellow color and a distinct pointed tip. In the evening, select male and female flowers on the same plant. With a paper clip for small flowers or a rubber band for larger ones, prevent the flowers from opening. Flowers only open early in the day.

In the morning, pluck the male blossom and touch the cluster of pollen (called *anthers*) to the center of the female flower (called the *stigma*). Close the female flower again so bees can’t get in. Tag the blossom. Grow the fruit to maturity for the desired seed.

The fruit must be very ripe for seeds to germinate correctly. Cucumbers must be entirely yellow, and squash and pumpkins must be thoroughly mature. Separate the seeds from the fruit flesh and dry them at room temperature.



Biennials: carrot, beet, onion, and cabbage family

Biennials are questionable for seed collection. It takes a lot of work to carry over the plant root from the first season to the second year when seed stalks form. Many members of the cabbage family intercross and can also cross with native wild crucifers such as mustard, cress, radishes, or turnips.

Carrots cross with the prevalent wild carrots. Select desirable beet or carrot roots and keep them cool and moist, perhaps buried outdoors in sand. In early spring, plant the roots in an uncrowded area of the garden because they grow very large. Keep onion bulbs cool and dry during the winter and then plant them in early spring.

After spring growth, seed heads form. When heads are quite dry, gather the mature, plump seed before it falls to the ground and complete the drying at room temperature.

Using transplants

For a greater choice of varieties, to control production from seed to harvest, and for economy, many gardeners prefer to start their own transplants. Others lack time and controlled growing conditions, so they prefer to purchase starts. The rules governing quality (discussed below) are the same in both cases.

Table 4 lists some common vegetables and how well they work as transplants.

Annual plants

Annual vegetable transplants should be stocky, healthy, free from disease, and have good roots. They should have a few sets of true leaves but should not be too mature (yellow, woody, or already flowering). Flowers or immature fruit often drop after transplanting. Be sure plants have been hardened off so they will easily adapt to environmental change.

Successful transplanting interrupts plant growth as little as possible, a major advantage in using peat pots, soil cubes, or peat pellets. Transplant on a shady day, in late afternoon, or in early evening to prevent wilting. Water plants several hours before transplanting. Do not let them dry out completely at any time. Handle plants carefully and avoid disturbing roots or bruising stems.

Dig a hole wider than and slightly deeper than the root ball. Tomatoes are an exception to this rule. They develop roots all along their stem, so plant them deeply enough to leave only two or three sets of leaves exposed. A common method is to lay a tomato plant in a trench and then prop up the top.

Finally, fill the hole with soil and press soil firmly around the plant's roots.

For a few days after transplanting, protect transplants from wind and sun by placing newspaper or cardboard on their south sides or by covering them with jugs, baskets, or flower pots. Floating row cover also is an excellent protective material. Water the plants as needed during the next week if there is insufficient rain.

Perennial plants

When buying perennial crowns such as asparagus, order early or buy from reliable local outlets. Select disease-resistant varieties that do well in the growing conditions. Dormant bare roots and 1 or 2-year-old crowns are preferred. Look for roots that are full, slightly moist, and light colored. Dry brown or soggy black roots indicate poor storage and will probably give poor results. Check crowns for viable buds and signs of insects or disease. If mail-order plants are unsatisfactory, write to the dealer.

Until they are planted, keep roots moist but not soaking wet by misting occasionally. Avoid temperature extremes. If it is necessary to keep crowns for more than a few days, place them in cold storage (not freezing) or "heel them in" in a trench of moist soil in a shaded location. Pack soil

Table 4.—Transplantability of vegetable plants.

Easily survive	**Require care**	**Not successful***
Broccoli	Beet	Bean
Cabbage	Carrot (young)	Pea
Cauliflower	Chard	Okra
Eggplant	Melon	Radish
Lettuce	Squash	
Onion (tends to bolt)	Corn	
Tomato	Cucumber	
Pepper		
Brussels sprouts		

*Using usual methods.

firmly against roots to eliminate air pockets.

Transplant crowns according to directions, digging holes large enough to give the roots plenty of room to spread.
Remove any discolored or dried-out roots. Perennials appreciate a dose of compost mixed into the bottom of the hole. Do not create a bowl of soil that is different from the native soil; the two must be thoroughly mixed.

Shade transplants if necessary and water when needed. Extra care at the beginning of their growth will result in productive, healthy plants.

Irrigating

Adequate moisture is essential for good crop growth. A healthy plant is 75 to 90 percent water, which is used for the plant's vital functions including photosynthesis, support (rigidity), and transport of nutrients and sugars. Plants also need water to build their root systems.

Vegetables need about 1 to 2 inches of water a week from April to September. The amount varies depending on the weather and stage of growth.

During dry periods, a thorough weekly watering of 1 to 2 inches (65 to 130 gallons per 100 square feet) is adequate for most soils. Water to a depth of 5 to 6 inches or to the root depth. Average garden soil stores about 2 to 4 inches of water per foot of depth although storage capacity varies by soil type.

Don't water again until the top few inches begin to dry out. Testing soil moisture by digging is the most efficient way to monitor water needs.

Frequent, light watering encourages shallow rooting; plants will suffer more during droughts and will not be as strong. Too much water, especially in poorly drained soils, deprives plants of oxygen, and they drown. Obviously, seedlings need more water at a shallower depth, and mature plants need less frequent but deeper watering.

Unless the soil has exceptionally good drainage, apply water at about 1/2 inch per hour to avoid runoff. Determine the rate of sprinkler application by placing small cans in the area and checking the water level in the cans after 15 minutes. Place oscillating sprinklers above the crop level so water isn't blocked by plants. Overlap the watering pattern by half at each move to even out the pattern.

To reduce foliar disease, water in early morning so leaves dry by evening. Place drip hoses close to the row. Water does not move well laterally. Soak the soil to a depth of at least 5 to 6 inches. You'll need about 2/3 gallon for each square foot or about 65 to 130 gallons per 100 square feet although the quantity needed varies with soil type.

To use limited water efficiently, know the critical watering periods for vegetables. Water is most needed right after transplanting, during the first few weeks of development, and during flower and fruit development. Table 5 shows critical moisture periods for specific vegetables. Irrigating with used water or household gray water (generated from hand washing, clothes washing, and dish washing) is *not* recommended.

See Chapter 1, *Botany*.

Irrigation methods

Trickle irrigation is much more efficient than sprinklers. Because it places water only at the crop roots, it also reduces diseases and weed growth.

Soaker hoses are probably the least expensive and easiest trickle-type irrigation to use. These fibrous hoses allow water to seep out slowly along their entire length.

There are also hoses with holes that work the same way. Use a flow regulator with these hoses so the water can reach the hose end but not spray at full force. Special double-wall hoses also maintain an even flow.

Finally, emitter-type systems deliver water right to plant roots. These systems are the most expensive form of drip irrigation and the most complex to set, but they do not water weeds and they minimize evaporation. Use them in combination with a coarse mulch or black plastic. These systems need filters and/or self-flushing features to prevent clogging.

Most gardeners, however, use overhead sprinkling. If sprinkling is done early in the day, there is less evaporation loss.

Moisture availability

Not all water in the soil is available to plants, particularly if the soil is heavy clay. Clay particles hold soil moisture tightly. For example, if there are 4½ inches of water per foot of clay soil, as little as 1½ inches may be available for plants.

Adding organic matter is the first step in improving moisture conditions in the garden. In clay soils, organic matter improves water availability. It causes clay to form aggregates or large clumps of particles, thereby creating air spaces. As a result, moisture drains to lower levels where it is stored as a reserve instead of puddling and running off the top of the soil.

Additions of organic matter also improve the moisture retention of sandy soils. Although water is available in sandy soils, it drains so quickly that plants are unable to reach it even a few days after a rain. Humus holds water until it is needed by plants.

Mulching can significantly decrease the amount of water needed. A 6 to 8-inch layer of organic mulch can reduce water needs by as much as half by smothering moisture-using weeds and reducing evaporation. Organic mulches hold water and increase humidity around plants. Black plastic mulch also conserves moisture but in-

Table 5.—Critical moisture periods for vegetables.

Crop	**Growth period**
Bean	During flowering and pod development
Broccoli and related cole crops	During head formation and enlargement
Corn	From tassel to silk and ear filling
Cucumber	During flowering and fruit development
Eggplant	From blossom set through fruit enlargement
Onion	During bulb formation
Pea	During flowering and pod filling
Pepper	From blossom set through fruit enlargement
Potato	After initial tubers form
Tomato	From blossom set through fruit enlargement

creases soil temperature dramatically during the summer if not covered by other mulches or foliage.

Shading also conserves moisture. Partial afternoon shade prevents wilting during summer. Protect small plants in particular.

Moving air removes moisture from leaf surfaces, causing plants to use more water. Roots may not keep up with leaf demands, and plants wilt. Windbreaks can help tremendously.

Fertilizing

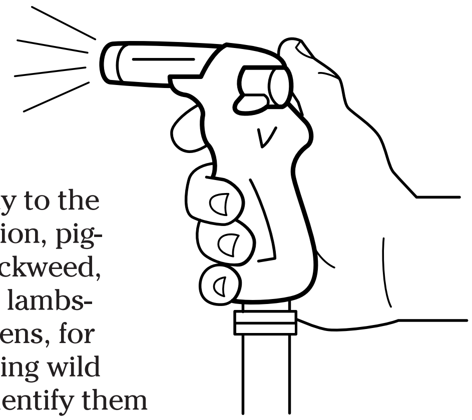
The amount of fertilizer to apply to a garden depends on the natural fertility of the soil, the amount of organic matter present, the type of fertilizer used, and the crop being grown. Test the soil to determine fertilizer needs.

Vegetables are heavy, medium, or light feeders (Table 6). Group crops according to their fertilizer requirements to make application easier.

Weed management

Most gardeners soon learn that the old saying, "One year's seeding—seven years weeding," contains more truth than myth. Weeds are much better adapted to garden conditions than are the vegetables prized so highly. Many weeds, which otherwise would grow in a lawn or natural area, spring up as if by magic when soil is cultivated. Weed seeds may remain viable for seven years or longer until conditions are right for growth. When brought to the surface by tilling and uninhibited by sod, shade, or other factors, they germinate and become pests that take water, nutrients, sunlight, and space from vegetables.

Beneficial weeds



Many weeds have positive attributes. Some are edible, providing nutritious variety to the regular diet. Dandelion, pigweed, purslane, chickweed, cress, mustard, and lambsquarter provide greens, for example. Before eating wild plants, be sure to identify them correctly. Taking a course in identifying wild edibles is probably the best way to learn.

Weeds provide habitat for various insects including beneficials. They provide shelter, pollen, and nectar for bees and garden pest predators such as parasitic wasps. Weeds in the Apiaceae (parsley) family and Asteraceae (daisy) family are especially valuable.

See Chapter 2, *Soils and Fertilizers*.

Wild plants may also have other virtues. Some are used in natural dyes and for other homemade products. Weeds are a good source of nitrogen and trace elements for the compost pile if pulled before flowering. Many have long roots which bring elements from the subsoil to the weed's aboveground tissues. Composting makes these elements available to other plants. Some native plants are indicators of certain soil problems like nutrient deficiencies, pH changes, and soil compaction.

Management methods

Since weeds extract large quantities of moisture and nutrients from the soil, it is best to remove them as soon as possible. Also, weeding is easier when weeds are young and tender. This section discusses weed-management issues specific to vegetable gardens. See Chapter 5, *Weeds,* for additional information.

Turning under weeds before they flower provides organic matter to the soil. One

See Chapter 2, *Soils and Fertilizers*.

also can add young weeds to a compost pile. Keep in mind, however, that composting may not destroy weed seeds if the pile doesn't heat adequately. Also, grasses that spread by rhizomes or stolons present a problem if not completely dried. Despite their potential value as organic material, it's better to let the trash or yard waste collection take away problem weeds or to burn them and spread the ashes.

Table 6.—Plants grouped according to nutrient needs.

Heavy feeders	Light feeders	Soil builders
Asparagus	Carrot	Alfalfa
Beet	Onion	Bean, snap
Broccoli*	Parsnip	Clover
Brussels sprout*	Pepper	Pea
Cabbage*	Potato	
Cantaloupe*	Rutabaga	
Cauliflower	Swiss chard	
Corn	Turnip	
Cucumber*		
Eggplant*		
Kale		
Kohlrabi		
Lettuce		
Okra		
Pumpkin*		
Radish		
Rhubarb		
Spinach		
Squash, summer*		
Squash, winter*		
Tomato*		
Watermelon*		

*Fertilize at least twice.

Cultivation

Hand pulling and digging work well in small gardens and raised beds. A scuffle hoe is preferable for larger areas. Manual and powered rotary cultivators cannot weed very close to vegetables without damaging their roots. Therefore, hand pulling or gentle hoeing is best for close weeding. Deep cultivation with any instrument is likely to damage roots or stems.

See Chapter 5 *Weeds*.

Pull or hoe weeds when the soil is damp but not wet. Working wet soil damages soil structure, especially in heavy soils. Conversely, when soil is too dry, weeds are hard to pull or hoe. A day or two after a rain or irrigation is probably the best time to cultivate. Remember that the work is more pleasant in the cool temperatures of early morning or evening.

Mulching

Mulching can be an alternative to weeding if materials are readily available. Thick layers of organic mulch prevent most annual weeds from poking through, and those that do are pulled easily. Weeds with runners are more difficult, so black plastic or landscape cloth may be a better choice where these weeds grow. For paths, newspaper, old carpeting, or similar materials covered with sawdust provide excellent weed suppression.

Close spacing

If vegetables are planted closely together, they shade the soil and prevent many weed seedlings from growing. One can achieve this effect with well-planned raised beds in which plants are spaced so that adjacent plants touch and form a closed canopy when mature. (See "Intensive gardening" later in this chapter.)

Other practices

Several other practices can help manage weeds in vegetable gardens. Planting cover crops for several seasons in a particularly weedy area can reduce weed problems. However, this method requires leaving part of a garden uncultivated, thereby reducing gardening space.

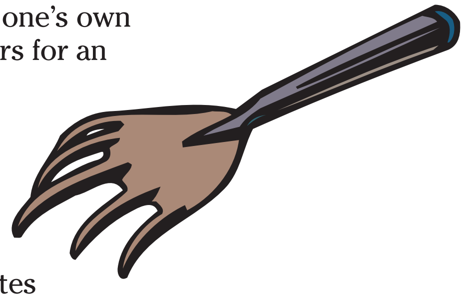
Mow or harvest cover crops regularly. Investigate crop rotations thoroughly and then try them in small sections of the garden to determine their effectiveness. Mowing around the garden helps prevent weeds and seeds from spreading. Regularly mowed grass works well in paths between raised beds.

Intensive gardening

The purpose of an intensively grown garden is to harvest the most produce possible from a given space. Traditionally, American gardens have consisted of long, single rows of vegetables spaced widely apart; much of the garden area is taken by the space between rows. An intensive garden, on the other hand, reduces wasted space to a minimum. Table 7 shows the average amount of produce needed for one adult for a year and the space needed to produce this amount if a garden is planted intensively.

Table 8 shows recommended spacing for an intensively planted garden. These spacings are for average-size cultivars and experienced gardeners. Be sure to fertilize and water adequately for the tighter spacings.

The distance recommended on a seed packet for plants within a row is the distance from the center of one plant to the center of the next. Many intensively planted gardens use equidistant spacing. To use this method, plant so the center of one plant is the same distance from each surrounding plant. In beds of more than two rows, stagger rows so that plants in one row are between those in adjacent rows. (*Tip*: Measure one's own hand span and fingers for an easy garden ruler.)



Intensive gardening is not just for those with limited space, however. Even in larger spaces, it concentrates effort to create an ideal plant environment. It gives better yields with less labor and uses water and other inputs more efficiently.

A good intensive garden requires early, thorough planning for the best use of time and space. Before planting, consider plant interrelationships, nutrient needs, shade tolerance, above and below-ground growth patterns, and growing seasons. Using the following techniques, anyone can develop a high-yielding intensive garden.

Raised beds

A raised bed or wide, flat growing bed is the basic unit of an intensive garden (Figure 5). Beds allow the concentration of soil preparation in small areas, resulting in effective use of soil amendments and creating an ideal environment for vegetable growth.

Raised beds are a form of wide-bed gardening, a technique by which seeds and transplants are planted in wide bands or broadcast in a wide strip. Space plants at equal distances from each other on all sides so their leaves will touch at maturity. This method saves space, and the close plantings reduce moisture loss and discourage weeds.

Raised bed gardening breaks work into units. Instead of gazing desperately at a garden full of weeds and thinking there will never be time to clean it up, you can look at each bed and say, “I can do that in half an hour today.” Other chores are accomplished with the same ease. Using permanent sides also reduces weeding, and defined beds can make record keeping and crop rotation easier.

Table 7.—Amount of produce and space needed per adult for one year.

Crop	Average pounds for one adult per year			Square feet needed		
	Fresh	Processed	Total	Fresh	Processed	Total
Bean, bush	15	25	40	38	62	100
Bean, pole	15	25	40	21	36	57
Beet	3	4	7	2	3	5
Broccoli	5	6	11	10	12	22
Cabbage	10	10	20	10	10	20
Cantaloupe	12	12	24	40	40	80
Carrot	8	8	16	4	4	8
Cauliflower	6	9	15	9	12	21
Chard	3	5	8	2	3	5
Corn, sweet	17	33	50	57	110	167
Cucumber	6	12	18	9	17	26
Eggplant	2	3	5	4	6	10
Kohlrabi	4	2	6	13	7	20
Lettuce, head	5	0	5	6	0	6
Lettuce, leaf	5	0	5	10	0	10
Onion	10	0	10	5	0	5
Parsnip	5	0	5	6	0	6
Pea	5	8	13	25	40	65
Pepper	3	7	10	4	9	13
Potato	70	0	70	47	0	47
Radish	1	0	1	3	0	3
Spinach	3	5	8	6	10	16
Squash, summer	7	10	17	10	14	24
Squash, winter	20	20	40	40	40	80
Tomato	35	50	85	14	20	34
Watermelon	10	0	10	33	0	33

Beds are generally 3 to 4 feet wide and as long as desired. The gardener works from either side of the bed, eliminating compaction caused by walking on the soil. Determine the proper width by reaching in from each side; one should be able to reach just past the center of the bed.

Soil preparation is the key to successful intensive gardening. To grow so closely together, plants must have adequate nutrients and water. Providing extra fertilizer and irrigation helps, but there is no substitute for deep, fertile soil high in organic matter. Humus-rich soil holds extra nutrients. Existing elements that are "locked up" in the soil are released by the action of earthworms, microorganisms, and acids, making them available for plant use.

If the soil is not deep, double-dig beds for best results. Remove the top 12 inches of soil from the bed. Insert a spade or spading fork into the next 10 to 12 inches of soil and wiggle the handle back and forth to break up compacted layers. Repeat every 6 to 8 inches. Mix the topsoil with a generous amount of compost or manure and return the mixture to the bed. It should be fluffy and slightly raised. To create a true raised bed, take topsoil from neighboring pathways and mix it in as well.

This method is a lot of work! Try one or two beds for the most valuable plants. If the results are satisfactory, proceed to other beds.

Table 8.—Planting distances for intensive gardens.

Crop	Space between plants (inches)
Bean, bush	6 x 6
Bean, pole	4 x 36
Beet	4 x 4
Broccoli	18 x 18
Cabbage	18 x 18
Cantaloupe	36 x 48
Carrot	2 x 2
Chard	9 x 9
Corn, sweet	9 x 24
Cucumber	12 x 48
Eggplant	18 x 18
Kohlrabi	4 x 4
Lettuce, head	12 x 12
Lettuce, leaf	6 x 6
Onion	3 x 3
Parsnip	4 x 4
Pea	2 x 2
Pepper	12 x 12
Potato	9 x 9
Radish	1 x 1
Spinach	4 x 4
Squash, summer	48 x 48
Squash, winter	60 x 60
Tomato	24 x 24
Watermelon	60 x 60

Vertical gardening

The use of trellises, nets, strings, cages, or poles to support growing plants constitutes vertical gardening (Figures 6 and 7). This technique is especially suited but not limited to gardeners with little space. Plants grown vertically take up much less ground space, and although the yield per plant may be less, the yield per square foot is much greater.

Vining and sprawling plants such as cucumbers, tomatoes, melons, and pole beans are obvious candidates for this type of gardening. Some plants entwine themselves onto the support while others require tying.

Because vertically grown plants are more exposed, they dry faster and require more water than if they were spread over the ground. Rapid drying is advantageous to plants susceptible to fungal diseases.

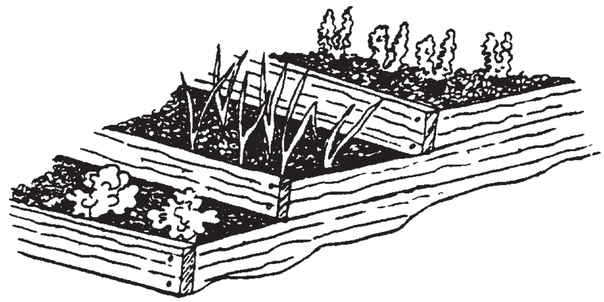


Figure 5.—Raised beds.

Vertically grown plants may need more fertilizer. Also, soil should be deep and well drained to allow roots to extend vertically so they don't have to compete with shallow-rooted plants.

Vertical planting casts a shadow, so avoid shading sun-loving crops. Plant shade-tolerant crops near vertical ones.

Interplanting

Growing two or more types of vegetables in the same place at the same time is known as interplanting. Proper planning is essential to obtain high production and increased crop quality. This technique has been practiced for thousands of years but is just now gaining widespread support in this country.

Interplanting helps keeps insect and disease problems under control. Pests are usually fairly crop specific; they prefer vegetables of one type or family. Mixing plant families breaks up expanses of crops and confines early pest damage to a small area, thereby allowing more time to respond. One disadvantage is that it's hard to ensure that all plants are protected when spraying.

When interplanting, consider the following factors for each plant:

- *Time to maturity*—Long-season (slow-maturing) and short-season (quick-maturing) plants such as carrots and radishes respectively can be planted at the same time. Harvest the radishes before they begin to crowd the carrots. See Tables 9 and 10.

- *Above-ground growth pattern*—Planting small plants close to larger plants—for example, radishes at the base of pole beans or broccoli—is an example of combining growth patterns. Table 11 shows some other possible pairings.
- *Root-growth pattern*—Combining plants with complementary root-growth patterns saves space. Roots of these plants won't compete with each other and will make the best use of the available space underground. Table 12 shows typical rooting depths of vegetables, and Table 13 lists suggested pairings based on root patterns.
- *Possible negative effects on other plants*—Don't place plants such as sunflowers, which can suppress growth of nearby plants, too close to other crops.
- *Light requirements*—Plant shade-tolerant species such as lettuce, spinach, and celery in the shadow of taller crops.
- *Season of growth*—Interplant cool-weather and warm-weather crops. By the time the warm-weather crops grow to full size, the cool-weather crops will have finished producing.
- *Nutrient requirements*—Interplant heavy feeders such as cabbage family crops with less demanding plants (Table 6).
- *Water requirements*—Group plants with similar water requirements together to avoid over-watering some plants in order to supply enough moisture to others.

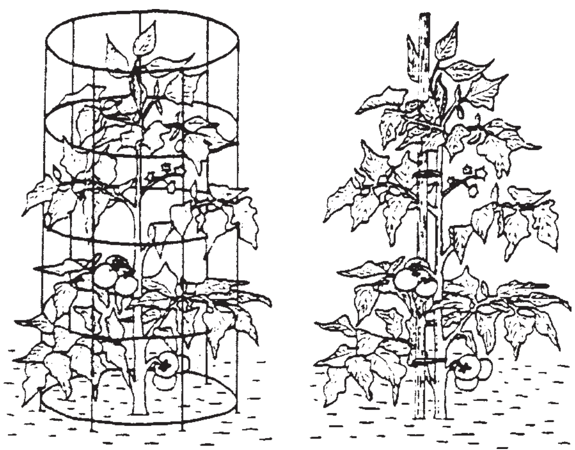
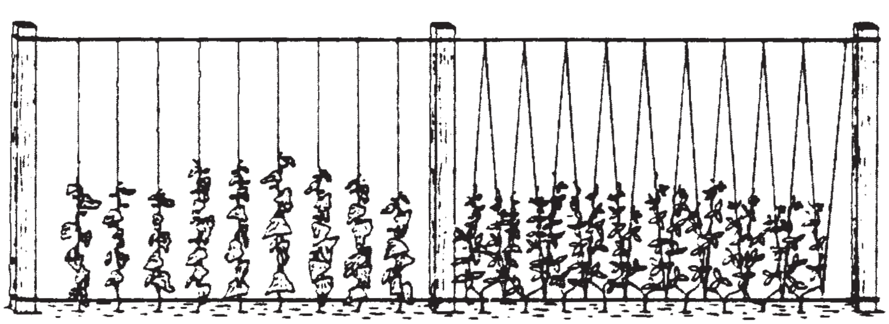


Figure 6.—Tomatoes supported with wire cages or stakes.

Interplanting can be accomplished by alternating rows within a bed (for example, planting a row of peppers next to a row of onions), by mixing plants within a row, or by placing various species throughout a bed. For beginners, alternating rows may be the easiest method.

Individual plants are spaced closely in an interplanted garden, resulting in efficient use of space and less area to weed and mulch. However, plants should not be so crowded that disease problems arise or competition causes stunting.



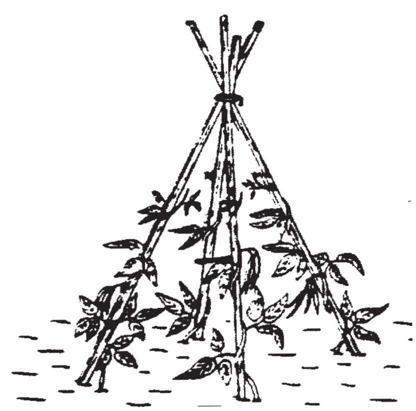


Figure 7.—String trellises and poles for vertical gardening.

Succession planting

Succession planting makes the most of an intensive garden and can be successful in certain areas of Wyoming. To obtain a succession of crops, plant something new in spots vacated by spent plants. See Figure 8 for an example of succession plantings. Graph paper makes it easy to plot times to maturity, especially if one square equals one week.

Planting a spring, summer, and fall garden is another form of succession planting. Cool-season crops (e.g., broccoli, lettuce, peas) are followed by warm-season crops (e.g., beans, tomatoes, peppers). Where possible, these may be followed by more cool-season plants.

Starting seeds indoors for transplanting is an important aspect of succession gardening. To obtain the most from a garden plot, a new crop should be ready to take the place of one being removed. One can gain several weeks by having 6-inch transplants ready for vacant areas. Don't forget to recondition the soil for the new plants.

Container gardening

If space is lacking for a vegetable garden or if a present garden is too small, consider raising fresh, nutritious vegetables in

Table 9.—Short-season crops.

Crop	Days to maturity	Season
Beet	50–60	Early or late
Carrot	70	Early or late
Kohlrabi	45–55	Early or late
Lettuce, leaf (heat-resistant types)	45–60	Any
Lettuce, loosehead	55–70	Early or late
Onion, green (from sets)	30–40	Any
Radish	20–25	Any
Spinach	45–50	Early or late
Swiss chard	55–60	Any
Turnip	40–75	Early or late

Table 10.—Long-season crops.

Crop	Average days to maturity	Season of growth
Bean, pole	108	Midseason
Broccoli	110 (60 after transplanting)	Early
Brussels sprout	130 (85 after transplanting)	Whole season
Cabbage	140 (90 after transplanting)	Early
Cauliflower	110 (60 after transplanting)	Early
Corn	70–90	Midseason
Eggplant	120 (70 after transplanting)	Midseason
Melon	90	Midseason
Onion, storage	100	Whole season
Parsnip	120	Whole season
Pea	70	Early
Pepper	125 (75 after transplanting)	Midseason
Potato	80–140	Mid to whole season
Pumpkin	110–120	Whole season
Squash, winter	80–100	Mid to whole season
Tomato	125 (70 after transplanting)	Midseason
Watermelon	75–90	Midseason

containers (Figure 9). A windowsill, patio, balcony, or doorstep can provide sufficient space for a productive container garden. Container gardening overcomes problems with soilborne diseases, nematodes, and poor soil.

Grow vegetables that take little space such as carrots, radishes, and lettuce or those that fruit over a period of time such as tomatoes and peppers. Dwarf or miniature varieties mature and bear early, but most do not produce as well overall as standard varieties. As interest in container gardening increases, plant breeders and seed companies are breeding vegetables specifically for container culture. These varieties are not necessarily miniature or dwarf and may produce as well as standard types if properly tended.

The amount of sunlight a container garden receives determines which crops can be grown. Root and leaf crops tolerate partial shade, but fruiting vegetables require at least 6 hours of full, direct sunlight each day and perform better with eight to ten hours. Increase available light by using materials such as aluminum foil, white-painted surfaces, or marble chips to reflect light.

Container gardening lends itself to attractive plantscaping. A dull patio can be brightened by baskets of cascading tomatoes or a colorful herb mix. Container gardening presents opportunities for creative innovation. Using trellises with containers greatly expands possibilities. For example, planter boxes with trellises can create a cool, shady apartment balcony.

Containers

There are many possible containers for gardening. Containers for vegetable plants should be large enough to support plants when they are fully grown. They should hold soil without spilling and should have

Table 11.—Complementary above-ground growth patterns.

Bean–celery	Kohlrabi–beet
Bean–corn	Leek–carrot
Bean–corn–squash, melon, cucumber	Leek–parsley
Bean–radish	Lettuce–carrot–onion
Bean–tomato (staked)	Lettuce–onion
Cabbage–chive	Lettuce–radish
Cabbage–pepper	Melon–radish
Cabbage–squash, melon, cucumber	Onion–cabbage
Cabbage–tomato	Onion–carrot
Cole crops–carrot, leek, onion	Onion–eggplant
Corn–cabbage	Onion–pepper
Corn–lettuce	Onion–spinach
Corn–potato	Peas on trellis–cole crops, lettuce, carrot, kohlrabi, spinach, radish, turnip
Corn–pumpkin	
Corn–squash, melon, cucumber	
Cucumber–okra	

Table 12.—Characteristic rooting depths.

Shallow rooting (18–36")	Medium rooting (36–48")	Deep rooting (48"+)
Broccoli	Bean, snap	Asparagus
Brussels sprout	Beet	Parsnip
Cabbage	Carrot	Pumpkin
Cauliflower	Cucumber	Squash,
winter		
Corn	Eggplant	Tomato
Lettuce	Pea	
Onion	Pepper	
Potato	Rutabaga	
Radish	Squash, summer	
Spinach	Swiss chard	
	Turnip	

Table 13.—Complementary root patterns.

Bean–carrot	Melon–radish
Bean–celery	Onion–cabbage
Bean–corn	Onion–carrot
Bean–cucumber	Onion–eggplant
Bean–onion	Onion–pepper
Bean–radish	Onion–radish
Bean–squash	Onion–spinach
Corn–lettuce	Parsnip–lettuce
Corn–potato	Pea–radish
Kohlrabi–beet	Pea–turnip
Leek–carrot	Swiss chard–cucumber
Lettuce–carrot–onion	
Lettuce–radish	

adequate drainage. They also should never have held *any* toxic products.

Redwood and cedar make the most decay-resistant planter boxes. Never use wood treated with creosote or pentachlorophenol (Penta) wood preservatives. These substances are toxic to plants and humans.

Some gardeners build vertical planters from wood lattice lined with black plastic and filled with a lightweight medium. Another design uses welded wire formed into cylinders which are then lined with sphagnum moss and filled with soil.

It's fun to be imaginative in using discarded items to create attractive patio planters. Consider barrels, flowerpots, cut-off milk and bleach jugs, recycled Styrofoam coolers, window boxes, plastic-lined baskets with drainage holes, or even pieces of drainage pipe or cinder block.

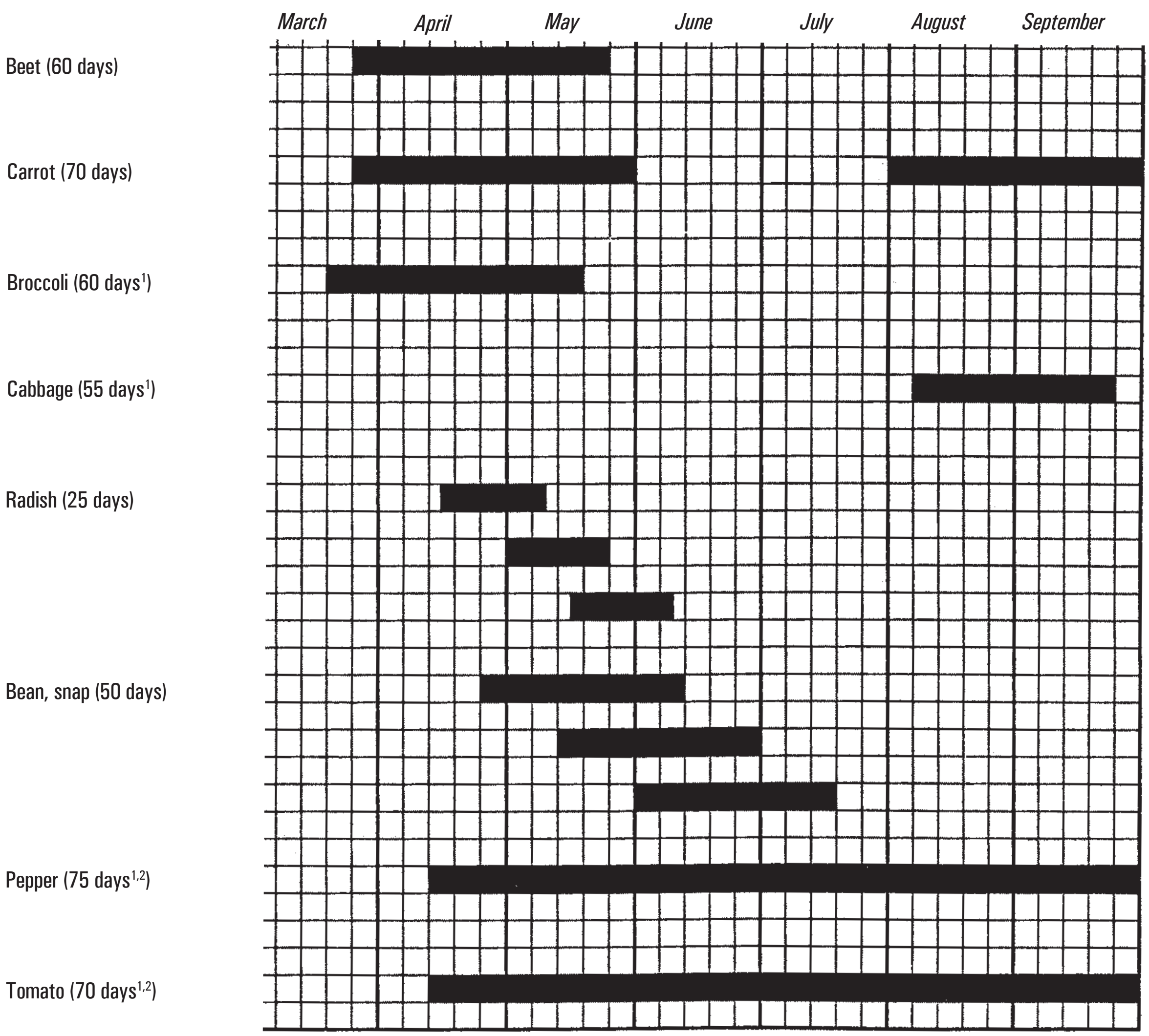


Figure 8.—Example of succession plantings in a vegetable garden. Beets, carrots, and early cabbage vacate areas for peppers and tomatoes. Early staggered plantings of radishes give way to staggered bush beans. When the beans are finished, fall cabbage and carrots are planted.

[1]Days from transplanting.

[2]These crops take 70 to 75 days to mature their first crop and continue to produce until frost.

Whatever type of container used, be sure there are drainage holes in the bottom so the roots do not stand in water. Containers should be at least 6 to 8 inches deep for adequate rooting. Place 2-inch diameter perforated plastic pipes inside large containers to aid watering.

Use dollies or platforms with wheels or casters to move heavy containers. The ability to move plants is especially useful for apartment or balcony gardening to make maximum use of available space and sunlight as well as to avoid particularly nasty weather.

Media

Container vegetable gardening requires a fairly lightweight potting mix. Straight garden soil is too heavy. Media must be porous because roots require both air and water. Packaged potting soil available at garden centers is relatively lightweight and makes a good container mix. There are even special mixes for large containers.

Soilless mixes such as peat-lite mix are too light for container vegetable gardening because they don't offer plant roots enough support. If the container is also lightweight, a strong wind can blow plants over. Soilless mixes contain few nutrients, so even if major nutrients are added, there are no trace elements. Add soil, leaf mold, or compost to a soilless mix to make it suitable for container gardening.

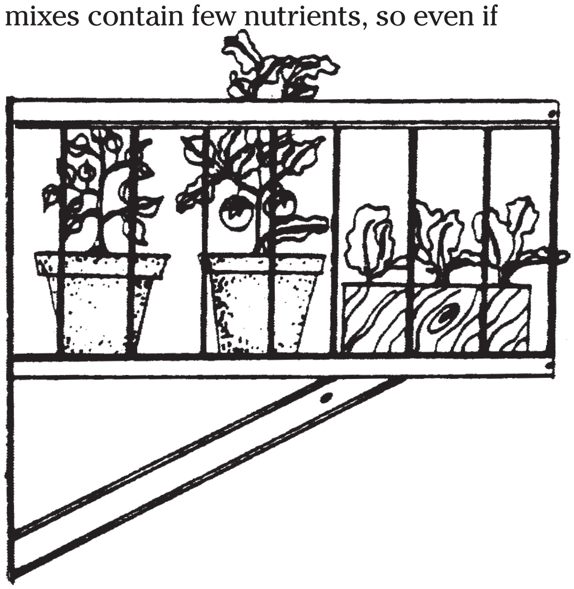


Figure 9.—Container gardening on a balcony.

Alternatively, one can make a mix with one part peat moss, one part garden loam, one part clean, coarse builder's sand, and just enough slow-release balanced fertilizer for the container size (about 1½ tablespoons of 10-10-10 for a 12-inch-diameter pot). Peat moss absorbs water and mixes better if soaked with warm water before mixing. Add lime to bring the pH to about 6.5.

Planting

Fill a clean container to within ½ inch of the top with slightly damp soil mixture. Sow the seeds or set transplants. Label each container with the name, variety, and date of planting. Gently soak the soil with warm water, being careful not to displace seeds. Thin seedlings for proper spacing when the plants have two or three leaves. If cages, stakes, or other supports are needed, add them when the plants are very small to avoid root damage.

Watering

Because the volume of soil in containers is relatively small, it dries out quickly, especially on a concrete patio in full sun. Daily or even twice-daily watering may be necessary.

Apply water until it runs out the drainage holes. On an upstairs balcony, water can drain onto a neighbors' balcony, so make provisions for drainage. Large trays filled with coarse marble chips or rocks and placed underneath a container work nicely. Soil should never be soggy, and water should never stand on top of the chips.

There are ways to maintain proper soil moisture in containers. Clay pots and other porous containers allow additional evaporation from their sides, so they must be watered more often. Small pots also tend to dry out more quickly than larger ones. If the soil appears excessively dry, group containers so the foliage shades the soil and keeps it cool.

On a hot patio, put containers on pallets or other structures that allow air movement beneath the pots and prevent direct contact with cement. Check containers daily (twice daily on hot, dry, or windy days). Feel the soil to determine its dampness. Mulching and windbreaks help reduce water requirements.

Someone who is away a lot might consider an automatic drip-emitter irrigation system. Dark pots create lethal root temperatures. Either insulate them or paint them white.

Fertilizing

If a soil mix with added fertilizer is used, plants will have enough nutrients for eight to ten weeks. Then add a water-soluble fertilizer at the recommended rate and repeat every two to three weeks. Slow-release synthetic or organic fertilizers work best. An occasional dose of fish emulsion or compost adds trace elements to the soil.

Do not add more than the recommended rate of fertilizer; too much fertilizer can burn and kill plants. Container plants do not have large volumes of soil and humus to protect them from over-fertilizing or over-liming.

General care

Periodically inspect plants for insects and diseases because common garden pests also attack container vegetables. Protect plants from very high heat caused by light reflection from pavement. Move them to a cool spot or shade them during the hottest part of the day. Shelter plants during severe rain, hail, or wind storms and protect them from fall frosts.

Indoor container gardening

Try indoor container gardening for fresh, home-grown vegetables over the winter. One cannot have a full garden indoors, but with a bright, sunny window, one can grow fresh food all year. Several types of greens and many herbs will grow indoors.

Follow directions given above for preparing pots, watering, fertilizing, etc. However, note that plants use less water and fertilizer indoors, because they grow more slowly. To make watering easier, set the pots in large trays containing an inch or two of decorative stones. Not only does this setup prevent having to move the plants to water them, it also provides humidity during winter when a house is warm and dry.

A sunny, south-facing window is a must for indoor vegetable growing. Insufficient light results in tall, spindly plants and failure to flower and set fruit. Generally, there is not enough winter sunlight to grow fruiting vegetables. They need supplemental light such as a combination warm white/cool white fluorescent fixture.

Herbs are a first choice for many indoor gardeners. They are less demanding than vegetables, and cooks find it pleasant to snip off a few sprigs of fresh parsley or chop some chives from the windowsill herb garden. Herbs prefer cool conditions with good light but grow well on a kitchen windowsill.

One or two pots of chives provide leaves for seasoning salads and soups. Plant seeds or small bulbs in a 6-inch pot. The plants should be about 1 inch apart over the entire surface. About 12 weeks after seeds are planted, start cutting a few leaves. For variety, try garlic or Chinese chives, which grow in a similar fashion but have a mild garlic flavor.

Plant parsley seeds directly into 6-inch pots or transplant young, healthy plants from the garden. One vigorous plant per pot is enough. Leaves can be clipped about 10 to 12 weeks after seeding. Standard parsley develops attractive, green, curly leaves about 6 or 8 inches tall. Italian (single-leaf) parsley has a slightly stronger flavor and is a favorite for pasta dishes.

Cilantro, the leaves of a young coriander plant, can also be grown in a windowsill. Cilantro is used fresh in Asian and Mexican dishes. Grow cilantro as one would parsley. Thyme and other herbs also do well indoors.

Some small-fruited peppers may be grown as houseplants. Like tomatoes, they need warm, bright conditions to grow well. Peppers and tomatoes are ready to harvest about 10 weeks after planting.

Whiteflies and aphids may present a problem on indoor tomato and pepper plants. Keep a close watch for these pests so they do not get established. Yellow sticky traps, either purchased or homemade, are effective in trapping whiteflies. Insecticidal soap or other pesticides approved for vegetable plants can be used to control aphids. Fortunately, problems with pests and diseases are less severe than in outside gardens.

For a quick-growing crop, try radishes. They must be grown in strong light to be crisp and succulent. Scatter radish seeds on moist soil in a 6 to 8-inch pot. Cover with ¼ inch of soil and place a piece of glass or plastic wrap over the pot to conserve moisture until the seeds germinate. Carrots grow more slowly but can be grown in the same way. Use small-rooted varieties such as "Little Finger" for best results indoors.

Experiment with various types of lettuce. Leaf lettuce and miniature Tom Thumb butterhead work well in pots. Space plants about 12 inches apart. Keep lettuce moist and in a sunny spot.

If light is limited, an old standby for fresh taste and high food value is sprouted seeds such as wheat, corn, barley, alfalfa, lentils, soybeans, rye, peas, radishes, mung beans, and sunflowers. Use only special seeds for sprouting (available from health food or grocery stores) to avoid the possibility of getting treated seeds. Use any wide-mouthed container such as a Mason or mayonnaise jar. Soak seeds overnight, drain, and place them in the container. Cover with a sprouting lid or a double layer of cheesecloth held with rubber bands. Set the container in a consistently warm spot and rinse and drain the seeds two or three times daily. In 3 to 5 days, sprouts will be 1 to 3 inches long and ready for harvest.

Fall and winter gardening

Fall gardening

By planting a fall vegetable garden, it is possible to have fresh vegetables up to and even past the first frosts. Just when retail vegetable prices are increasing, one can reap large and varied harvests from a still-productive garden.

Many varieties of vegetables can be planted in mid to late summer for fall harvest. Succession plantings of warm-season crops such as corn and beans can be harvested until the first killing frost. Cool-season crops such as kale, turnips, mustard, broccoli, and cabbage withstand frost and grow well during cool fall days.

Some of the best vegetables are produced during the warm days and cool nights of fall. These environmental conditions add sugar to sweet corn and crispness to carrots. Parsnips and kale are examples of crops that are greatly improved by a touch of frost.

Timely planting is the key to a successful fall garden. To determine the time to plant a particular vegetable for the latest harvest in an area, one needs to know the average date of the first killing frost and the number of days to maturity for the variety grown. Choose the fastest maturing varieties for late plantings. The formula below will help determine when to start a fall garden:

Number of days from seeding or transplanting outdoors to harvest
+ Number of days from seed to transplant (if one's own transplants are grown)
+ Average harvest period
+ Fall factor (about two weeks)
+ Frost-tender factor (if applicable)

= Days to count back from first frost date

The *frost tender factor* is added only for those crops that are sensitive to frost (e.g., corn, beans, cucumbers, tomatoes, and squash) because these crops must mature two weeks before frost to produce a reasonable harvest. The *fall factor* takes into account the fact that plants grow more slowly during the cool, short days of autumn.

One can reduce the fall factor by two to five days by presprouting seeds. (See "Planting seeds directly in the garden" earlier in this chapter.) Almost any crop can benefit from presprouting. Sprout seeds indoors, allowing the seedlings to reach a length of up to 1 inch. Be careful not to break the roots when planting. Plant sprouted seeds more deeply than normal to help prevent drying out. Water well until the plants break the soil surface.

When planting fall crops, prepare the soil by restoring nutrients removed by spring and summer crops. A light layer of compost or aged manure or a small application of complete chemical or organic fertilizer boosts soil nutrients in preparation for another crop.

Once young plants are established, use a heavier mulch to hold moisture and control weeds. Irrigate when necessary so the young plants have sufficient moisture.

Fall plantings often have few insect problems because they avoid the peak insect activity of midsummer. However, some insects such as cabbage worms and cabbage root maggots may be even worse late in the year than in summer. Vigilance is still required! Limit pests and diseases by planting crops where those of a different family were growing before. Row covers and cloches also help deter insects as well as extend the season.

Fall garden care intensifies when the weather forecast predicts the arrival of frost. The main concern then should be to harvest all ripe tender crops before they are chill damaged. For example, tomatoes, summer squash, melons, eggplants, cucumbers, and peppers cannot withstand frost and should be picked immediately. Store the vegetables until needed.

If the frost warning is mild (the temperature is not expected to fall below 30°F), try covering tender plants that still hold a lot of immature fruit. Baskets, burlap or canvas sacks, boxes, blankets, or buckets help protect plants from frost. Warm days will mature some of the fruit as long as the plants have nightly frost protection. Much depends on a garden's microclimate. If the spot is low and unsheltered, it is likely to be a frost pocket. Gardens sheltered from wind and on the upper side of a slope are less susceptible to early frost damage.

Season extenders

To get the most from a garden, extend the growing season by sheltering plants from cold weather in both early spring and fall. Cool-season crops such as leaf lettuce, cabbage, kale, cauliflower, collards, broccoli, spinach, mustard greens, and brussels sprouts can withstand some cold.

Some vegetables may overwinter, especially at lower elevations. Lettuce, parsley, and carrots may survive all winter. Row covers, cloches, Wall-o-water, plastic mulches, and other tricks can greatly extend the season in Wyoming.

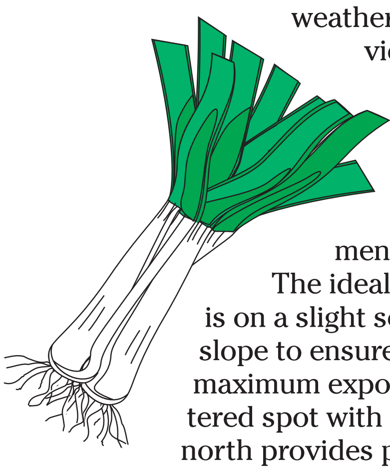
Cold frames and hotbeds

Cold frames and hotbeds are inexpensive structures for growing cool-weather crops in early spring, fall, and even into winter. They range from simple to elaborate. *Cold frames* rely on the sun for their sole source of heat. Heat is collected when the sun's rays penetrate clear plastic, glass, or fiberglass (Figure 10). *Hotbeds* are heated by soil-heating cables, steam-carrying pipes, or fresh, strawy manure buried beneath the plant rooting zone.

In early spring, a cold frame is useful for hardening off seedlings that were started indoors or in a greenhouse. Hardening off is important because seedlings can be set back seriously if they are moved directly from a protected location to a garden. A cold frame provides a place for gradual adjustment to outdoor weather. One can also start cool-weather crops right in the cold frame to transplant later to the garden or to grow them to maturity in the frame.

Spring and summer uses of cold frames center around plant propagation. Young seedlings of hardy and half-hardy annuals can be started in a frame many weeks before they can be started in the open. Replace the soil in a portion of the cold frame bed with a medium suitable for rooting cuttings.

Fall is another good time to sow cool-weather crops in frames. If provided with adequate moisture and fertilization, most cool-season crops continue to grow through early winter in the protected environment of a cold frame.



The ideal location for a cold frame is on a slight southern or southeastern slope to ensure good drainage and maximum exposure to the sun. A sheltered spot with a wall or hedge to the north provides protection against winter winds. Sinking the frame into the ground a bit also provides earth insulation.

To simplify use of the frame, consider a walkway to the front, adequate space behind the frame for removing the top, and perhaps a counterbalance to make it easier to raise and lower the top. Some gardeners make their cold frames lightweight enough to be moved from one section of a garden to another. An example is the Dutch light (Figure 11), which is a large but portable greenhouse-like structure.

Frames can be built from many materials; wood and cinder block are most common. If using wood, choose a species that resists decay or one of the new plastic woods. Never use creosote or pentachlorophenol-treated wood because these substances are harmful to plants and humans. Kits are available, some of which contain automatic ventilation equipment.

There is no standard size for a cold frame. Size depends on the amount of available space, desired crops, and size of the available covering. Do not make the frame so wide that parts of the interior for weeding and plant care cannot be reached; 4 to 5 feet usually is the maximum width.

A simple method of insulation is to place burlap sacks filled with leaves over the frame at night to protect against freezing. Another method is to stack bales of straw against the frame.

New cold frame designs include systems for passive solar energy storage such as black containers filled with water that absorb heat during the day and release it at night. An example is the solar pod, which is shaped like a tunnel (Figure 12). Other designs have a very high back and a steep glass slope and are well insulated. They may include movable insulation that is folded up in the day and down at night or during extremely cold weather.

Ventilation is most critical in late winter, early spring, and early fall on clear, sunny days when temperatures rise above 45°F. Raise the top to prevent heat buildup inside the frame. Lower it early enough to conserve heat for the night. An automatic nonelectric lifter is a good investment.

A cold frame can be converted to a hotbed. For a manure-heated bed:

1. Dig out an area 8 or 9 inches deep (deeper if gravel needs to be added for increased drainage).
2. Add an 8-inch layer of strawy horse manure.
3. Cover with 6 inches of good soil.

For an electric-heated bed:

1. Dig out an area 8 or 9 inches deep.
2. Lay down thermostatically controlled electric cable in 6 to 8-inch loops, evenly spacing the cable but never allowing it to cross.
3. Cover with 2 inches of sand or soil.
4. Lay out hardware cloth to protect the cable.
5. Cover with 4 to 6 inches of good soil.

Cloches and row covers

Cloches were originally bell-shaped glass jars set over delicate plants to protect them from the elements. The definition now includes many types of portable structures that shelter plants from drying winds, rain, and cold air. The idea is to provide a greenhouse-like atmosphere for seeds and small plants in order to get an early start on the season or to extend the fall garden as long as possible.

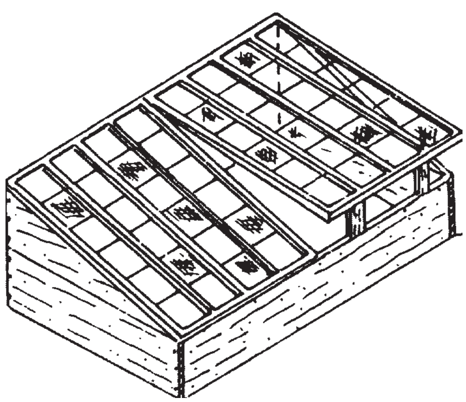


Figure 10.—Cold frame.

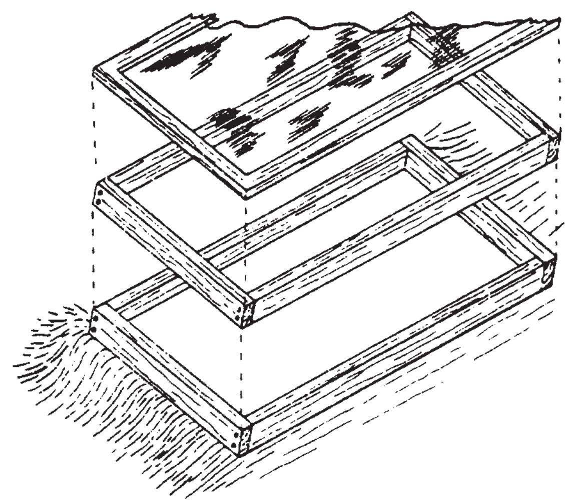


Figure 11.—Dutch light.

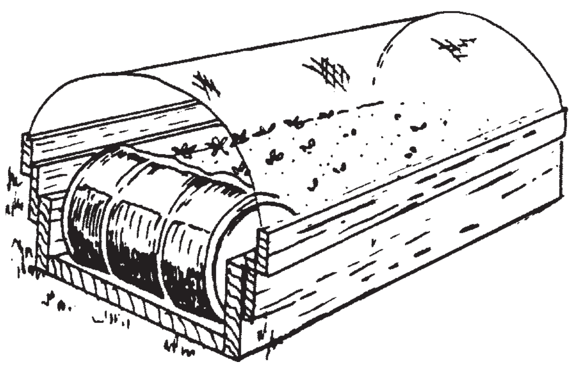


Figure 12.—Solar pod.

Figure 13.—Cloche made from a cut-off plastic jug. (Reprinted by permission from Short-Season Vegetable Gardening, *PNW 497, University of Idaho.)*

Cloches are set over individual plants or made into tunnels for whole rows. They trap solar radiation and moisture evaporating from the soil and plants. Cloches generally are lightweight, portable, and reusable. The best designs can be closed completely at night to prevent frost damage and opened or completely removed during the day for good air circulation. Make sure cloches are anchored or are heavy enough that they won't blow away.

Hotcaps and cut-off plastic jugs are simple cloches (Figure 13). More elaborate ones include fiberglass tunnels, special plastic cloches, row covers with slits to allow aeration, and panes of glass connected by specially designed hinges to form a tent (Figure 14).

One can quickly assemble an excellent Quonset-type cloche by covering a 4 to 5-foot piece of concrete reinforcing wire with row cover or plastic. The heavy-duty wire comes in 5 and 7-foot lengths. It is strong enough to shrug off snow loads.

Now popular is a row cover made of spun-bonded polypropylene. It permits the passage of air and water but is substantial enough to trap heat, shield young plants from wind and insects, and provide a modified atmosphere for early vegetable crops. Lay these row covers loosely over a planted row in early spring. As the plants grow, they will raise the lightweight cover. These covers can be left on most vegetable plants until warmer weather.

Harvesting vegetables

Home grown is no guarantee of quality if harvesting does not occur at the proper time. Table 16 shows typical maturity times for several vegetables.

Pick tomatoes when they are fully colored but still firm. Once fully colored, tomatoes remain in prime eating condition for about one week. Overripe tomatoes become mushy and lose flavor. Tomatoes also lose flavor when exposed to temperatures below 50° F. There may be unripe tomatoes on vines at the end of the season. Those with a clear white star on the blossom end will ripen with good flavor. Use others as fried green tomatoes or in other recipes.

Cut green bell peppers when they are firm and at the desired size. All green bells eventually turn red and become more nutritious. Pick other bells when they turn their genetically programmed color, e.g.,

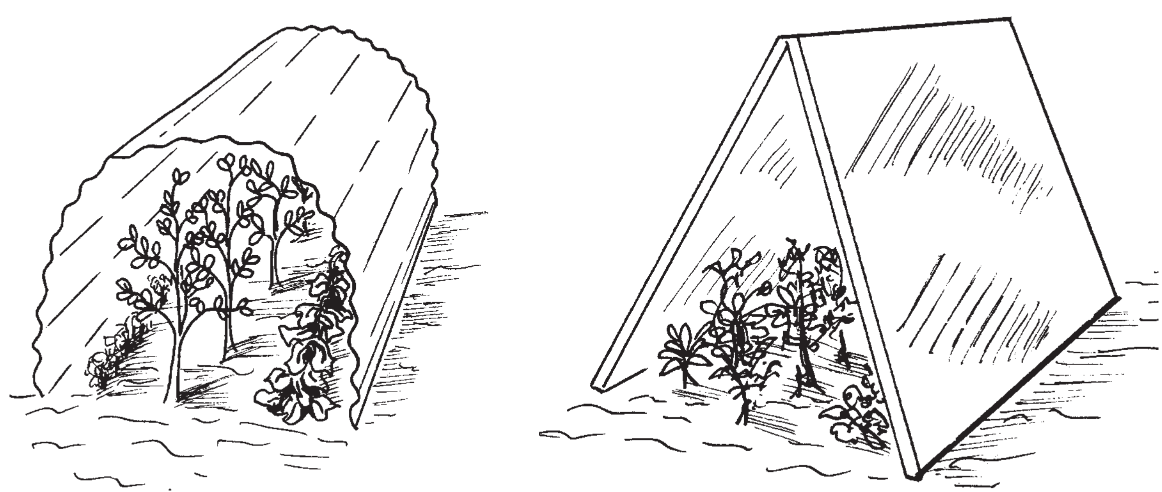


Figure 14.—Season extenders and plant-protection methods. (Reprinted by permission from Short-Season Vegetable Gardening, *PNW 497, University of Idaho.)*

orange or purple. Hot peppers usually become hotter as they mature. Sample for heat once they are full size.

Snap beans are best when the bean is about half developed in the pod. The pods are edible and of good quality at any stage until the beans are nearly full size and the pods begin to soften.

Harvest shelling peas when the pods are full and still a uniform green color. As they become lighter green, they lose quality. Use snap peas from the time they first set on until they fill the pods. Pick snow peas before the peas inside swell.

Harvest summer squash while the skin is still tender. Once the skin begins to feel smooth or slick, squash are past the best eating stage. Baby squash with the flower still attached are a gourmet vegetable.

Winter squash (such as hubbard, acorn, butternut, and sweet meat) must be fully mature before harvesting. The skin should not puncture when a thumbnail is pushed into it. There is no hurry to harvest these squash until cold weather. Cut them with the stem attached and cure at 60° to 70° F for at least a week. Then store them at cool room temperature. They will keep three to five months.

Harvest sweet corn as soon as the kernels are well filled and still milky. Feel the husk. When it is firm, the ear should be ready. If in doubt, peel back the husk a little and look at several kernels. If it is not ready, fold the husk back over the ear and check again in a day or two.

Begin to use head lettuce and cabbage as soon as the heads are firm. If there are a lot of cabbages, give a quarter-turn twist to those with firm heads to break part of the roots, retard further growth, and help prevent splitting. Both of these vegetables grow new small heads if left after harvesting the main head.

Beets, turnips, and kohlrabi are usually best when they are 2 to 2½ inches in diameter. As they grow larger, they tend to become woody.

For those new to gardening and unsure about the best size or stage of maturity for vegetables, try them at different stages.

Table 16.—Days from pollination to maturity under warm conditions.

Vegetable	Days to maturity
Bean, green	17–20
Cantaloupe	42–46
Corn, sweet (from 50 percent silking)	18–23
Cucumber, pickling (3/4" to 1 1/8" diameter)	4–5
Cucumber, slicing	15–18
Eggplant	25–40
Okra	4–6
Pepper, green	45–55
Pepper, red	60–70
Squash, acorn	55–60
Squash, summer crookneck or straightneck (1/4 to 1/2 pound)	5–7
Squash, zucchini (1/4 to 1/2 pound)	3–4
Tomato, cherry	35–40
Tomato, mature green	35–45
Tomato, vine red	40–50
Watermelon, icebox type	28–32

Garden cleanup

When tender crops have been harvested and overwintering crops cared for, pull up all stakes and trellises in the garden except those that are clearly marking the sites of overwintering plants. Clean remnants of plant materials and soil off stakes and trellises. Hose them down and allow them to dry in the sun. Sunlight is a great disinfectant.

Tie stakes in bundles and stack them so they won't get lost during the winter. If possible, roll up trellises and tie them securely. Store these items inside your attic, barn, garage, or shed where they are out of the way and where rodents and other animals cannot get to them.

Pull all dead and unproductive plants and place this residue in the compost heap. Remove any diseased or insect-infested plant material to protect next year's crops. If plant material is left in the garden, an inoculum of diseases and insects that will reproduce the next spring and cause serious problems remains.

Cleanup also provides the chance to add compost or other organic material to the garden. Some excellent sources of organic material are available during the fall. Leaves are abundant, and neighbors are usually glad to give them away. Put some on the garden now and store some for next year's mulch. If leaves are put on too thickly, however, they will mat and will not decompose quickly. Help leaves break down more easily by shredding them or running a lawn mower back and forth over the pile. Put the shredded leaves directly onto the garden or compost them. Leaves are prone to blowing away.

Sawdust and wood chips are easy to obtain from farms and stables; however, they may take years to fully decompose. In the meantime, they tie up valuable nitrogen and make it unavailable to plants. It's best to use these materials as mulch only.

Hot or very fresh manure can burn young seedlings. Adding these materials in the fall, gives them plenty of time to decompose and blend into the soil before planting time.

If there isn't enough organic material for the entire garden, at least try to cover the areas expected to be especially rich for next summer's crops.

If the weather stays dry enough, plow or rototill in the fall. Turning under vegetation in the fall allows earlier planting in the spring and is especially good for heavy soils. Exposure to freezing and thawing during winter helps improve soil structure.

Cover crops

If there is a wet fall, or if a garden is steep and subject to erosion, it might be good to plant a cover crop for winter protection. A cover crop decreases soil erosion, prevents compaction, adds organic material when it is incorporated in the spring, improves soil tilth and porosity, and reduces leaching of nutrients.

Winter cover crops can be planted as early as August 1. They make some growth before frost kills them or stops their growth. Where fall crops are growing, sow cover crop seed between the rows a month or less before the expected harvest. This technique lets the cover crop get a good start without interfering with vegetable growth. Chapter 2, *Soils and Fertilizers*, includes a list of cover crops suitable for winter use. Mixtures of legumes and nonlegumes are most effective. Ask a Cooperative Extension Service office about recommended varieties and planting rates for the area.

Prepare the soil for cover crop seed by tilling under plant wastes from the summer. Broadcast the seed and rake it evenly into the soil.

Spring planting may be delayed somewhat by cover cropping since time must be allowed for the cover crop residue to break down. If some crops need to be planted very early, one may prefer to leave a section of the garden mulched.

When time or weather conditions prohibit tilling or cover cropping, one may wish to let a garden lie under a mulch of compost, plant wastes, or leaves all winter to be plowed or tilled under in the spring. However, a heavy mulch such as whole leaves does not break down quickly and may keep the soil cold and wet long enough to delay planting. The addition of high-nitrogen fertilizer helps break down organic matter more quickly.

Herb gardening

While a discussion of herbs and their culture could fill two large volumes, a concise list of the more common herbs, their uses, and growing hints is included (Table 17). All require essentially the same soil and growing conditions as vegetables. Herbs can often be grown in small plots or containers to complement the vegetable garden in appearance, taste, and aroma.

Herbs do have a few special requirements. When growing herb seedlings, sow 9 to 12 in a 6-inch pot. Allow them all to grow together. They support each other and grow much better than if sown singly. When it's time to transplant, they will be strong enough to divide.

Italian-type herbs such as thyme and rosemary resent moisture around their crowns and should be mulched with rock only. They also lose quality if overfertilized or overwatered.

For more information

University of Wyoming Cooperative Extension Service publications

Gardening: Vegetables for Wyoming (B-1115)

Backyard Composting: Simple, Small-Scale Methods (B-974R)

Gardening: Growing Herbs in Wyoming (B-1144)

Gardening: Extending the Vegetable Growing Season (B-1148)

Gardening: Hot Beds and Cold Frames (B-1151)

Other publications

Rogers, M. *Saving Seeds* (Storey Publishing, Pownal, VT, 1990).

Table 17.—Herb uses and growing hints.

Common name/ Botanical name	Height (inches)	Spacing Row (inches)	Spacing Plants (inches)	Cultural hints	Uses
Annuals					
Anise *Pimpinella anisum*	24	18	10	Grow from seed. Plant after frost. Sun.	Leaves used for seasoning, garnish; dried seed for spice.
Basil, sweet *Ocimum basilicum*	20–24	18	12	Grow from seed. Plant after frost. Sun.	Used as seasoning for soups, stews, salads, omelets.
Borage *Borago officinalis*	24	18	12	Grow from seed, self-sowing. Best in dry, sunny areas.	Young leaves, flowers used in salads and cool drinks.
Caraway* (zone 3) *Carum carvi*	12–24	18	10	Grow from seed. Biennial seed bearer. Sun.	Used as flavoring, especially in bakery items.
Chervil *Anthriscus cerefolium*	10	15	3–6	Sow in early spring. Partial shade.	Aromatic leaves used in soups and salads.
Coriander (cilantro) *Coriandrum sativum*	24	24	18	Grow from seed. Sow in spring. Sun or partial shade.	Seeds used in confections; leaves in salads, Mexican, Chinese dishes.
Dill *Anethum graveolens*	24–36	24	12	Grow from seed. Sow in early spring. Sun or partial shade.	Leaves and seeds used for flavoring and pickling.
Fennel (Florence fennel) *Finocchio foeniculum* *Foeniculum officinalis*	60	18	18	Grow from seed. Sow in early spring. Sun or partial shade.	Has anise-like flavor. Stalks eaten raw or braised.
Parsley* *Petroselinum crispum*	6	18	6	Grow from seed. Sow in early spring. Slow to germinate. Sun.	Brings out flavor of other herbs.
Rosemary *Rosmarinus officinalis*	36–72	18	12	Grows in well-drained, nonacid soil. From cuttings or seed. Sun.	Leaves used to flavor sauces, meats, soups.
Summer savory *Satureja hortensis*	18	18	18	Grow in well-worked loam. Sow seed in spring. Sun.	Leaves used fresh or dry for salads, dressings, stews.
Sweet marjoram *Marjorana hortensis* *Origanum marjorana*	12	18	12	From seed or cuttings, as annual, or overwinter as pot plant. Sun.	Used as seasoning, fresh or dried.

continues on next page

Table 17.—Herb uses and growing hints (cont.)

Perennials					
Catnip (zone 4) *Nepeta cataria*	36–48	24	18	Hardy. Grow from seed or by division. Sun or shade.	Leaves used for tea and seasoning.
Chives (zone 3) *Allium shoenoprasum*	12	12	12	Little care. Divide when overcrowded. Grow from seed or by division.	Favorite of chefs. Snip tops finely. Good indoor pot plant.
Hyssop (zone 4) *Hyssopus officinalis*	24	18	15	Grows in poor soil. From seed. Hardy. Sun.	A mint with highly aromatic, pungent leaves.
Lavender (zone 5) *Lavandula vera*	24	18	18	Grows in dry, rocky, sunny locations with plenty of lime in soil.	Used fresh in salads; flowers dried for sachets, potpourri.
Lovage (zone 4) *Levisticum officinale*	36–48	30	30	Rich, moist soil. Sow seed in late summer. Sun or partial shade.	Cultivated in European gardens as an herbal remedy.
Oregano (zone 4) *Origanum vulgare*	24	18	9	Grows in poor soil from seed or division. Sun.	Used as flavoring for tomato dishes, pasta.
Peppermint (zone 4) *Mentha piperata*	36	24	18	Can start from seed, but cuttings, division recommended. Sun or shade. Cut before it goes to seed.	Aromatic, leaves used as flavoring; oil used in products such as chewing gum, liqueurs, candy, toilet water, soap
Sage (zone 3) *Salvia officinalis*	18	24	12	From seed or cuttings. Full sun. Grows slowly from seed. Renew bed every three–four years.	Used as seasoning for meats, herb teas; use either fresh or dried.
Spearmint (zone 4) *Mentha spicata*	18	24	18	Grows in most soils. Hardy. From cuttings, division. Sun.	Aromatic, used for flavoring, condiments, teas.
Sweet woodruff (zone 3) *Galium odoratum*	8	18	12	May need winter protection. Semishade.	Used as flavoring in drinks.
Tarragon (zone 4) *Artemisia dracunculus*	24	24	24	Does best in semishade. From divisions or root cuttings. Protect in cold winters.	European herb of aster family; used as aromatic seasoning.
Thyme (zone 4) *Thymus vulgaris*	8–12	18	12	Grows in light, well-drained soil. Renew plants every few years. From cuttings, seed, division. Sun.	Aromatic foliage used for seasoning meats, soups, sauces, dressings.
Winter savory (zone 5) *Satureja montana*	24	15	18	Grow in light, sandy soil. Trim out dead wood. From cuttings or seed. Sun.	Used as seasoning for stuffing, eggs, sausage; accents strong flavors.

Divider goes here

Berry Crops

11

Growing raspberries, strawberries, gooseberries, currants, grapes, or other berry crops can be an interesting, challenging, and rewarding experience. Success depends to a large extent on selecting the proper site as well as on providing proper soil conditions and care to allow the plants to flourish.

All grapes and berry crops grow and produce best in full sun. Avoid planting them in shaded areas or near trees or large shrubs which compete for moisture and soil nutrients. Take advantage of sunny areas and locations protected from drying winds. Try to avoid planting berries and grapes in areas where potatoes, tomatoes, peppers, eggplants, or other berries have grown within the past three years. These plants can harbor soilborne diseases that might affect the new planting.

Plan for a long-term space investment when planting berry crops. Strawberry plants, properly cared for, remain productive for three to five years. Raspberries often produce a good crop for 15 to 20 years. Grapes can survive for 40 to 100 years.

Topics in this chapter

- Raspberries
- Strawberries
- Currants and gooseberries
- Grapes
- Elderberries
- Saskatoon berries

Raspberries

Raspberries are among the most delicious and delicate of berry crops. This section discusses summer and fall-bearing red raspberries, black raspberries (blackcaps), and purple raspberries (Figure 1). All are species and hybrids of the genus *Rubus*, and all have similar fruiting habits. Purple raspberries are hybrids of black and red types. Yellow or amber-colored raspberries are single gene mutations of red types and thus

By Bernadine Strik, extension berry crops specialist, Oregon State University. Adapted for Wyoming by Patti Ellis, Honey Creek Nursery, Ranchester, Wyoming, and Karen L. Panter, Cooperative Extension Service horticulture specialist, University of Wyoming.

have the same cultural requirements as do reds. See Table 1 for a list of cultivars.

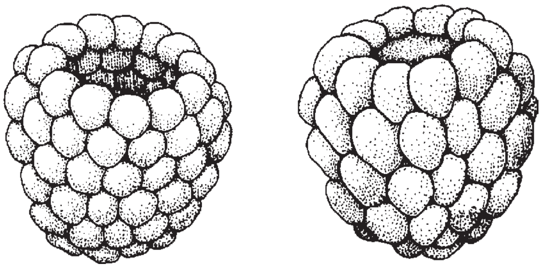
All raspberry plants are perennial; the roots live for many years. The canes are biennial; they grow one year (primocanes) and produce fruit the next (floricanes). Floricanes die after they have fruited and should be removed at that time. New primocanes are produced each year from the roots or at the base of old canes. New floricanes which will fruit the following year need to be trained.

There are two types of red raspberry cultivars: “summer bearing” and “fall bearing” (primocane fruiting). *Summer bearers* produce a crop in July. *Fall bearers* produce fruit on the top portion of the current season’s primocanes in late summer (usually late July to early October). If these canes are left, they become floricanes and bear fruit on the lower portions the next July. Thus, fall bearers can produce two crops per year: one in July on last year’s canes and one in late

Table 1.—Raspberry cultivars.

Cultivar (Hardiness Zone)	Fruit size	Fruit quality	Susceptibility to root rot	Comments
Red summer-bearing				
Boyne (3)	Medium	Firm	Unknown	Very cold hardy
Canby (3)	Small–medium	Medium firm	Susceptible	Bright red fruit
Latham (4)	Large	Firm	Unknown	Old variety; good producer
Liberty (3)	Medium	Firm	Excellent virus resistance; indexed	Hardy; excellent quality
Nordic (4)	Medium	Firm	Superior resistance to anthracnose	Similar to Boyne
Red fall bearing*				
Amity (3)	Medium	Firm	Some resistance	One week earlier than Heritage, good flavor
Autumn Bliss (4)	Large	Firm	Some resistance	Fruit size drops off quickly, susceptible to RBDV (virus)
Heritage (4)	Medium	Firm	Some resistance	Good flavor, cold hardy
Redwing (4)	Medium	Firm	Susceptible	Early summer crop, small, cold hardy
September (3)	Medium	Firm	Unknown	Early summer crop; reliable; excellent flavor
Yellow fall bearing*				
Fallgold (4)	Medium	Medium-firm	Some resistance	10 days earlier than Heritage
Black				
Bristol (4)	Large	Firm	Fairly susceptible	A little later than Munger
Cumberland (4)	Large	Firm	Some resistance	Cold hardy
Black Hawk (4)	Very Large	Firm	Unknown	Good for commercial use. From Iowa State. Heavy yielder.
Purple				
Royalty (4)	Large–very large	Soft	Some resistance	Cold hardy

*If grown only for a fall crop (pruned to the ground in winter), fall-bearing raspberries are cold hardy in most regions.



(a) Raspberry *(b) Blackberry*

Figure 1.—Raspberry (a) and blackberry (b).

summer on the current season's canes. In areas with early frosts, this late crop may not mature.

For a high volume of fruit and best freezing quality, grow a summer-bearing raspberry. Grow a fall bearer for one crop in late summer (see "Pruning") and use the fruit mainly for fresh eating.

Raspberry cultivars differ in fruiting habit, tolerance to pests and heavy soils, and fruit characteristics. Thus, it is important to choose a cultivar adapted to one's needs and site. Buy only certified, disease-free plants from a reputable nursery. Digging up a neighbor's raspberry suckers is not a good idea. Black raspberries are not as hardy as red raspberries and should be given some winter protection.

Establishing the planting

Red raspberries should remain productive for 15 to 20 years, so choose and prepare a good site. Soil should be moderately fertile and well drained, with a pH between 6 and 7. During the year before planting, incorporate organic matter into the soil. If drainage is poor, install drain tiles or use raised beds.

Before planting, spread 1 pound of 12-12-12 fertilizer per 100 square feet (or the equivalent rate of another well-balanced fertilizer). Till the fertilizer into the soil. If fertilizer can't be incorporated before planting, wait four to six weeks after planting and apply 1 tablespoon of 12-12-12 per plant. Apply this fertilizer in a wide band 6 to 8 inches away from the new shoots and rake it in shallowly. If using manure to improve soil structure, decrease the fertilizer rate by one-half.

See Chapter 2, *Soils and Fertilizers*.

Caneberry terminology

Primocanes—First year of growth, usually vegetative. (Only fall-bearing raspberries produce fruit on primocanes in late summer.)

Floricanes—Second year of growth; these canes produce fruit on laterals. All caneberries produce fruit on floricanes.

Planting

Plant as early in the spring as the soil can be worked. Dig a shallow hole, large enough to accommodate the roots. Spread the root mass and set the plant so that the highest point where roots are attached to a cane is 1 to 2 inches below ground level. Cover the hole with soil and water to settle the soil. Cut the canes back to 6 inches tall.

Hedgerow and hill-planting systems are most popular for home gardens. In the *hedgerow* system, space red raspberry plants 2 feet apart in rows about 8 feet apart. Allow the new primocanes that develop to spread along the row but don't let them spread wider than 8 to 12 inches.

In the *hill* system, "hill" refers to the cluster of canes that develops around a single plant, not to planting atop a mound of soil. For red raspberries, space plants 2½ feet apart within the row, with 8 feet between rows. Confine hills to a diameter of about 1 to 1½ feet. Remove all suckers that develop between hills or in aisles.

Black and purple raspberries generally need more space than red raspberries. Set plants 3 to 4 feet apart in the row with

8 to 10 feet between rows. Keep plants confined to hills about 2 feet in diameter.

Plants may produce a small crop the year after planting and a full crop in the third year.

Trellis

Summer-bearing red raspberries need a supporting structure to hold the canes upright. Make a simple trellis by stringing wire (12-gauge or heavier) between posts spaced 15 to 20 feet apart. Posts may be treated wood or metal. Figures 4 and 5 show methods used in training and supporting primocanes.

With fall-bearing raspberries, you can use a temporary support structure if the plants are cropped only in the fall (see "Pruning").

Black and purple raspberries do not need a trellis.

Caring for established plantings

Fertilizing

Apply fertilizer in early spring when new growth is starting. Apply 4 to 6 pounds of 10-20-20 (or equivalent) as a broadcast or band application to each 100 feet of row. Fall-bearing raspberries need additional fertilizer before fruiting. When new canes begin to bloom, spread 1 to 2 pounds of ammonium nitrate (33-0-0) per 100 feet of row.

If using manure, apply it in late fall or early winter. Reduce the rate of nitrogen fertilizer by one-half.

Cultivation

Weeds and primo-canes that grow between hills or in row aisles must be controlled. Cultivate shallowly or use herbicides recommended by a county extension office.

Mulches can be applied once plants are established. Place sawdust or bark in a 3-inch layer over the row. Do not use cedar sawdust. Additional nitrogen may be needed to assist in breaking down organic mulches.

Watering

Raspberry plants need about 1 inch of water per week. Irrigate when rainfall doesn't provide this amount. Ample soil moisture is essential from the time fruit begins to form to the end of the harvest season. Water fall-bearing varieties adequately throughout the fruiting period, usually until the end of September, and during the winter.

Overhead irrigation during the harvest period may promote fruit rots. If possible, water only the bases of the plants during this period, using trickle irrigation or hand watering.

Pruning

Summer-bearing raspberries

Don't top primocanes during the growing season. Remove the dead floricanes in late summer/fall. From January through early March while the plants are dormant remove all weak, broken, diseased, and insect-damaged canes. In the hill system, leave all of the healthy primocanes in each hill. In the hedgerow system, narrow the row to 8 to 12 inches wide.

For maximum fruit size, shorten the canes in both systems to about 5½ feet tall and tie them to the trellis as shown in Figure 2 or 3. If, however, one is willing to sacrifice about ½ gram in average fruit weight to obtain a higher yield, retain almost the entire cane length. Tie the bundle of canes from each hill to the top wire and then loop the canes downward and tie the end of the bundle to the bottom wire (not illustrated).

Fall-bearing raspberries

In Wyoming it is best to grow fall-bearing raspberries for a fall crop only. Cut all canes to ground level in late March. When the new primocanes emerge, maintain a row width of about 12 inches. Fruit will be produced on the tips of the primocanes in late summer.

Black and purple raspberries

Remove the top 3 to 4 inches of primocanes during late spring or early summer. Go over the planting several times during the summer and top primocanes to a height of 2 to 3 feet. This topping causes the canes to produce lateral branches. After harvest, remove all dead floricanes (2-year-old canes). When plants are dormant, remove all damaged canes and those that are less than ½ inch in diameter. Shorten lateral branches to about 1 to 1½ feet. Cut unbranched canes to 2½ to 3 feet.

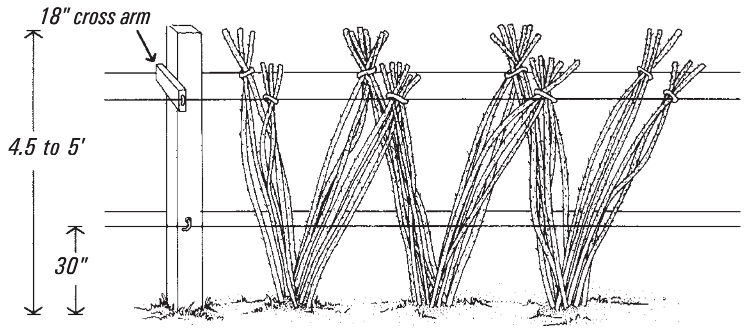


Figure 2.—A four-wire trellis with cross arms for raspberries is shown. Cross arms for the top two wires spread out the fruiting canes and leave room for new primocanes to grow between the wires.

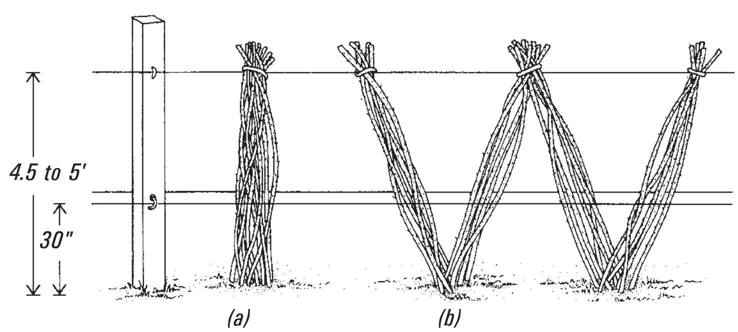


Figure 3.—This is a three-wire trellis with wires fastened directly to posts. The single top wire is stapled to the post, and the two bottom wires are on hooks or bent nails so they can be lifted and swung out over primocanes to pull them in. (a) Hills with up to 6 or 7 canes are tied in a single bundle. (b) Hills with more canes can be split, with part going halfway to the next plant in the row.

Harvest

Pick fruit every three or four days. Avoid picking fruit that is wet from dew or irrigation. Place fruit in shallow containers. Berries are quite perishable and should be refrigerated or processed as soon as possible.

Pest and disease problems

Several insect and disease problems may affect raspberries such as root weevils, leafroller larvae, spider mites, aphids, powdery mildew, anthracnose, verticillium wilt, and phytophthora root rot.

See Chapter 13, *Diagnosing Problems*.

Red and purple raspberries generally are quite hardy; however, in cold regions, be aware that some cultivars are more cold hardy than others. Black raspberries, in general, are not as cold hardy as reds and purples.

Strawberries

Strawberry types include June bearers, everbearers, and day neutrals. *June bearers* produce only one crop per year in June/July. *Everbearers* produce two crops: one in June/early July and another in the fall. *Day neutrals* produce a crop almost continuously throughout the normal growing season. See Table 2 for a list of cultivars.

The fruit of everbearers and day neutrals is typically smaller than that of June bearers, and total yields are often lower. However, the advantage in growing these types along with June bearers is that one can harvest fruit for most of the growing season. Note that day neutrals are the best choice for fresh fruit throughout the season because they have a longer fruiting period and better fruit quality. Unfortunately, retail nurseries often lump day-neutrals and everbearers together as "everbearers."

Establishing the planting

Soil preparation

Strawberries grow best in well-drained, reasonably fertile soil. A good supply of organic material worked into the soil improves aeration, drainage, and water-holding capacity. Apply organic matter the year before planting if possible. If using fresh or woody organic matter, add ammonium nitrate at 1 pound per 100 square feet to aid in decomposition.

Before planting, apply 1 pound of 10-20-20 fertilizer (or equivalent) per 100 square feet. If using manure, decrease the fertilizer rate by one-half.

In soil that drains relatively slowly, one can improve strawberry plant growth by planting on raised beds about 10 to 12 inches high.

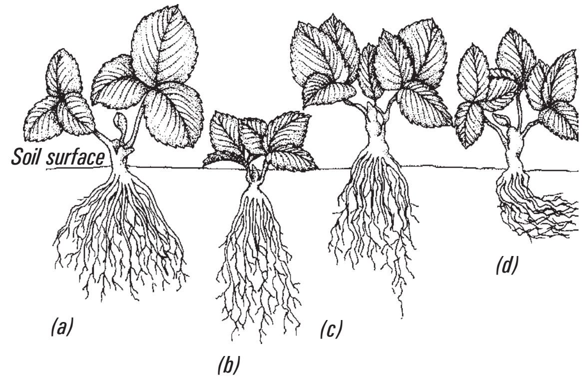


Figure 4.—(a) This is the proper planting depth for strawberries. (b) The crown is too deep. (c) The crown is too high. (d) The roots are bent and remain near the surface.

Planting

Purchase certified, disease-free plants from a reputable nursery. Avoid using runner plants from an old, established patch; they're often diseased. Plant strawberries in early spring as soon as the soil can be worked.

Dig a hole for each plant large enough to place the roots straight downward but somewhat spread. The midpoint of the crown should be level with the soil surface, and the top root should be just below the soil surface (Figure 4). Irrigate the plants as soon as they're planted.

The matted-row and hill systems are the most common training methods for strawberries (Figure 5). The hill system is preferred for everbearers and day neutrals because they don't produce as many runners as do June bearers. June bearers are usually grown in a matted row; however, they can be grown in either system.

In the *matted-row* system, set plants 15 inches apart in the row or raised bed with 3 to 4 feet between rows (Figure 5a). Allow the runners that form from these "mother" plants to take root; they will form a matted row 18 inches wide. Keep the remaining 1½ to 2½ feet between rows clear by sweeping early forming runners

Table 2.—Strawberry cultivars.

Cultivar (Hardiness Zone)	Season	Berry size	Flavor	Comments
June bearers				
Dunlap (3)	Mid	Large	Excellent	Very productive
Guardian (3)	Mid	Large	Good	Disease resistant
Honeoye (3)	Mid	Medium	Sweet	Conical shape; firm
Redcoat (3)	Mid	Large	Excellent	Fresh, canning, freezing
Surecrop (3)	Mid	Large	Slightly tart	Heavy crop; freezing; disease resistant
Trumpeter (3)	Mid	Large	Good	Intense red color; very hardy
Everbearers				
Fort Laramie (3)	2 crops	Medium	Fair	Sweet, scarlet red
Ogallala (3)	2 crops	Medium-large	sweet	Rich, dark red; processes well
Ozark Beauty (3)	2 crops	Large	Fair	Sweet, bright red
Quinault(3)	2 crops	Large	Fair	Open center
Day neutrals				
Tristar (4-5)	All	Small–medium	Good	Deep red
Tribute (4-5)	All	Small–medium	Good	Deep red

into the row and by cutting off late-forming runners.

The *hill* system is ideal for cultivars that produce few runners such as everbearers. Set plants 12 to 15 inches apart in double or triple-wide rows (Figure 5b). Aisles should be 1½ to 2 feet wide. Remove all runners that develop throughout the growing season.

First-season care

For June bearers, remove all flower clusters during the planting year. Young plants are stressed if allowed to produce fruit the year they are planted. Crown and leaf growth will be limited, decreasing the following year's yield.

For everbearers and day neutrals, remove only the first flush of flowers, allowing flower clusters formed after July 1 to develop fruit. This allows plants to become well established before fruiting.

On a few occasions during the summer, cut off all runners from plants growing in the hill system. In the matted-row system, most of next season's crop will come from the mother plants plus runners that develop and root before September. Ideally, position runner plants as they develop to attain about five runner plants per square foot of matted row. Place a little soil just behind each runner plant to keep it in place. Once this density is achieved, remove all other runners. A simple method is to remove all runners that have not rooted by September 1.

Cultivation and weed control

Weeds compete with shallow-rooted strawberry plants for water and nutrients. Hoe often enough to destroy weeds and keep the soil loose. Use sawdust, bark, or black plastic film to suppress weeds, conserve moisture, and keep fruit clean.

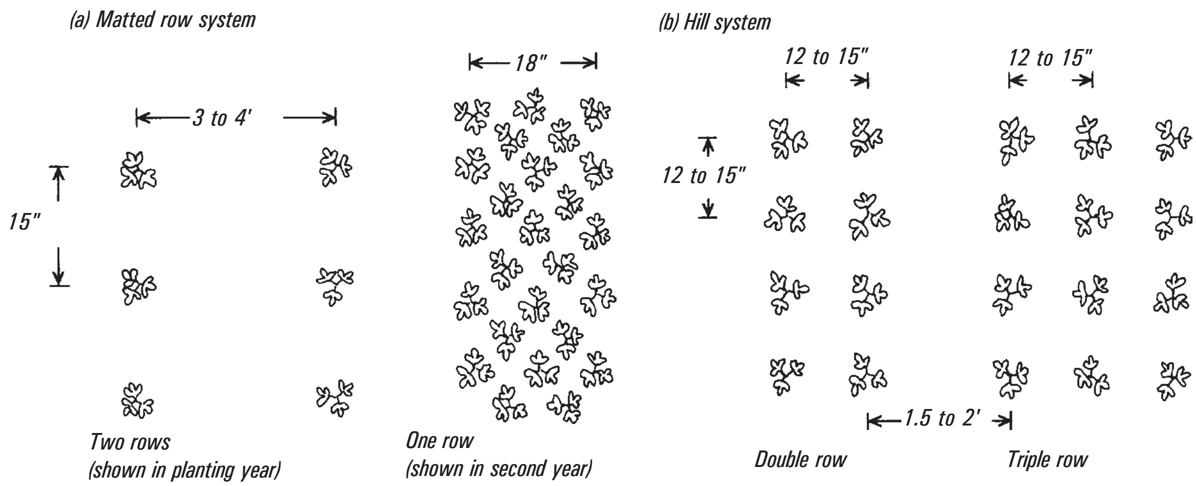


Figure 5.—Proper spacing for strawberry plantings: (a) Matted row system; (b) hill system.

Fertilizing

If plant growth is weak and leaves are light green in color, add additional nitrogen fertilizer six weeks after planting. Broadcast ammonium nitrate at a rate of ½ pound per 100 square feet of row. Make a similar application in late July or early August if the plants lack vigor.

Broadcast the fertilizer when foliage is dry. Avoid placing fertilizer directly on crowns because they can be burned. If necessary, remove fertilizer from leaves and crowns with a brush or sprinkler irrigation.

Watering

Strawberries are shallow rooted. To obtain maximum growth and yield, never let them be stressed by lack of water. Keep new strawberry plants well irrigated throughout their first season.

Caring for established plantings

Winter and frost protection

In Wyoming, it may be necessary to give winter protection. Minimize damage by covering plants with several inches of loose straw after temperatures first drop below freezing. Don't place straw on the plants before freezing weather and be sure to remove it when plants start to grow in the spring.

Spring frosts can kill open blossoms. Small plantings can be protected with a sheet of spunbound row cover or light canvas. Put the cover on in the early evening and remove it in the morning after the danger of frost has passed.

Weed control

See Chapter 5, *Weeds*

Keep weeds out of the planting by cultivating or using registered herbicides. Check with a county extension office for information.

Fertilizing

Fertilize established June-bearing strawberries in late summer to promote fall growth. After harvest, apply 2 to 3 pounds of 10-10-10 (or equivalent) per 100 square feet of row. One can broadcast fertilizer and brush it off the foliage or apply it in a 2 to 3-inch band 2 to 3 inches from both sides of the row. Water the plants to carry the fertilizer down to the roots. Fertilize day neutrals and everbearers in small amounts throughout the growing season.

Watering

During the growing season, strawberries need 1 inch of water per week. Wet the soil to a depth of 6 to 8 inches each time it is watered. After the first season, there are two times when soil moisture is important. The first is from bloom through harvest to ensure that berries swell to their maximum size. The second is from late August through early fall when plant growth resumes and flower buds form for the next season's crop.

Renovation

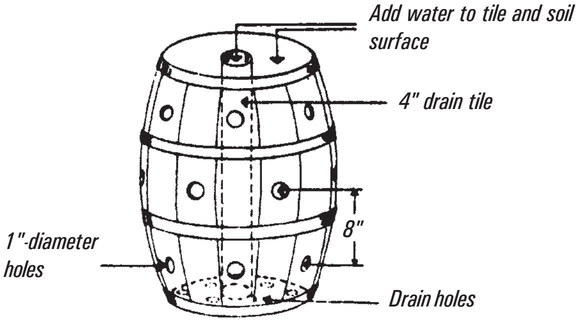
One can maintain strawberry planting for several fruiting seasons by managing and renovating it properly. If plants are vigorous and relatively free from weeds, insects, and diseases, renovate June bearers to prepare them for next season. Renovation improves the next season's yield and may decrease fruit rot significantly, especially if leaves are removed. Renovation is not recommended for day neutrals or everbearers.

For matted-row beds, the procedure is as follows:

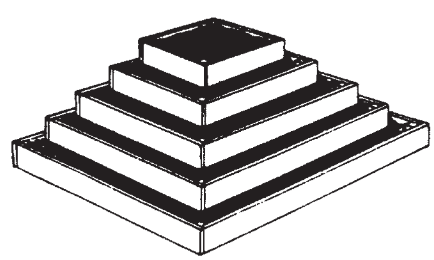
1. After the crop has been harvested, mow the foliage to about 2 inches above the top of the crowns. Use hedge clippers or a rotary mower with the blade raised high. Remove all plant debris.
2. Narrow the rows to 8 to 10 inches wide using a rototiller, shovel, or hoe. Till no deeper than 1 to 2 inches.
3. In older plantings, thin out old and weak plants, leaving 1-year-old, vigorous plants. The best plant density is about 5 to 6 plants per square foot of row.
4. Keep the planting free of weeds and remove all excess runners as they form. Remove all runners that form after September 1.
5. Irrigate as needed.

To renovate June bearers in the hill system, mow off foliage above the crown, remove and burn or bury all plant debris, and remove all runners through the fall.

(a) Barrel planter



(b) Pyramid planter



Materials to build a 72"-wide, 5-level, square-sided pyramid planter in which each ascending level is 12" less in width than the previous level:
4 boards 6' long and 6" wide
4 boards 5' long and 6" wide
4 boards 4' long and 6" wide
4 boards 3' long and 6" wide
10' of 2-by-2s for corners
1 pound of 6-penny galvanized nails

Figure 6.—Alternative methods for growing strawberries: (a) barrel planter; (b) pyramid planter.

Remove plantings that are no longer productive or lack vigor. To make a new planting, plant in another location.

Harvest

Pick fruit every other day or daily during hot weather. Fruit harvested in the morning usually has a longer shelf life. Pick all ripe berries; fruits left on the plant become overripe, and disease and insect problems can develop. To prevent fruit softening and decay, avoid washing fruit until just before using it.

Novel growing methods

Strawberries can be planted in barrels, planters, mounds, or hanging baskets (Figure 6). These planting methods require close care in watering, fertilizing, and other cultural needs. Everbearing or day-neutral types are best suited for this type of production. Plants may not overwinter well in Wyoming using these aboveground systems.

Pest and disease problems

See Chapter 13, *Diagnosing Problems*.

The most serious disease problems of strawberries are fruit rot and verticillium wilt. Insect problems include root weevils, aphids, spider mites, crown moths, and symphylans.

Currants and gooseberries

Currants and gooseberries are closely related perennial bush fruits, both belonging to the genus *Ribes*. Their relatively small plant size, ease of culture, and distinctive, attractive fruit make them well suited for home gardens. Gooseberries and currants are very hardy and can be grown in most areas of Wyoming.

Black currants are prized for their distinctive flavor in juice, jelly, and liqueurs. They are also rich in vitamin C. Red currants are used mainly for fresh eating or jelly. Gooseberries can have red-purple or green-yellow fruit and are eaten fresh or made into jams, pies, and other desserts. Both currants and gooseberries can be frozen easily and kept for later use. See Tables 3 and 4 for a list of cultivars.

Establishing the planting

Gooseberries and currants do best in partially shaded locations or on a north or northeast exposed slope. In these locations there is less likelihood of leaf and fruit scalding, which can occur in hot, dry areas. Planting on a slope also decreases disease problems, especially powdery mildew, by improving air circulation. Avoid frost pockets (areas into which cold air drains) because plants flower early in the spring.

Most currant and gooseberry cultivars are alternate hosts for a disease called white pine blister rust. Although this disease does not cause excessive damage to these plants, five-needled pines (for example, bristlecone or foxtail pines) are very susceptible. If there are five-needled pines in the landscape, one may wish to plant a resistant gooseberry or currant cultivar or consider another berry crop.

Red currants and gooseberries generally are self-fruitful, so only one cultivar is needed for fruit production. However, both types produce larger fruit if planting more than one cultivar for cross-pollination. Some black currants are self-sterile and require a second cultivar for fruit production.

Soil preparation

The average life span of currants is 10 to 15 years; for gooseberries it is 15 to 20 years. Thus, it's important to choose and prepare a site carefully.

Currants and gooseberries tolerate a wide range of soil conditions but perform best in a well-drained loam soil with an organic matter content greater than 1 percent. One can improve a poorly

Table 3.—Currant cultivars.

Cultivar (Hardiness Zone)	Susceptibility to Mildew	Rust	Fruit size (g)	Yield	Harvest date
Black currants					
Consort (3)	Low	None	0.8	Moderate	Early July
Crusader (3)	Unknown	Low	0.7	Good	Mid July
	Susceptibility to mildew	**Cluster length (cm)**	**Fruit size (g)**	**Yield**	**Harvest date**
Red currants					
Wilder (4)	Medium	9.3	0.7	Good	Mid July
Red Lake (4)	Medium	8.9	0.8	Low	Mid July
Hinnomaki Red (4)	Unknown	9.0	0.8	Good	Mid July

drained site by installing drain tiles or building raised beds. Improve heavy clay or sandy soil by adding organic matter.

Gooseberries and currants grow best in a slightly acidic to neutral pH (5.5 to 7.0). Test soil pH the year before planting and adjust it if necessary.

Plant in the spring. Several days before planting, apply 1 pound of 10-10-10 fertilizer (or equivalent) per 100 square feet. Work the fertilizer into the soil. If fertilizer cannot be applied before planting, apply 1/4 pound of 10-10-10 per plant two weeks after planting. If using manure to improve soil structure, decrease the rate of fertilizer by one-half.

Planting

Plant healthy 1 or 2-year-old plants in early spring. Purchase bare-root or container-grown stock from a reputable nursery.

Space gooseberries and red currants 3 to 4 feet apart in rows. Black currants are more vigorous and should be spaced 4 to 5 feet apart. Rows can be as close as 7 feet, but 8 to 10 feet allows for better air circulation in vigorous plantings.

At planting, prune all branches to a length of 4 to 6 inches to stimulate new growth. Strip off flower buds or blossoms the first year so that no crop is produced. It's important that plants grow well the first year, and flower and fruit production reduces growth.

Mulching around the plants with sawdust or decomposed leaves is recommended to conserve moisture, control weeds, and keep roots cool. Apply mulch 2 inches deep in the planting year. Fresh or undecomposed mulching material may require additional fertilization above recommended rates.

Watering

Gooseberries and currants need about 1 inch of water per week from fruit set through harvest. Irrigate when natural rainfall doesn't supply this amount.

Caring for established plantings

Mulching

Once plants are mature, add mulch as required to attain a depth of about 4 inches. In row plantings, widen the mulched area to about 4 feet as plants become larger.

Fertilizing

In the second year, apply about ¼ pound of 10-10-10 fertilizer (or equivalent) per plant. Apply this fertilizer when

Table 4.—Gooseberry cultivars.

Cultivar (Hardiness Zone)	Fruit Spines	Fruit Color	Weight (g)	Yield	Mildew Susceptibility	Harvest	Flavor
Pixwell (3)	Yes	Red	2.0	Moderate	None	Late July	Good
Captivator (3)	No	Red	3.9	Moderate	Low	Late July	Good
Gooseberry x black currant hybrids							
Jostaberry (4)	No	Black	2.0	Moderate	None	Late July	Good

the buds are swelling in the spring. Spread it evenly over an area approximately equal to the plant's maximum spread. Do not let fertilizer touch the plant's base or crown.

If fresh mulch was applied to young plants, they may require additional nitrogen. Increase the fertilizer rate if plants lack vigor or if older leaves turn pale green to yellow.

Increase rates slightly in the third year. Fourth-year and mature plantings should receive about ½ pound of 10-10-10 per plant. Depending on plant vigor and site fertility, apply fertilizer only once in the spring or split it to encourage better seasonal growth. For split applications, apply ¼ pound of 10-10-10 at bud break and another ¼ pound in mid to late June.

If manure was applied in the fall, decrease the recommended fertilizer rate by one-half. In cold regions, manure applied in the fall may increase the risk of winter injury.

Pruning

Red currants and gooseberries

Prune when plants are dormant in late winter. These plants produce most of their fruit on spurs on 2 and 3-year-old wood. Canes (stems arising from the base of the plant) that are 4 or more years old are no longer productive.

After pruning, a healthy bush should have 9 to 12 main canes—3 to 4 each of 1, 2, and 3-year-old canes. Remove all canes older than 3 years and those that are damaged or diseased. Prune to form an open center. Remove canes that are low to the ground.

Black currants

Prune when plants are dormant in late winter. Black currants produce best on 1-year-old wood. Strong 1-year-old shoots and 2 or 3-year-old canes with a lot of strong 1-year-old shoots are most productive.

When pruning, keep 10 to 12 canes per mature bush; about half should be 1-year-old shoots. One can leave a few more shoots if the plant is very vigorous. Remove all shoots that are more than 3 years old. Make pruning cuts close to the ground.

Harvest

The year after planting, one can harvest a light crop. By the third or fourth year, plants usually bear full crops. A yield of 4 to 6 quarts per mature bush is considered good for red and white currants and gooseberries. However, yields for black currants are often only about half this amount.

Currants ripen over a 2-week period. Once a berry ripens, however, it can usually remain on the bush a week or more without dropping or becoming overripe. Therefore, one can harvest most of the berries on a bush in one or two pickings. If picking more frequently, one may tend to pick berries that aren't fully ripe.

Pick black currants as individual berries. However, trying to pick red currants individually will tear the fruit, causing a loss of juice. Therefore, pick whole clusters (strigs) and strip the berries from the stems later, just before processing or eating. For making juice or jelly, crush the berries without removing them from the strig since the juice will be strained anyway.

Gooseberries ripen over a 4 to 6-week period. Harvest them individually as they ripen. Some people prefer slightly immature berries for jams and pies, so they harvest the berries when they reach full size but are not yet fully ripe. Others prefer fully mature or ripe berries; certainly these are better for eating fresh.

Pest and disease problems

Many black currants and European types of gooseberries are especially susceptible to powdery mildew. Choose a site with good air circulation, plant resistant or tolerant cultivars, and prune to an open bush shape. Use fungicides for control as needed.

See Chapter 13, *Diagnosing Problems*.

Leaf spot or anthracnose can be a problem in gooseberries and sometimes in currants. Infected leaves have brown spots and may turn yellow and drop prematurely.

The three most common insect problems are aphids, currant fruit flies (also known as gooseberry maggots), and currant borers.

Grapes

Because grapes are self-fertile, only one cultivar is needed for fruit production. However, one may prefer growing several for variety. Cultivars differ in their suitability for eating fresh or as juice, wine, raisins, and jelly. It is important to choose a cultivar that will mature in a particular area. See Table 5 for a list of cultivars.

Three types of grapes are grown in the Pacific Northwest: American, European, and French-American hybrids. Each has specific qualities.

- *American* cultivars (*Vitis labrusca*) have a strong “foxy” (musty) flavor and aroma. These cultivars are used mostly for juice and fresh eating.
- *European* cultivars (*Vitis vinifera*) differ from American cultivars in fruit characteristics, vine growth habit, and climate adaptation. They have tight clusters, generally thin skins, and a winelike flavor. They require more heat units for fruit maturation than do American types.
- *French-American* hybrids have some characteristics of both American and European types, depending on parentage.

Establishing the planting

The first step toward consistent production of high-quality grapes is choosing a sunny location. Because new shoot growth in April and May is very tender to frost, avoid frosty areas. Sites sheltered from wind and open to the south are usually warmer.

For fastest yields, purchase dormant bare-root vines or potted 2-year-old plants; there is no need to buy older plants. One can also easily root grapes from cuttings. (See *Growing Grapes in Minnesota*, *Northern Winework - Growing Grapes and Making Wine in Cold Climates*, and *Colorado Grape Growers’ Guide* for more information.) In retail nurseries, nongrafted vines are most common although grafted plants may be available.

Soil preparation

Remove perennial weeds and till the soil before planting. Incorporate organic matter (1/3 soil volume) into heavy soils to improve aeration and fertility. Fertilizer is generally not needed at planting time.

Planting

Plant grapes in the spring after all frost danger has passed. Before planting, prune off broken roots, trim very long roots, and

Table 5.—Grape cultivars.

Cultivar (Hardiness Zone)	Color	Clusters	Berry size	Comments
Beta (3)	Blue-black	Small-medium	Small	Extremely hardy; used for dessert, wine
Bluebell (4)	Blue-black	Medium-large	Medium-large	Very hardy; superior to Concord, produces a lighter juice
Canadice (5)	Red	Medium	Medium	Hardy, seedless
Concord (4)	Blue-black	Medium-large	Medium-large	Winter hardy; used for juice, wines, fresh.
Concord Seedless (5)	Blue	Medium	Medium	Seedless
DeChaunae (4)	Red			Productive, vigorous, wine; Southeast Wyoming only
Elvira (4)	White	Small	Small	Vigorous; wine
Esprit (4)	White	Large	Large	Mild, fruity flavor; table or wine
Frontenac (4)	Red	Medium-large	Small	Full-bodied red; wine
Himrod (5)	White	Medium	Medium	Seedless
Kay Gray (4)	White	Small-medium	Large	Mild, foxy flavor; table or wine
LaCrescent (4)	White	Large	Small-medium	Sweet; hardier than Lacrosse; Southeast Wyoming only
Lacrosse (4)	White	Medium	Medium	Sweet; very hardy
Marecheal Foch (5)	Red	Medium	Small-medium	Fruity; very hardy French hybrid; red burgundy type; wine
Prairie Star (4)	White	Large	Small-medium	Blending, neutral wine
Reliance (5)	Red	Medium	Medium	Hardiest seedless
St. Croix (4)	Red	Medium	Medium-large	Sweet; wine or dessert
Seyval Blanc (4)	White	Large	Medium-large	Sweet; wine or dessert
Traminette (4)	White	Large	Medium	Spicy; unique; wine
Swenson Red (4)	White-red	Large	Large	Sweet
Valiant (4)	Blue	Small	Small	Wine; dessert; jelly, very hardy
Worden (4)	Blue-black	Large	Large	Fresh; juice; wine

prune off all but one of the canes. Set plants in a hole wide enough to spread the roots without bending them and as deep as the plant was grown in the nursery. Irrigate as needed. A drip line with one-gallon-per-hour emitters works very well when attached to the bottom wire of the trellis and allowed to drip near the newly planted grapevine. Remember, a mature grape vine only needs five gallons of water per week and excess watering is going to promote vegetative growth rather than fruit production.

Spacing

Space plants 6 to 8 feet apart in the row. Spacing between rows depends partly on the training and trellis system used as well as the space available. In home gardens, 9 feet is generally suitable.

Trellis

Most common training systems require a trellis support. Grape plants become very heavy with wood and fruit, so the trellis must be strong and well braced. Most post and wire trellises are made with treated wood or metal posts and 12-gauge

Grapevine terminology

Arm—Wood that is 2 or more years old. Short branches of the trunk from which canes or spurs develop.

Cane—A mature shoot after leaf fall.

Cordon—A long arm, usually trained along a wire, from which canes or spurs grow.

Internode—The portion of a shoot or cane between two nodes.

Lateral—A branch of a shoot.

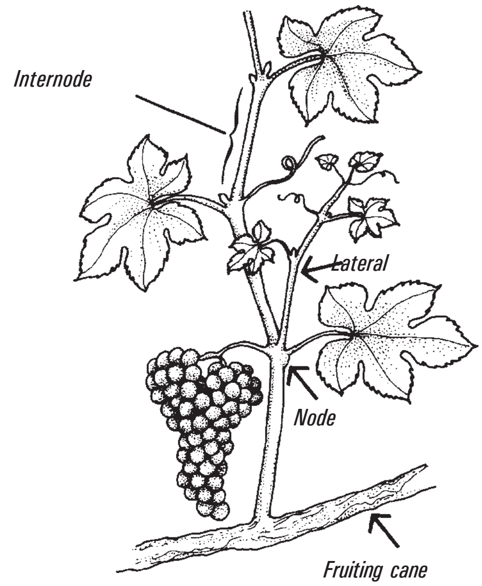
Node—(1) The thickened portion of a shoot where the leaf and lateral bud are located. (2) The location of a bud on a cane or spur.

Shoot—New green growth with leaves, tendrils, and often flower clusters, developing from a bud on a cane or spur.

Spur—A cane pruned back to one, two, or three buds.

Sucker—Also called “water sprout.” A shoot growing from old wood, often the trunk base, rather than from shoots or canes.

Trunk—A grapevine’s permanent, above-ground stem.



Parts of a grape shoot

or heavier wire. The top wire of the trellis needs to be a maximum of five feet from the ground.

Training

The objectives of training a young grapevine are to establish a good, strong support structure for fruit production and to develop a good root system. Select the strongest shoot that grows from the newly planted vine and train it to twine, a stake, or wire so that a straight trunk develops. Promptly remove any other shoots that appear so as to direct the plant’s energy to trunk and root growth.

Many different training and trellis systems may be used such as the fan, modified chautauqua, mini J, or a 4 cane-Kniffen system (see *Growing Grapes in Minnesota*, pages 15-20).

For all seedless and wine types in northern Wyoming, it is recommended that they be buried in the fall for winter protection. Planting a new vine at a 45-degree angle aids in laying the trunk on the ground after fall pruning. Use heavy-gauge wire to stake the cane to the ground in several places and then sprinkle with some form of mouse control, especially around the base of the cane. Cover with one foot of straw and place enough soil on the straw to keep the wind from blowing it away. Uncover the vine May 7th to 10th, depending on current weather conditions and after all frost danger has passed. Lift the trunk off the ground and tie the main cane and side canes to the trellis. Placing a rock or brick under the cane will make room for air movement, helping to prevent trunk rot.

Caring for established plantings

Watering

Irrigate young plants as needed. Mature plantings usually need irrigation only about once a week. During the fruiting period avoid overhead irrigation, which promotes fruit rots.

Fertilizing

Grapes do not need high levels of soil fertility. Apply 10 ounces of 10-20-20 fertilizer per vine (or equivalent) in the spring. If using manure or compost, avoid heavy applications which promote excessive shoot growth and delay fruit maturity. Soil tests should be done periodically to gain firsthand knowledge of grape plants' nutritional needs.

Pruning

Prune vines when they are dormant, removing about 80 to 90 percent of the wood that grew the previous season. There are two methods of pruning: cane pruning and spur pruning.

In some cultivars such as French-American hybrids ('Maracheal Foch,' for example) or American types ('Concord') the shoots that grow from basal buds of canes do not produce fruit. Thus, do not spur prune these cultivars; cane prune them instead. If one is uncertain as to whether the basal canes of a cultivar are fruitful, it's best to cane prune.

Cane pruning

Cane pruning involves pruning annually to remove all growth except selected new fruiting canes and renewal spurs. In the first growing season, train the young vine to the wire and remove any lateral shoots as shown in Figure 7a.

In the second growing season, shoots will develop from buds on the young vine. Retain two shoots that grow 2 to 6 inches below the trellis wire. Train these along the wire, one on each side of the trunk, and remove all other shoots and any flower clusters that develop (Figure 7b). Next winter, prune the two canes back to seven or eight buds each (Figure 7c). Fruit will be produced from these buds.

In the third growing season, shoots grow from buds on 1-year-old canes, and fruit is produced on these shoots (Figure 7d). If an average of more than one fruit cluster is produced per shoot, thin the remaining clusters to keep the young plant from overbearing (see "Fruit Thinning"). In the third winter, select new fruiting wood and remove the remainder (Figures 7e and 7f).

When selecting canes to keep, choose those that were exposed to light during the growing season, are pencil thickness in diameter, and have average internode length. (Long internodes indicate too much vigor.) These canes will be the most fruitful.

As the vine gets older, one may need to leave a short renewal spur near the "head" of the trunk; this spur acts as a source of fruiting wood the following winter. Fruiting is thus kept close to the trunk.

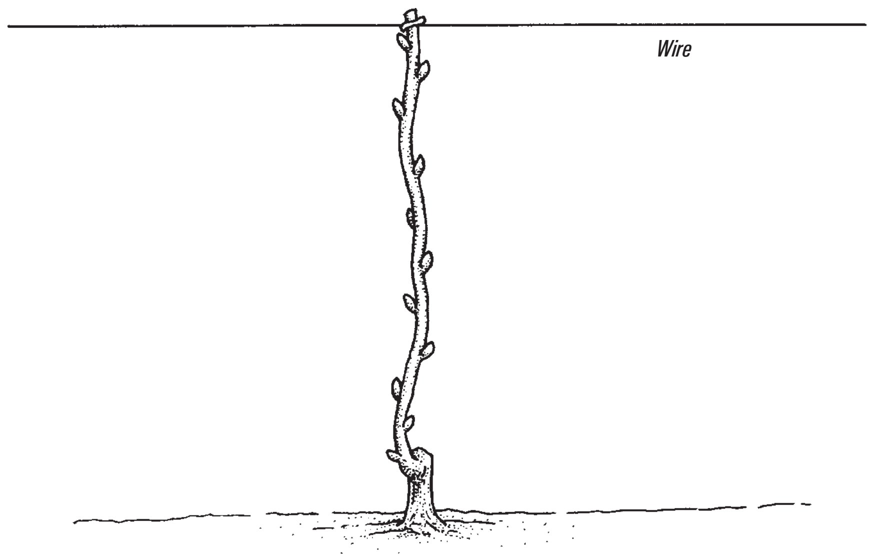
On mature vines, select two new fruiting canes each year. On wine grapes, cut each back to about 15 buds (Figure 7g and 7h). Wrap the canes loosely around the trellis wire and tie at the end. In table and juice grapes, as many as 40 to 80 buds can be left on mature vines. Prune mature plants yearly to remove all growth except new fruiting canes and renewal spurs.

Spur pruning

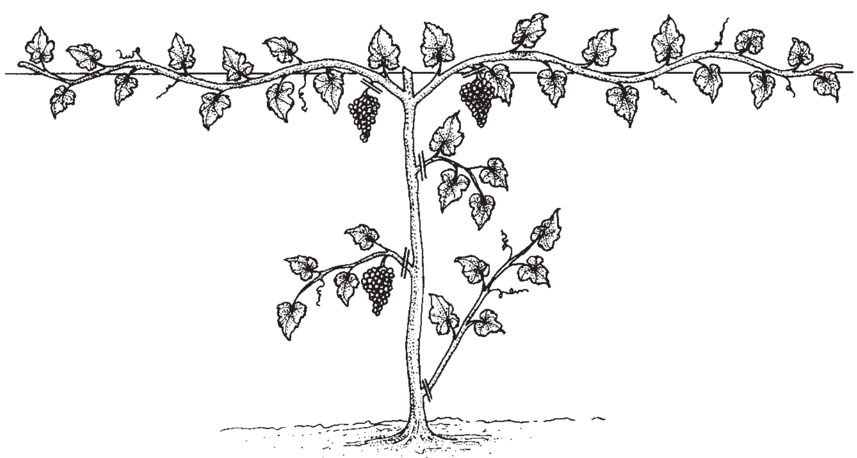
Spur pruning requires little or no decision about what to select for fruiting wood. Differences between cane and spur pruning begin in the third winter. Until then, prune the young vine as illustrated for cane pruning in Figure 7a through 7d.

In the third winter, cut selected canes along the cordon to two or three bud spurs as shown in Figure 8a and 8b. Fruit will be produced from buds on spurs. Spurs should be 4 to 6 inches apart. If

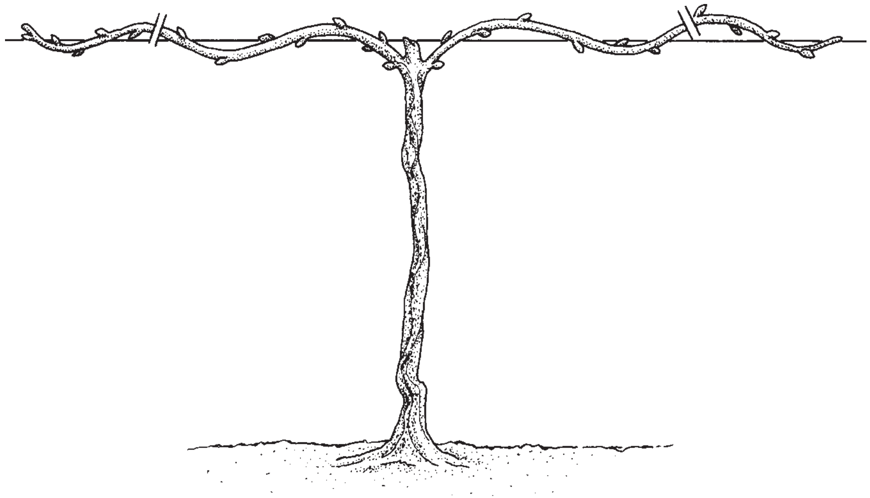
Figure 7.—Cane pruning.



(a) Cane pruning, first growing season.

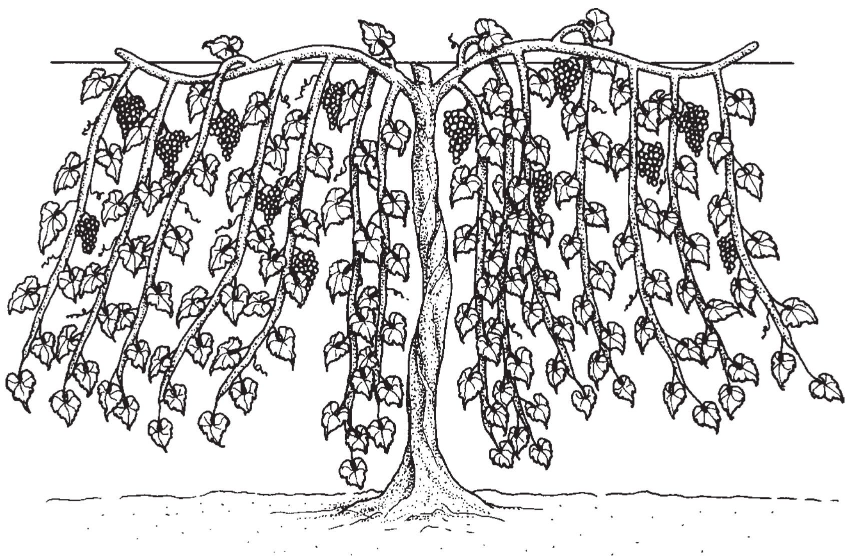


(b) Cane pruning, second growing season, Two-Arm Kniffen System. (Double lines show pruning cuts.)

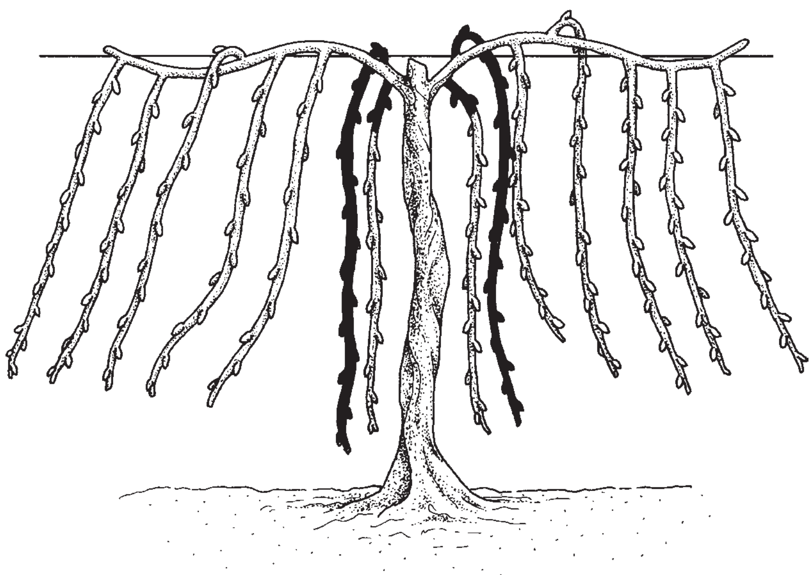


(c) Cane pruning, second winter. (Double lines show pruning cuts.)

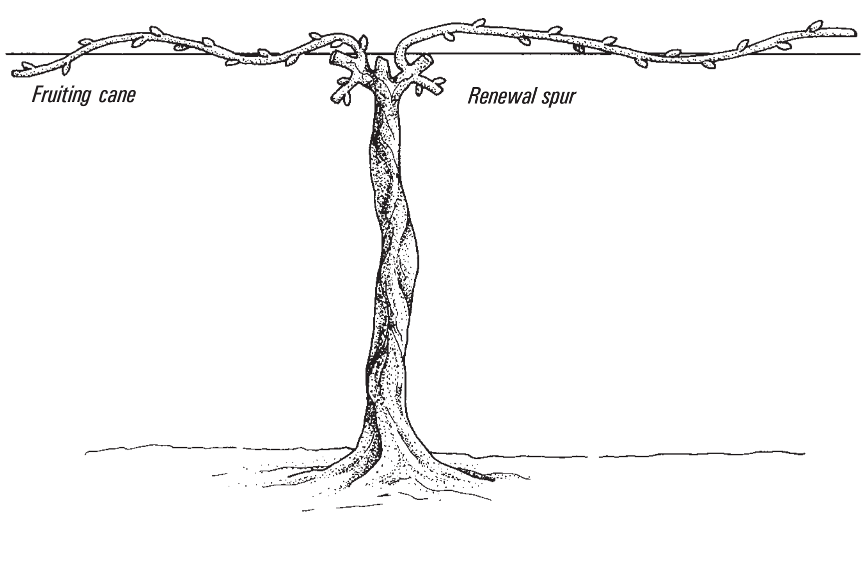
Figure 7.—Cane pruning (continued).



(d) Cane pruning, third growing season.



(e) Cane pruning, third winter before pruning. (Solid black canes will be retained for next season's fruiting wood.)



(f) Cane pruning, third winter after pruning.

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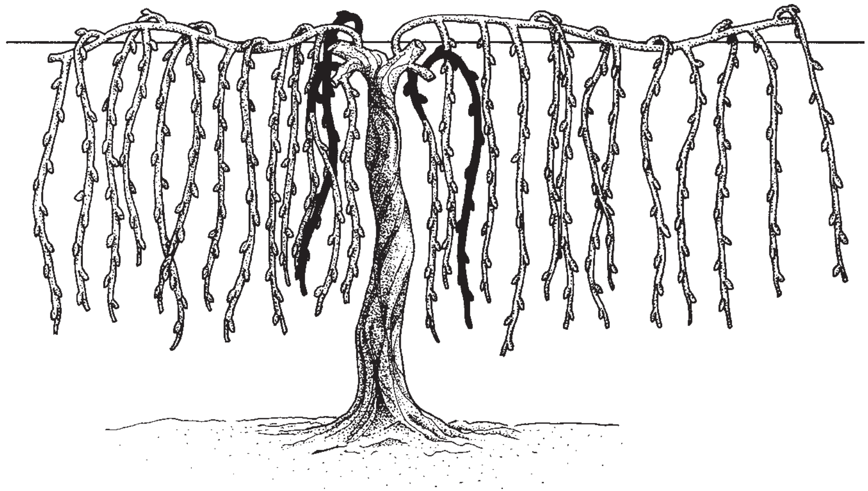
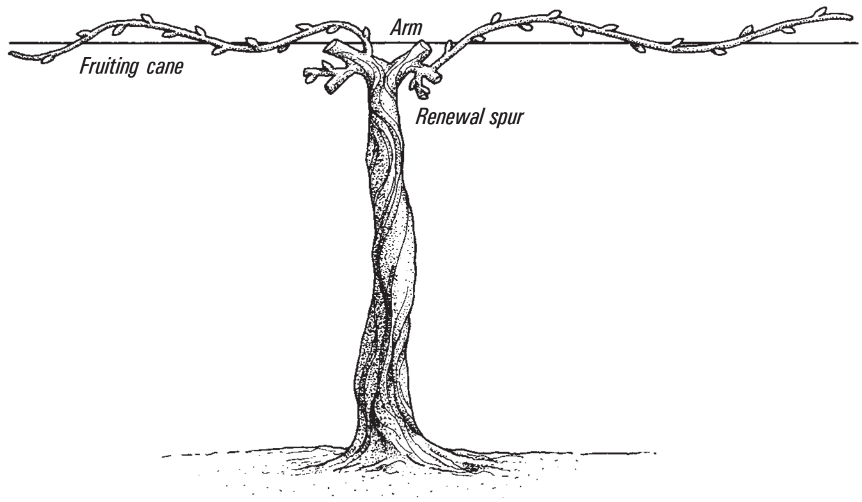


Figure 7.—Cane pruning (continued).

(g) Cane pruning, fourth winter before pruning. (Solid black canes will be retained for next season's fruiting wood.)



(h) Cane pruning, fourth winter after pruning.

more than one shoot grew from a node on the cordon, select the strongest one and cut off the others. Leave no more than 40 to 50 buds per plant. If plants are low in vigor, leave fewer buds.

Prune mature plants by selecting spurs, cutting them back to two or three buds, and removing all other canes as shown in Figure 8c and 8d. See *Growing Grapes in Minnesota*, *Northern Winework - Growing Grapes and Making Wine in Cold Climates*, and *Colorado Grape Growers' Guide* for more information.

Training

Grapevines can be trained in many ways. Some training systems require slight modifications to the trellis described earlier.

The *single curtain* system and *two-cane Kniffen* system (also called "Guyot" or vertical hedgerow) require pruning to two fruiting canes or *cordons*. This is the system used in Figures 7 and 8. It is easy to use and highly recommended for home gardeners in northern Wyoming growing hardy varieties such as "Valiant." Hardy wine grape growers in southern Wyoming may also find this system practical.

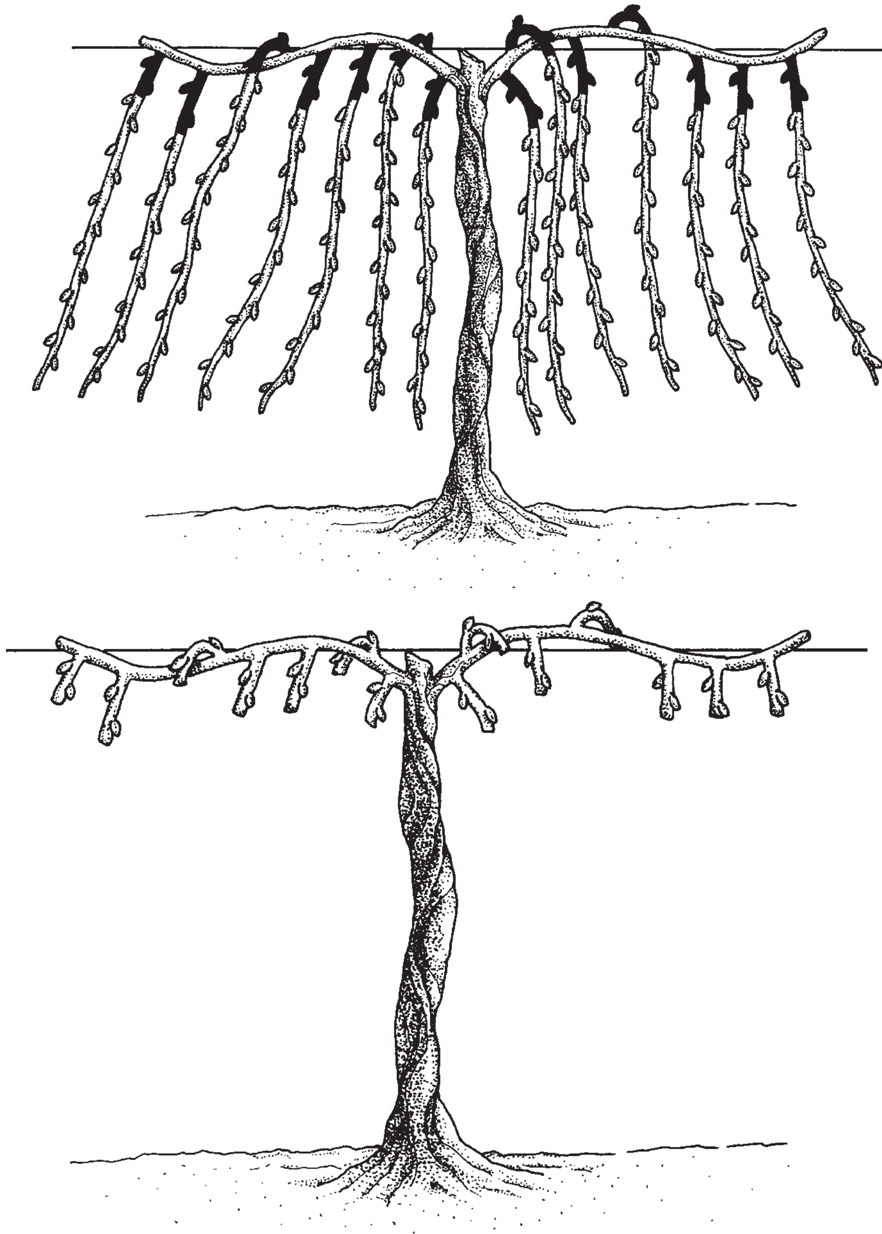


Figure 8.—Spur pruning.
(a) Spur pruning, third winter before pruning. (Solid black indicates fruiting spurs that will be retained for next season.)

(b) Spur pruning, third winter after pruning.

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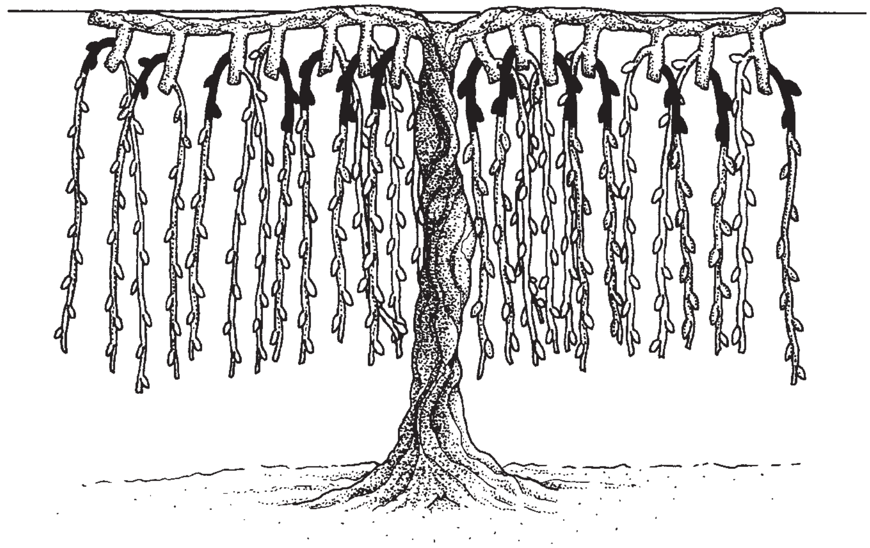
In the single curtain system, train the trunk to the top of a single-wire trellis. The shoots then grow and hang downward. Some fruit is well exposed at the top of the canopy, and some is shaded underneath.

In *head training* (Figure 9), tie the vine trunk to a stake when it is young. It will become self-supporting as it grows. This method is inexpensive and requires less space than other methods, but yields are lower.

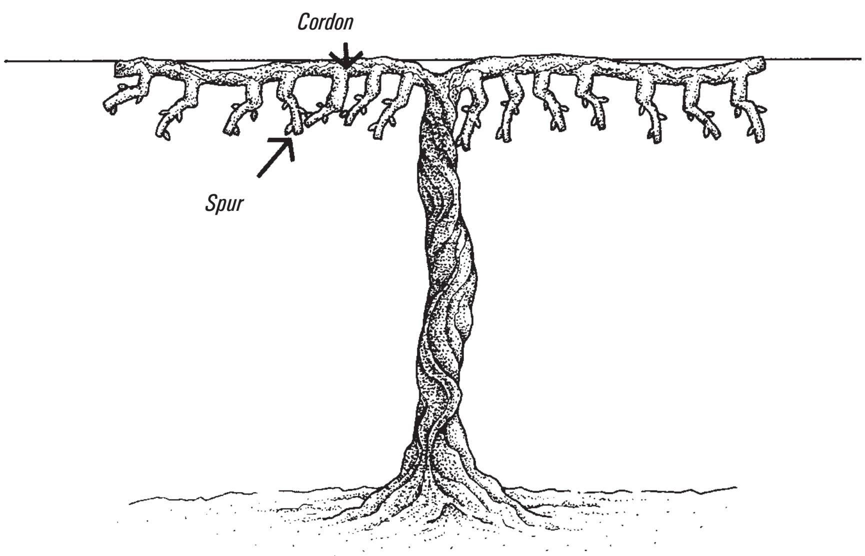
Grapes can be trained on walls, fences, and arbors. The plants make attractive ornamentals and provide shade. To train grapes onto an arbor, take the time to train a long trunk with fruiting canes spaced at suitable distances. This process takes several years. Prune the vine less severely so that the arbor is covered with foliage and fruit. Training several different-colored table grapes to an arbor is very attractive.

Figure 8.—Spur pruning (continued).

(c) Spur pruning, fourth winter before pruning. (Solid black indicates fruiting spurs that will be retained for next season.)



(d) Spur pruning, fourth winter after pruning.



Summer pruning

Usually 3 to 4 feet of growth per shoot is enough to ripen the crop. If plants become too vigorous, top or trim the shoots. This pruning will cause laterals to be produced; trim or hedge them as well. In addition, a minimal amount of leaf thinning around clusters in late July allows sunlight penetration and air movement, promoting faster and more even ripening of the berries in the cluster. Do not remove the leaf next to the cluster.

Fruit thinning

If grapevines are not pruned severely, a large number of small, scraggly bunches will be produced. This excess growth decreases vigor and can severely stunt young plants. If too many bunches are produced, thin to one or two bunches per shoot by removing clusters when the berries are no more than $^1/_8$ inch in diameter. Thinning also improves berry size. One can thin fruit clusters from

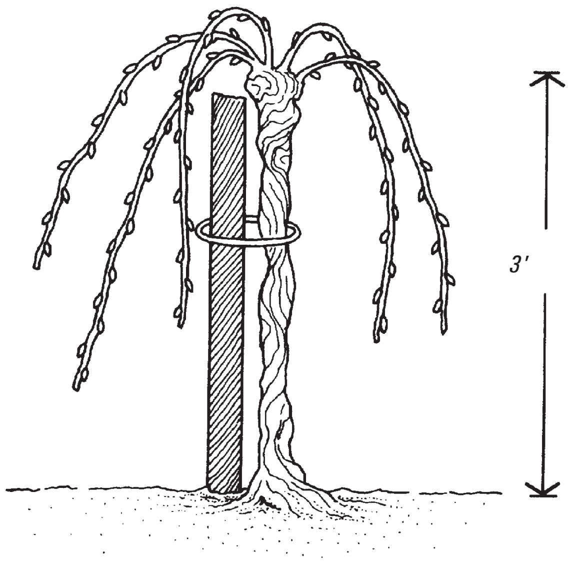


Figure 9.—A head-trained vine.

adequately pruned vines to improve berry size and promote earlier fruit maturation. Yields, however, will be lower.

Girdling

Girdling is an old practice that when done correctly may improve the size and appearance of table grapes. About two weeks before bloom, girdle by removing a ring of bark about $^1/_8$ to $^1/_4$ inch wide from each fruiting cane at the third internode. The girdle will heal by the end of the growing season. Girdling at the third internode allows the two basal shoots to support the root system and weakens the plant less than girdling at the bases of the canes. If there is uncertainty about the effects of girdling, practice on one cane.

Harvest

Usually a grapevine produces its first crop in the third year. By the fifth year, plants are mature.

The most important aspect of harvest is picking at the proper maturity. Fruit color is not a good indication of maturity. In table grapes, maturity is usually determined by taste or seed color, which changes from green to brown. All grapes become sweeter (and usually less acid) as they approach maturity.

In deciding when to harvest, consider the weather and its potential effects on fruit. Rain on mature fruit causes shattering, cracking, and increased fruit rot. Fruit also becomes more attractive to birds as it matures. In cool years, late-ripening varieties do not always ripen in some regions.

The average temperature must be greater than 50°F for grapes to continue to mature on the vine. Fruit does not ripen further once it is picked. Rain on mature fruit causes splitting. A Brix refractometer measures the sugar content of the fruit and is a valuable tool for harvesting grapes for making wine, jelly, or juice. Since grapes do not mature after being frosted or picked, earlier-maturing varieties should be selected, especially in northern Wyoming.

Pest and disease problems

The most important insect pest of grapes is grape phylloxera. There is no remedy for this root-feeding pest other than planting susceptible vines grafted to a resistant rootstock. Disease problems include powdery mildew (American types are more resistant), botrytis bunch rot, and crown gall.

See Chapter 13, *Diagnosing Problems*.

Deer and antelope may be problems for grapes, especially when they are just beginning to bud in the spring. Fencing, either electric or tall wire, works the best. Fishing line has also proven to be a cost-effective method.

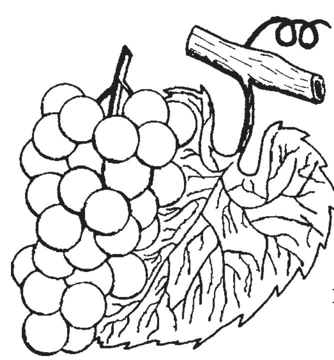


Table 6.—Spacing and yield of berry crops.

Crop	In-row spacing (feet)	Expect mature crop in year*	Yield (pounds/plant)	Yield (pounds/20-foot row)
Currant				
Black	4	4	4–8	20–40
Red	4	4	8–12	40–60
Gooseberry	4	4	8–14	40–70
Grapes, table	6	5	22–35	—
Raspberry				
Red, summer	2.5**	3	6–9	48–72
Red, fall	2**	3	3–4	30–40
Black	3	3	2–3.5	13–23
Strawberry	1.3**	2	1–2	16–32

*Expect lower yields for immature plantings; planting year = year 1.
**Form solid hedgerow or matted row.

Elderberries

There are many species of elderberries native to North America. The commercially grown species is *Sambucus canadensis.* All parts of the elderberry have been used at some time in medicine. The fruit can be used for juice, sauces, jelly, and wine. However, the roots, bark, and mature leaves of native *Sambucus racemosa* are considered poisonous to livestock.

Often, elderberries sold through nurseries are not distinguished by a cultivar name. Recommended cultivars include "Adam" and "York." Although these cultivars are partially self-fruitful, they will benefit from cross-pollination.

Elderberries prefer full sun and grow in a wide range of soil types—from quite wet to dry. Plants grow to a height of 12 feet.

Establish plants in the spring. Space them 5 to 6 feet apart in the row with 12 to 13 feet between rows. No fertilizer is needed in the planting year. Starting the second year, apply 1 ounce of actual nitrogen per year of plant age, up to a maximum of ½ pound per plant. Use a well-balanced fertilizer.

Elderberries produce large (umbel) fruiting clusters at the tip of the current season's growth. The most productive wood is 2 or 3 years old. When pruning, remove weak and damaged canes and leave equal numbers of 1, 2, and 3-year-old canes. Remove canes more than 3 years old. Leave a total of about nine canes per plant.

Full production of about 12 to 15 pounds of fruit per plant may be expected in three or four years. Fruit matures from mid August to mid September, depending on cultivar and growing location. Clusters ripen over a period of five to 15 days. Harvest the entire fruit cluster and quickly process or freeze. It's impossible to harvest individual fruits without losing too much juice.

Saskatoon berries

Saskatoons (*Amelanchier alnifolia*) are also known as juneberries, serviceberries, servisberries, and mountain blueberries. This species is native to North America. The plants are great ornamentals with attractive blossoms and good fall color. Fruit may be eaten fresh or used in pies, wine, jellies, jams, and syrup.

Recommended cultivars include "Pembina," "Northline," and "Smokey." Establish plants in the spring at a spacing of 6 to 8 feet. No fertilizer is needed in the planting year. Starting the second year, apply 1 ounce of actual nitrogen per year of plant age, up to a maximum of ½ pound per plant. Use a well-balanced fertilizer.

Plants bear fruit after two to four years (depending on the age of the plant at establishment), and full production occurs after seven to 11 years. Fruit is borne on the previous year's growth.

For more information

Colorado State University Cooperative Extension Service publication

Growing Small Fruit for the High Plains and Rocky Mountain West (Bulletin 561A)
Colorado Grape Growers Guide (Bulletin 550A)

Washington State University Cooperative Extension Service publications

Botrytis Bunch Rot of Grapes (EB1370)
Crown Gall of Grapes (EB0742)
Grape Phylloxera (EB1566)
Protecting Strawberries from Birds with Netting and Mylar Tape (EB1641)
Raspberry and Strawberry Root Rots in Home Gardens (EB1082)
Raspberry Crown Borer (EB0920)
Root Weevils on Berry Crops (EB0965)
Small Fruit Pests: Biology, Diagnosis, and Management (EB1388)
Small Fruits and Berries: Insect and Disease Control for Home Gardens (EB1015)
Vertebrate Pests of Grapes (PNW0220)
Weed Control in Strawberry (EB1808)

Oregon State University Cooperative Extension Service publications

Growing Grapes in Your Home Garden (EC 1305)
Growing Raspberries in Your Home Garden (EC 1306)
Growing Strawberries in Your Home Garden (EC 1307)

Other publications

Growing Grapes in Minnesota (Minnesota Grape Growers Association, Lake City, Minnesota, 1993). 64 pp.
Plocher, T. and B. Parke. *Northern Winework - Growing Grapes and Making Wine in Cold Climates.* (Northern Winework Inc., Stillwater, Minnesota, 2001). 178 pp.

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Fruit Trees

12

Growing tree fruits and/or nuts can provide a great deal of satisfaction, but it takes a commitment to care for trees year-round.

Orchard trees grow best in deep, well-drained soils. To have adequate room for root development, they need at least 4 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.

Because Wyoming has several climatic and geographic regions, consult a Cooperative Extension Service agent for specific recommendations on varieties, fertilizing, pest management, and other cultural practices.

Always remember that dwarf trees are the best choice for home orchards.

Planning

Variety selection

When planning an orchard, choose varieties that are hardy, disease resistant, and easy to care for. Generally, the more varieties of fruit grown, the more complex it is to manage them. However, if to enjoy a diversity of fruits and the challenge of managing them, by all means plant them.

Nearly all fruit tree varieties are grafted to a genetically different root system called a *rootstock*. When choosing a variety based on flavor, harvest period, disease resistance, color, etc., it is the grafted variety that is being selected 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 rating for a rootstock and grafted variety, one can determine how big a tree will grow. See Table 1 for vigor ratings for some apple varieties. See the section

Topics in this chapter

- Planning
  - Variety selection
  - Rootstock selection
  - Pollination
  - Tree spacing
- Planting and fertilizing
- Irrigating
- Fruit thinning
- Harvest and handling
- Insect and disease management
- Pruning

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on rootstocks to learn more about vigor of various rootstocks.

The lists in this chapter do not include all recommended varieties. There are thousands of apple varieties alone. The lists of other fruits could also be much longer. Consult the resources listed under "For more information" to learn about additional varieties.

Apples

General types of apples include old style, cider, English, and flavor varieties. 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 2).

An important part of an orchard pest management program should be the selection of disease-resistant varieties. Apple scab, fire blight, powdery mildew, and anthracnose are important diseases to consider when buying trees. To reduce their impact use disease-resistant varieties (Table 3). In most of Wyoming, apple scab and anthracnose are not serious problems except in very wet springs or microclimates with high humidity and excessive irrigation.

Other tree fruits

- Cherries—See Table 4.
- Pears—See Table 5.
- Plums—See Table 6.

Table 1.—Apple variety vigor ratings.

High vigor	Moderate vigor
Northern Spy	Cortland
	Jonagold (needs pollinator)
	Jonathan
	Liberty

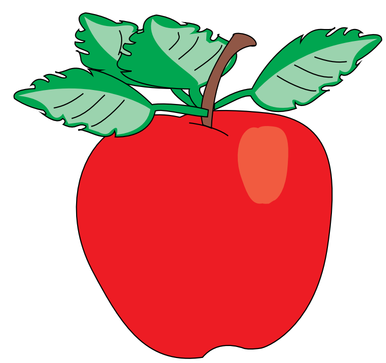


Table 2.—Apple varieties grouped by general time of maturity.

Early	Midseason	Late
Beacon	Cortland	Connell
Centennial	Honeycrisp	Fireside
Chestnut	Jonathan	Freedom
Duchess Red	Liberty	Goodland
Hazen	Macorn	Haralred
Heyer #12	McIntosh	Haralson
Lodi	Northern Lights	Honeycrisp
Norland	Prairie Spy	Honeygold
Patten Greening	Red Baron	Keepsake
State Fair	Sweet Sixteen	Northwest
Whitney	Wealthy	Northwest Greening
Yellow Transparent		Wolf River

Table 3—Apple variety disease resistance.

Scab resistant only	Fire-blight resistant	Cedar apple rust
Freedom	Fireside	Freedom
Jonagold (slight)	Freedom	Keepsake
Jonathan (slight)	Haralred	Northwest Greening
Liberty	Haralson (moderate)	Red Baron
Red Baron	Hazen (moderate)	Sweet Sixteen
Wealthy	Keepoahe (moderate)	Wealthy
	Northwest Greening	
	Red Baron	

Rootstock selection

When choosing a fruit tree, check to see what rootstock it uses. Rootstocks are not chosen for their fruit. Most were originally selected for their ability to control overall tree size. Some were selected for other characteristics such as:

- 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 offer the opportunity to select trees that grow to specific heights. The height may be anywhere from dwarf (4 to 8 feet) to semistandard (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 (Figure 1). Higher numbers don't represent taller trees.

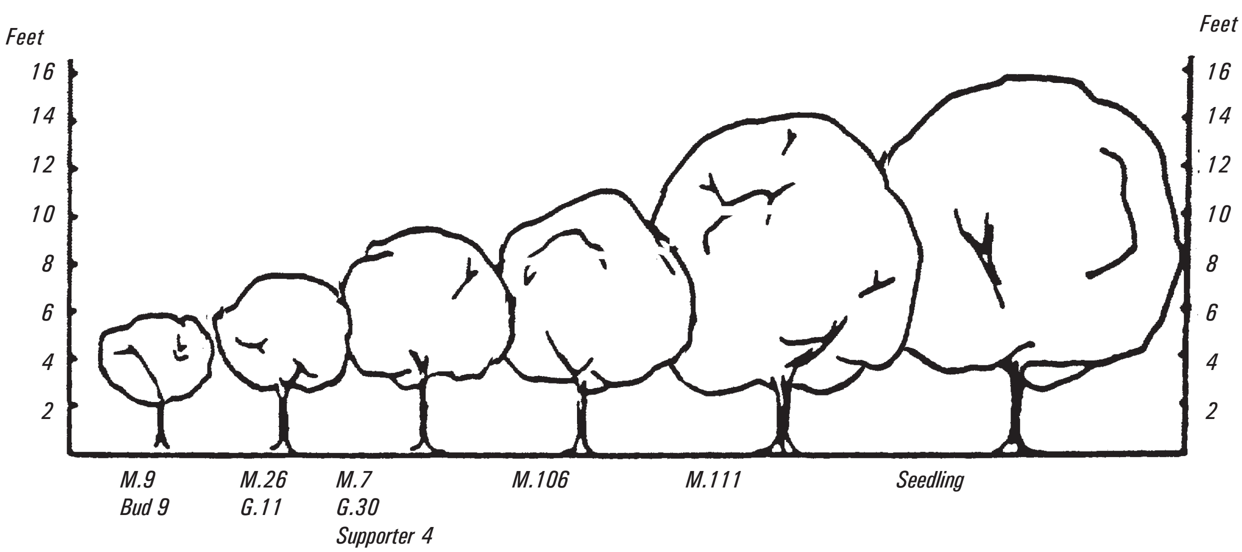


Figure 1.—Approximate size of mature trees grown on various rootstocks.

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, Geneva, New York.

The following list shows approximate sizes as a percentage of the size of a tree on seedling rootstock:

- MM.111: 90 percent
- MM.106: 60–75 percent
- M.7, G.30, Supporter 4: 55–65 percent
- M.26, G.11: 40–50 percent
- M.9, Bud 9: 25–35 percent
- M.27: less than 25 percent

Most home orchardists select dwarf rootstocks such as M.9 or M.26. Trees on these rootstocks should be supported by stakes, poles, or wires. Dwarf rootstocks are especially appropriate to train a tree to grow along a trellis.

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 do not require staking. However, some support might be required if early production is encouraged by training the trees.

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. Rootstocks that impart more vigor simply make it harder to contain trees to the height and width desired.

Cherries

Sour cherries are the only form of cherry tree that will survive in Wyoming. ‘Montmorency’ is one variety of cherry grown. Due to the potential for deer damage, all cherry trees need to be fenced for many years following planting. Out of all the fruit trees grown at the UW Sheridan Research and Extension Center, deer strongly prefer cherry trees over apple, plum, and pear trees.

Pears

Like apple trees in Wyoming, pear varieties need to be selected for fire-blight resistance. “Summercrisp” is a unique variety that is eaten when the fruit is still green and crisp (early fall). Allowing “Summercrisp” to ripen until the fruit becomes yellow results in a mushy overripe taste. All the pear varieties listed in Table 5 are standard-size trees.

Plums

Plums are produced on a wide variety of *Prunus* rootstocks such as plum and apricot (Table 6).

Pollination

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*). Examples of self-fruitful crops are tart (pie) cherries and most European plums.

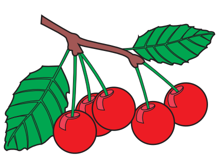


Table 4.—Sour cherry varieties.

Balaton	Black Tartan
Compass	Montmorency
Nanking	North Star
Red Diamond	

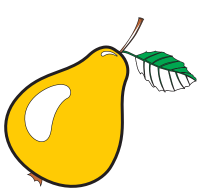


Table 5. Pear varieties.

Golden Spice	Parker
Luscious	Summer Crisp

Table 6. Plum varieties.

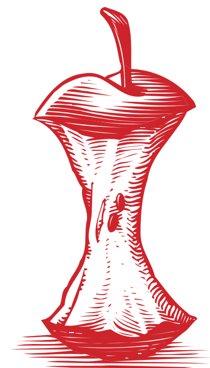
Pipestone
Pambina
Toka

Table 7.—Apple varieties grouped by general time of bloom.

Early	Midseason	Late
Beacon	Chestnut	Haralred
Centennial	Connell Red	Haralson
Duchess Red	Cortland	Keepsake
Hazen	Fireside	Macoun
Heyer #12	Freedom	Regent
Lodi	Honeycrisp	
Mantet	Honeygold	
Norland	Jonathan	
State Fair	McIntosh	
Wealthy	Northwest Greening	
Yellow Transparent	Prairie Spy	
	Red Baron	
	Sweet Sixteen	
	Whtney	
	Winesap	
	Wolf River	

Table 8. Good pollinators.

Chestnut
Most crab apples
Wealthy



Apples and pears are generally not self-fruitful. Two varieties should be used in each apple and pear planting to serve as a source of pollen for the other variety. Cross-pollination is possible only when varieties bloom at approximately the same time. Length of bloom is usually 7 to 15 days. Early bloomers should be planted with early or midseason bloomers, and late bloomers with late or midseason bloomers (Table 7 and 8). In an orchard planting, all trees should be within 100 feet of the pollinator tree. Wind does not carry pollen from one apple tree to another, but bees do. Consequently, bees are indispensable in an orchard. Use one good hive per acre.

Tree spacing

Spacing between rows for fruit trees ranges from 12 to 24 feet. Apple trees typically are spaced from 4 to 5 feet apart (high density) to more than 20 feet apart. Dwarf trees trained on trellises have the closest spacing. Other tree fruits are commonly spaced farther apart because they often lack growth-controlling rootstocks. True genetic dwarf trees can, of course, be planted closer.

In planning an orchard, compare the amount of space available to the number of trees wanted. 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.

Planting and fertilizing

Dig a hole large enough to comfortably accommodate a 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.

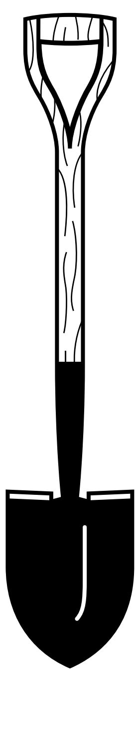
Fruit trees are usually sold bare-root. Place the roots over a low mound of soil in the center of the hole. It's very important to plant a tree at the right level. Try to plant the tree at the same level that it was growing in the nursery. Make sure the graft union is above ground; if it is not, the 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.

Paint, especially oil based, is not recommended for treatment of pruning cuts or to prevent sunscald. A better option to protect against sunscald and animal damage is to vertically split a 1.5' tall, 5 to 6" diameter perforated sewer pipe and place this around the tree as a collar. Remove suckers growing in the tube immediately as they serve as a breeding site for aphids and other pests. Tree wrap may also be used, but it should be removed during the growing season.

Protection from deer is important, and fencing is the best method. Caging also works. Hanging soap, human hair, animal scents, or other deer repellents can help prevent damage for a short time.

A tree's need for fertilizer varies according to the amount of available minerals in the soil. Soil types vary within a specific area as well as regionally across Wyoming. Consult local specialists for specific recommendations.

Fruit trees do need nitrogen in all regions. The amount needed varies from very little to 2 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. Over-application of nitrogen may cause excessive tree growth as well as physiological problems in the fruit such as bitter pit in apples.



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. However, if they are used each 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. Have a soil test done to determine if boron is needed.

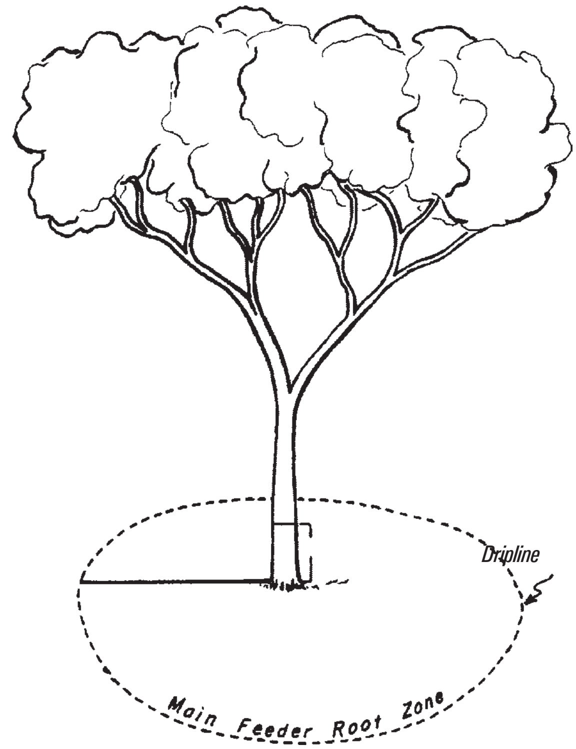


Figure 2.—Locating a tree's dripline.

Irrigating

The amount of water needed by fruit trees depends on rainfall and soil type. The best way to determine their needs is to check the soil moisture in the root zone. Test the soil at 12 and 24 inches deep.

To test soil moisture, remove some soil with a soil probe or shovel. Squeeze a handful of soil 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 a very undeveloped root system and cannot absorb much water at a time. Watering young trees regularly in warm weather is very helpful to get them off to a good start.

Drip irrigation is preferred by many orchardists because the foliage, flowers, and fruit remain dry—an important factor in disease prevention. Take care not to overwater, especially near the base of the trunk. Excessive moisture at the base can lead to crown rot and excess suckering.

Fruit thinning

Fruit thinning of apples and pears is a very important part of orchard management. It improves the size and quality of fruit and helps ensure an adequate crop the next year.

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. In commercial orchards, plant-growth regulators are sprayed onto apple and pear trees during and after bloom to thin the crop.

Timing

Early thinning of blossoms or fruit helps stimulate flower initiation for next year's crop, especially on cultivars that tend toward biennial bearing (bearing fruit every other year). Thinning removes some of the developing embryos that otherwise would produce flowering inhibitors.

Apples initiate flower buds for the following year's crop within 40 days of full bloom, so thinning has a positive effect on next year's bloom if done within this period. Pears form buds a little later, so they can be thinned within 60 days of full bloom.

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 while 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.

See Chapter 7, *Woody Plants*.

Sometime during the cell-division phase, cell enlargement begins. Enlargement continues throughout the growth of the fruit and is often positively influenced by fruit thinning. The effect is greatest on cultivars that tend to have a heavy fruit set. Determine the size of fruit wanted and thin accordingly.

How to thin

Home orchardists generally rely on thinning by hand. For apples, first remove the smaller fruit. The relative sizes of the fruit do not change throughout the season. The king bloom is the middle blossom or fruit in the cluster, and it always produces the largest fruit.

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, leaving every other spur without fruit helps ensure adequate return bloom. Leaving more than one fruit per spur is possible except on short-stemmed cultivars and red cultivars that color poorly. Fruits of short-stemmed varieties tend to push each other off the spur if there are two fruits per spur.

Asian pears must also be thinned. Each blossom cluster contains several flowers in a row. Save the fruit in the middle and remove the rest. Research has shown that this middle fruit is the roundest. By counting the flowers as they appear, starting from the base of the cluster, one can determine which fruit to remove. For example, if there are seven flowers, save the fourth fruit from the base of the cluster. Thin early to get large fruit. Depending on the tree's vigor, a gardener might experiment by leaving two fruits per spur and checking the fruit-size response.

Harvest and handling

See Chapter 2, *Soils and Fertilizers*.

Nursery catalogs, 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. Apples with codling moth damage drop about 1 to 1½ 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. Remember, fruit continues to ripen in cold storage, so pick fruit before it is ripe if it is to be stored.

Fruit changes color as it ripens. The *base color* or ground color is the color underneath the red striping or blush of apples, pears, and cherries. In most fruits, the fruit is ripening when the ground color turns from greenish to yellowish. The surface color may develop before the fruit is actually mature.

See Chapter 7, *Woody Plants*.

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 in decent condition.

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.

Insect and disease management

Many insect and disease problems can affect home orchards. One can control or prevent them by knowing the probability of such problems and by closely monitoring trees. Keep insects and diseases in check through a system called *integrated pest management* (IPM).

IPM integrates cultural, mechanical, chemical, and biological controls in addition to taking the environment into consideration. Successful IPM programs are based on solid research and practical experience.

One of the cornerstones of IPM is accurate pest monitoring. One can use visual inspection, trapping, and *phenology* (crop development stage) models to first determine the presence or absence of a pest and then to measure its population density. Figure 3 shows phenological stages of several tree fruits.

The IPM approach differs from a standard “calendar” approach in which control sprays are applied based on dates and developmental stages of the plant regardless of whether pests are present.

Economic thresholds—the level at which pest damage justifies the cost of control—are important in IPM. Of course, economics are not as important in home orchards as in commercial situations. Each orchardist decides how much damage to allow before applying a control. The level of acceptable damage can vary from one gardener to another.

Pheromones are chemical messengers used by animals to communicate with each other. They are sometimes called *ectohormones* (meaning outside hormones). Pheromones are used in IPM in various 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 a miticide to attract pests to the chemical control.

Learning the life cycles of important insects and diseases that may attack an orchard is part of an integrated pest management approach. The following section discusses some of the more common orchard insect pests and their IPM control strategies.

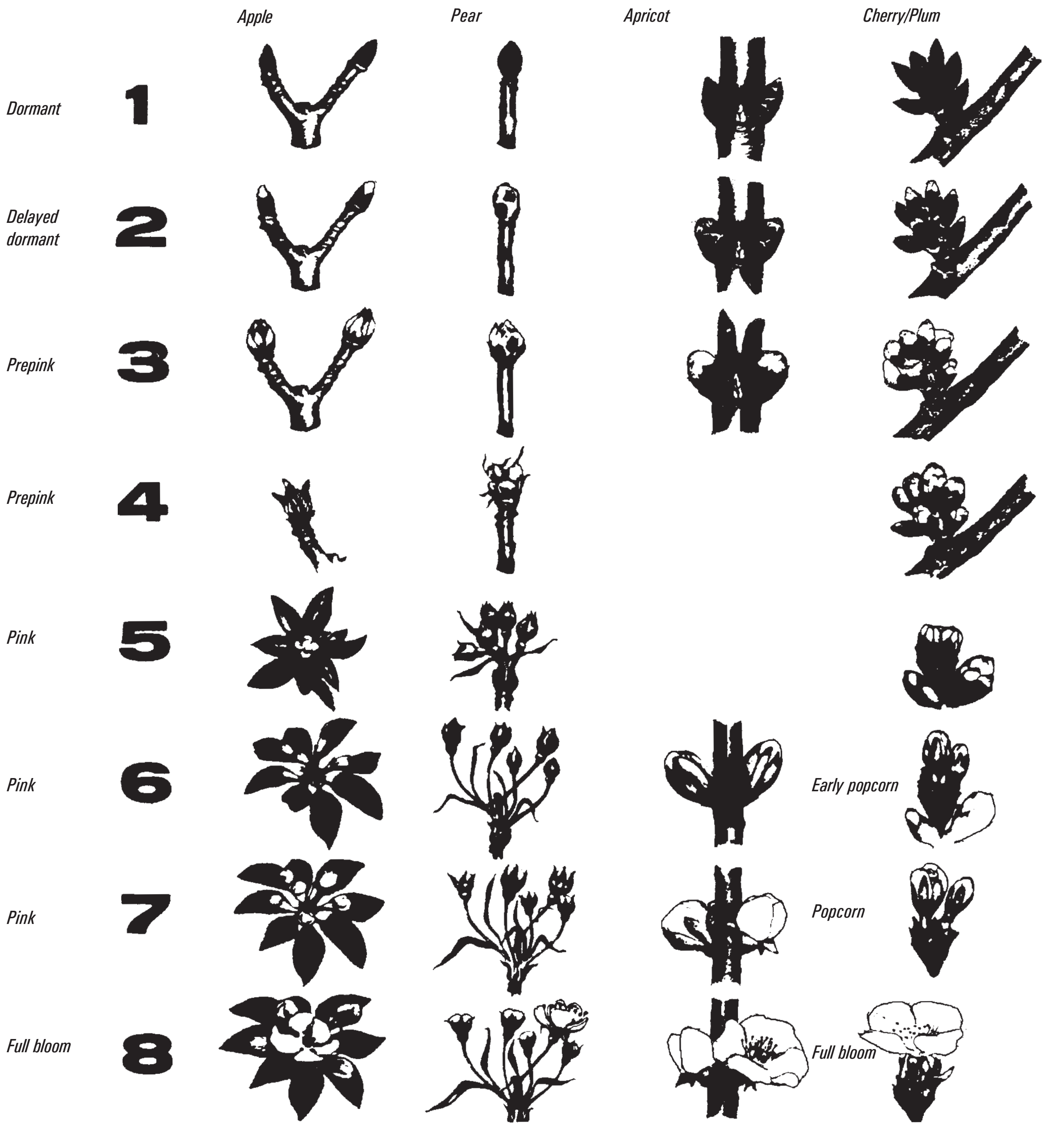


Figure 3.—Growth stages of tree fruits. Stages not shown include the calyx stage *(when about three-quarters of the blossoms have fallen but before the calyx closes over the end of the fruit) and the* first-cover stage *(about two weeks after petal fall).*

Codling moth

Life cycle

- Overwinters as a mature larva under loose bark on trees, in leaf litter under trees, or in other protected places.
- 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 for a month.
- Eggs hatch in 12 to 14 days, and larvae enter fruit.
- Larvae feed for about three weeks and 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 remain in fruit for a month and then emerge and look for overwintering sites.

See Chapter 3, *Entomology*, Chapter 4, *Disease*, Chapter 13, *Diagnosing Problems*, and Chapter 14, *IPM*.

Pheromone-trapping program

- 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 traps every four weeks.

Thresholds and control program

- After the first week, apply a control to catch two moths per trap for two weeks in a row.
- Cardboard tubes placed along the trunk during egg laying may induce the adults to lay their eggs in the tubes. The cardboard can then be disposed of to reduce moth populations for the following year.

The calendar approach to control

- For the first generation, spray 15 to 21 days after petal fall and again three weeks later.
- For the second generation, spray the first week in July and again three weeks later.

Apple maggot

Life cycle

- Overwinters as a pupa in the soil.
- Emerges as an adult from June through August. (A small percentage can carry over as pupae until the next year.)
- Begins egg laying seven days after emergence.
- Larvae hatch and feed in fruit for three to five weeks.
- One generation per year in Wyoming.

Trapping program and control

- Place Pherocon or Biolure traps in the orchard in late June. In larger orchards, place the traps every 150 feet around the border; in smaller ones, use one trap for every 10 trees. Remove all foliage within 1 foot of each trap.
- Monitor traps three times per week.
- Spray as soon as possible after the first fly capture. Repeat sprays at 7 to 14-day intervals. Sprays applied for codling moths in early and midseason also control apple maggots.

Using sprays for disease and insect control

Dormant (winter) sprays

Most home orchardists try to control overwintering mites, aphids, and scales with a dormant oil spray. The oil essentially smothers the pests. An even more effective approach to dormant-season control is to add an insecticide to the oil. The added insecticidal activity gives more thorough control.

Winter sprays are also used to control diseases that enter a 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.

Perhaps the most common disease that requires winter sprays is *Pseudomonas syringae*. This disease primarily affects cherries but can also infect prunes and apricots. It is also referred to as bacterial blight, bacterial gummosis, bacterial canker, and dead bud disease. Symptoms vary. The disease can kill leaf buds (hence the name dead bud disease), which causes a lot of dead wood in the tree. Branches, trunks, or entire trees can die back from cankers that destroy the vascular tissues carrying food and water throughout the tree. *Pseudomonas* also produces a *necrotic* (dead) spot on leaves.

Spray first for this disease in the fall before rains begin. Use fixed copper materials. A second spray is recommended as soon as possible after January 1.

Anthracnose is not prevalent in Wyoming due to the arid climate. However, in wet years the disease may develop. Its cankers cause limb or trunk dieback. The fungus destroys all of the tissue in a given area except the vascular tissues, giving cankers a "fiddle-string" appearance. It can also cause a form of fruit rot called bull's-eye rot. The disease continues to live and produce spores in dead tissue of cankers. Therefore, pruning out infected wood is an important part of controlling this disease.

For anthracnose on apples, spray fixed copper in the fall. Avoid spraying late-season yellow varieties before harvest because fruit may develop red spots around the lenticels (small openings that allow gas exchange between the internal tissues and the atmosphere).

Fire blight is a disease caused by a bacterium, *Erwinia amylovora*. This bacterium attacks mountain ash, apples, crabapples, pears, and other plants in the rose family. Infected trees can show symptoms on almost any above-ground part of the plants, with most typically visible on branch tips. Infected blossoms will look water soaked, turn brown to black, and then shrivel and die. Twigs affected by fire blight will often show a characteristic "shepherd's crook" where the ends curl back and leaves remain attached. The bacterium overwinters on cankers from the previous growing season, from which they are disseminated by rain splash, wind, and insects. Infection is favored by moisture, warm weather, and relative humidity above 60 percent. Problems with fire blight may be more noticeable after a hailstorm because the bacteria enter the wounds created by the hail.

One of the best management strategies is to plant resistant cultivars whenever possible. Also avoid overfertilization with nitrogen. Excess nitrogen can encourage excessive growth, which in turn favors fire blight.

Careful pruning of affected branches is a good way to remove diseased tissue to protect the remaining healthy tissue. Pruning also serves to reduce inoculum sources from which the pathogen can be disseminated. Using disinfested tools (a 10 percent solution of household bleach will work), prune branches 6 to 12 inches *below* the symptomatic area. Disinfect tools between cuts. Infected plant parts should be pruned out, bagged, removed from the site, and promptly destroyed.

See Chapter 16, *Pruning*.

There are few chemical options for managing fire blight. Streptomycin, an antibiotic, can be sprayed on a plant as a preventive before infection occurs in the spring. The bacterium can become resistant to streptomycin, however, so repeated use is not recommended. Copper sprays may inhibit the disease but must be applied before infection. Coppers can also be phytotoxic, damaging the trees. Timing is critical because chemical control measures must be in place before infection occurs.

Summer sprays

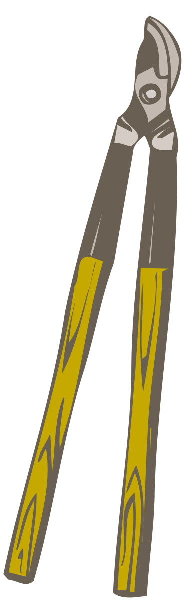
If an orchard has a mite, aphid, or scale problem, a winter dormant oil spray can reduce the pest populations. However, some summer control is often necessary.

In the case of scale insects, the timing for summer control is important. Apply the spray when the insects are in the crawler stage. At this time, the young scales move out from under their protective shells and are vulnerable to pesticides.

Look for these tiny insects in June. Place double-sided sticky tape around infested branches or smear Tanglefoot on them. These adhesives trap the crawlers so they can be seen with a hand lens (20 power is good). Spray when there is substantial insect activity.

Repeated applications of insecticidal soap will also work against aphid pests. Applications will need to be made every few days for control.

Ant control can be important in a home orchard because ants will “farm” aphids to harvest their nectar. They also prevent predatory insects from attacking the aphids. There are both inorganic and organic controls for ants. Flooding ant mounds with repeated applications of water will generally cause them to move to a more desirable location.



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 16. The discussion here only covers guidelines specific to pruning fruit trees.

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.

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:

- Plums 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*.
- Apples, apricots, sour cherries, pears, and plums (European and Japanese) produce fruit on *long-lived spurs*.

Good light penetration is necessary for fruit spur formation and productivity. Trees that fruit on spurs should be maintained in a fairly open form. Those that form their crop on 1-year-old wood benefit from pruning because it stimulates new wood formation (and more fruit).

Pruning guidelines

- Prune all fruit trees at planting time, but leave some lower branches for root growth. Take one lower level of branches off per year until the height is reached where the lowest branch is to grow.
- Prune young trees very lightly. Heavy pruning delays fruiting.
- Prune mature trees more heavily, especially if they have shown little growth.
- Prune the top portions of trees more heavily than the lower portions.
- Train young trees in the first few years after planting to avoid corrective pruning later. Bend main scaffolds to a 45° to 60° angle.
- To keep trees small, prune moderately every year and do not apply excess fertilizer, manure, or compost. (This point does not apply to dwarf trees.)
- Prune during the dormant season (after fall or early winter freezes but before full bloom in spring).
- When removing large limbs, first cut part way through from the underside about 6 inches out from the collar and 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

University of Wyoming Cooperative Extension Service publications

Iron Deficiency Chlorosis on Woody Landscape Plants in Wyoming (B-1097)

Washington State University Cooperative Extension Service publications

See Chapter 19, *Pesticides*.

Aphids in Apples (EB1075)
Apple Anthracnose (EB0940)
Apple Maggot (EB1603)
Apple Maggot Trap Placement (EB1320)
Apple Scab (EB1044)
Bacterial Canker of Prunus (EB1013)
Brown Rot of Stone Fruits (EB1047)
Cherry Fruit Flies (EB1068)
Cherry Leaf Mottle (EB0981)
Codling Moth Control: A New Tool for Timing Sprays (EB1072)
Cold Resistance of Stone Fruit Flower Buds (PNW0221)
Collar Rot of Pome and Stone Fruits (EB1497)
Coryneum Blight of Stone Fruits (EB1266)
Fire Blight (EB1352)
Grafting and Budding Plants to Propagate, Topwork, Repair (PNW0496)
Green Peach Aphid Control on Peach Trees (EB1067)
Insect and Mite Control in Home Orchard Tree Fruits and Nuts (EB0932)
Peach Leaf Curl (EB1046)
Peach Twig Borer (EB0931)
Pear Psylla Detection and Control (EB1230)
Pear Slug (EB1369)

Perennial Canker and Bull's Eye Rot of Apples (EB1517)
Powdery Mildew of Cherry (EB1539)
Selecting and Monitoring Pheromone Traps in Insect Pest Management (OREC1207)
Spotted Tentiform Leafminer (EB1238)
Storing Fruits and Vegetables (EB1326)
Using Horticultural Spray Oils to Control Orchard Pests (PNW0328)
Why Cherry Trees Die (EB0668)
Why Fruit Trees Fail to Bear (EB0838)
Wood Rots of Tree Fruits (EB1452)

Oregon State University extension publications

Controlling Diseases and Insects in Home Orchards (EC 631)
Picking and Storing Apples and Pears (FS 147)
Pruning to Restore an Old, Neglected Apple Tree (EC 1005)
Training and Pruning Your Home Orchard (PNW 400)

Other publications

Stebbins, L., and L. Walheim. *Western Fruit, Berries and Nuts* (H.P. Books, Portland, OR, 1981). 192 pp.
Westwood, M. *Temperate Zone Pomology* (Timber Press, Portland, OR, 1993). 523 pp.

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13

Diagnosing Plant Problems

Topics in this chapter

- Plant identification and appearance
- Damage patterns
- Development of damage over time
- Distinguishing among living causes of damage
- Distinguishing among nonliving causes of damage
- A step-by-step method of diagnosis
- Diagnostic key
  - Vegetables
  - Tree fruits
  - Berries and grapes
  - Ornamental trees and shrubs
  - Annual and perennial flowers

To determine what factors damaged a plant, one will need to systematically and carefully observe the plant, its environment, and other plants in the area and put all the pieces together to reconstruct the event(s) that produced the damage. An accurate diagnosis must be made before taking corrective action. Even if no corrective measures are available, it is satisfying to know what the problem is and what its future development might be.

Factors causing plant damage can be grouped into two major categories:

- *Living organisms* such as pathogens (fungi, bacteria, viruses, and nematodes) and pests (insects, mites, mollusks, mammals, and birds)
- *Nonliving factors* such as mechanical damage or injuries (e.g., breakage or abrasions), environmental conditions (e.g., extremes of temperature, light, moisture, or oxygen), and chemicals (e.g., herbicides or nutritional disorders).

Some pathogens, insects, and nonliving factors cause damage only if a plant is weakened by other primary factors. For example, borers generally attack only trees that are already suffering moisture or other physical stress.

The probability of correct diagnosis based on only one or two clues or symptoms is low. Completely different factors may cause similar symptoms on the same plant. Thus, the use of symptoms alone for diagnosis is frequently inadequate. However, symptoms often provide important clues about the affected plant part.

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By James L. Green, extension horticulture specialist, Oregon State University; Otis Maloy, extension plant pathologist, Washington State University; and Joseph Capizzi, extension entomologist emeritus, Oregon State University. Adapted for Wyoming by Karen L. Panter, Gary D. Franc, Kelli Belden, and Alex V. Latchininsky, Cooperative Extension Service specialists, University of Wyoming.

Diagnostics terminology

General

Bacterium—A single-celled microscopic organism having a cell wall but no chlorophyll. Reproduces by cell division.

Fungus—A plant organism that lacks chlorophyll, reproduces via spores, and usually has filamentous growth. Examples are molds, yeasts, and mushrooms.

Host—A plant afflicted with a disease or insect pest.

Nematode—A microscopic roundworm, usually living in the soil. Many feed on plant roots and can be disease pathogens.

Pathogen—Any organism that causes disease. Generally applied to bacteria, viruses, fungi, and nematodes.

Phytotoxic—Toxic to a plant (phyto = plant).

Sign—Direct evidence of a damaging factor (for example a pest or pathogen itself, secretions, insect webbing, chemical residues, records of weather extremes, or chemical applications).

Symptom—A change in a plant's growth or appearance in response to living or nonliving damaging factors.

Vector—A transmitter or carrier of disease.

Virus—An infectious agent too small to see with a compound microscope. Multiplies only in living cells.

Symptoms

Abscission—The dropping of leaves, flowers, or fruit by a plant.

Blight—Rapid, extensive discoloration, wilting, and death of plant tissue.

Blotch—A blot or spot (usually superficial and irregular in shape and size) on leaves, shoots, or fruit.

Canker—A dead place on the bark and cortex of twigs, stems, or trunks; often discolored and either raised or sunken.

Catfacing—Disfigurement or malformation of a fruit. Fruits typically affected include tomatoes and strawberries.

Chlorosis—An abnormal yellowish-white or gray color of plant parts resulting from the incomplete destruction of chlorophyll.

Defoliation—The unnatural loss of a plant's leaves, generally to the detriment of the plant's health. Can be caused by high wind, excess heat, drought, frost, chemicals, insects, or disease.

Desiccation—Drying out of plant tissue.

Dieback—Progressive death of shoots, branches, or roots, generally starting at the tips.

Dwarfing—The underdevelopment of any plant organ.

Enation—Epidermal outgrowths on leaves or stems.

Epinasty—An abnormal downward-curving growth or movement of a leaf, leaf part, or stem.

Etiolation—Yellow, long, spindly growth resulting from insufficient light.

Fasciation—A distortion of a plant that results in thin, flattened, and sometimes curved shoots.

Flagging—The wilting and/or death of plant parts, usually starting from the tip(s) of one or a few branches or stems.

Gall—An abnormal, localized swelling on leaf, stem, or root tissue.

Mosaic—Nonuniform foliage coloration with a more or less distinct intermingling of normal green and light green or yellowish patches.

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Diagnostics terminology (continued)

Mottle—An irregular pattern of light and dark areas.

Necrosis—The death of plant tissue.

Phyllody—A change from normal flower structures to leafy structures.

Rot—The decomposition and destruction of tissue.

Rugose—Wrinkled.

Russet—Yellowish-brown or reddish-brown scar tissue on a fruit's surface.

Scab—A crust-like disease lesion.

Stippling—Small, light green, or chlorotic specks.

Water-soaked—Lesions that appear wet and dark and are usually sunken and/or translucent.

Wilt—Lack of turgor and the drooping of leaves from lack of water.

Witches' broom—The abnormal brush-like development of many weak shoots.

Signs

Bacterial slime—A gooey or dried mass of bacterial cells that oozes out of plant tissues.

Conk—A fungal fruiting structure (e.g., shelf or bracket fungi) formed on rotting woody plants.

Cyst—The swollen, egg-containing female body of certain nematodes; can be seen on the outside of infected roots.

Frass—Sawdust-like material associated with insects chewing into plant tissues.

Fruiting body—A fungal structure that contains or bears spores.

Girdling—The cutting, removing, or clamping of bark all the way around a trunk or branch, sometimes caused by insect feeding.

Honeydew—A sticky substance excreted by aphids and some other insects.

Mycelia—Masses of fungal threads (hyphae), which compose the vegetative body of a fungus.

In diagnosing plant damage, one can follow a series of deductive steps to gather information and clues from the big, general situation down to an individual plant or plant part. Through this systematic process, one can determine the most probable cause of the damage.

The first steps are to identify the plant and the problem and then attempt to distinguish between living and nonliving damaging factors based on observed damage patterns, the development of patterns over time, and other diagnostic clues. Once the probable causes of the damage have been limited, one can obtain further information to confirm the diagnosis from reference books, plant pathologists, entomologists, horticulturists, and/or laboratory analyses.

These diagnostic steps are described in detail below.

Plant identification and appearance

See Chapter 18, *Plant Identification*.

First, determine whether a real problem exists. It is essential to identify a plant (genus, species, and cultivar or variety) to know what it should look like. Use personal knowledge or plant reference books or consult experts.

If possible, compare the damaged plant with a healthy or normal plant of the same species and variety. Normal plant parts or seasonal changes are sometimes mistakenly assumed to be evidence of disease. For example:

- The "Sunburst" honeylocust might seem to be suffering from a nutrient deficiency because of its chlorotic yellow-green leaf color. However, it was selected for this genetic characteristic, and the color is normal.

- The brown, spore-producing bodies on the lower surface of fern leaves are a fern's normal propagative organs, not disease spores or insects.
- The small, brown, club-like tips that develop on arborvitae foliage in early spring are male flowers, not deformed shoots.
- Small galls on the roots of legumes such as beans and peas are most likely nitrogen-fixing nodules essential to normal development, not symptoms of root-knot nematode infection.
- The leaves of some plants are covered by conspicuous, fuzzy epidermal hairs. They are sometimes thought to be evidence of disease, but they are a normal part of the leaf.
- Some plants have variegated foliage that may resemble the symptoms of viral diseases.
- Premature leaf or needle drop by evergreen plants (e.g., pines) frequently causes alarm. These plants normally retain their leaves or needles for three to six years and gradually lose the oldest ones during each growing season (Figure 1a). This normal leaf drop is obscured by the production of new leaves.

  However, prolonged drought or other stress may cause a whole tree to temporarily turn yellow and may accelerate leaf loss. There is no reason for concern in this case. The leaves that drop or turn yellow are the oldest ones, and their dropping protects the tree by reducing water loss.

  If new leaves drop, however, there probably is a problem (Figure 1b). The cause may be a pathogen, insect, chemical deficiency, toxicity, or root problem.

In describing a plant abnormality, distinguish between symptoms and signs. *Symptoms* are changes in a plant's growth or appearance (like galls, blotches, or wilting) in response to living or nonliving damaging factors. Many factors produce the same symptoms, so symptoms often do not produce a definitive diagnosis. For example, inadequate soil moisture or roots destroyed by a root-rotting fungus or a root-feeding insect all might result in a wilting symptom. Additional diagnostics work would be required to determine the true cause of the wilt.

Signs are direct evidence of the damaging factor (for example, the pest or pathogen itself, secretions, chemical residues, or records of weather extremes). A combination of signs and symptoms is more likely to produce a definitive diagnosis than are symptoms alone.

Examine the entire plant. In defining a plant problem, it is essential to determine the real primary problem. The plant part exhibiting obvious symptoms may not be

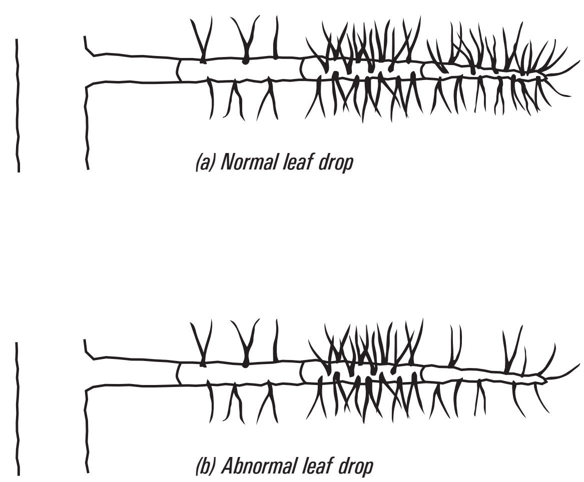


Figure 1.—Normal versus abnormal needle or leaf drop from evergreens: (a) If drop is confined to older leaves, it is normal. (b) If newly produced leaves are lost, there is a problem.

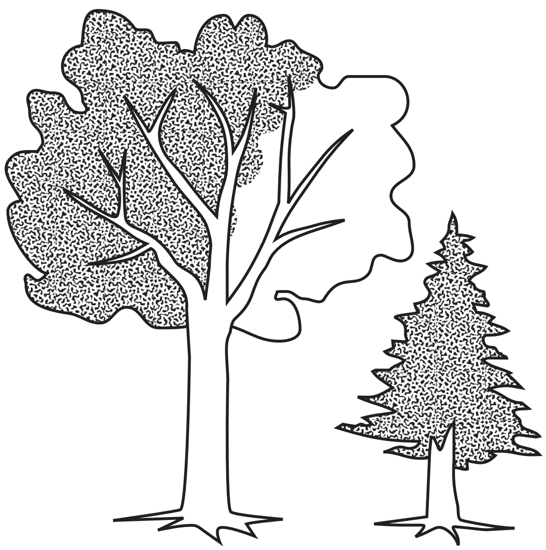


Figure 2.—If all or a major portion of a tree or shrub dies, suspect a root problem.

the part experiencing damage. For example, some root problems cause foliage symptoms. In this case, the primary problem is damage to roots, not foliage.

In general, if the entire top of a plant or entire branches look abnormal, examine the plant downward to find the primary damage (Figure 2). Look for the factor causing the damage at the edge of the symptomatic area. If possible and practical, examine the roots.

Damage patterns

Here is where one can start making the distinction between living and nonliving causes of plant damage. Damage patterns are excellent diagnostic clues.

Nonuniform or random damage (living factors)

With problems caused by living organisms such as pathogens or insects, there is usually no uniform pattern of damage. Damage may appear randomly on parts of a plant or on some plants in a group.

If scattered damage occurs in the plant canopy, suspect a problem in the foliage

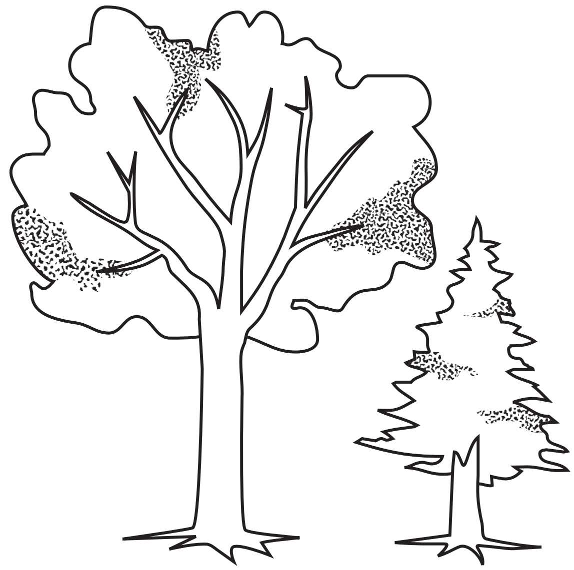


Figure 3.—Nonuniform damage patterns on a tree canopy.

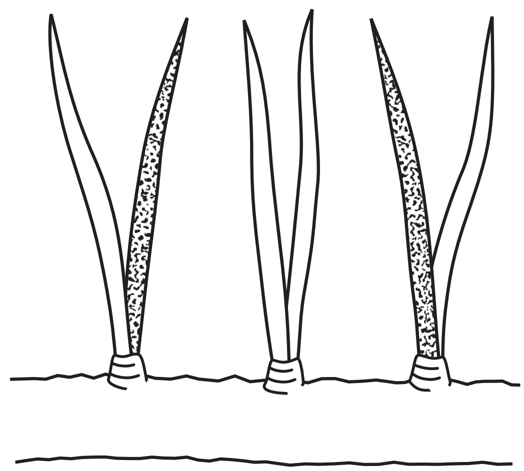


Figure 4.—Random, scattered damage on conifer needles.

or aerial environment, not the roots (Figure 3). If scattered branches gradually decline and eventually die, suspect a canker pathogen, shoot blight, or borers. Verticillium wilt, on the other hand, is characteristically one sided on a tree or shrub and can develop relatively quickly—in a month or so on some species.

Similarly, living organisms usually damage leaves or needles in a random pattern (Figure 4). For example, conifer needles are usually affected over varying lengths and often appear straw yellow or light tan. Black fruiting fungal bodies may be present on diseased needles. Often damage appears first on lower and inner parts of the canopy where humidity is higher and then progresses upward and outward.

With living damaging factors, there may not be a sharp line between affected and healthy tissues. Bacterial shoot blight is an exception, however. With this disease, the margin between affected and healthy tissue is often irregular and sunken. Bacterial shoot blight usually causes the shoot tip to wilt and bend over.

With fungal shoot dieback, there may be small, pin-like projections or bumps over the surface of dead bark (Figure 5). These structures are the spore-producing parts of the fungi. Note, however, that small, woody bumps normally radiate from all sides of spruce twigs where old needles were attached.

Uniform damage (nonliving factors)

Damage patterns produced by nonliving factors such as frost or toxic chemicals are generally more regular. For example:

- Damage may appear on all leaves of a certain age (e.g., those forming the plant canopy when a toxic spray is applied).
- Damage may affect all leaves with a certain exposure (e.g., those on the southwest side of a plant that are not shaded by other leaves).
- Damage will likely appear on more than one type or species of plant. Look for similar damage patterns on weeds, neighboring plants, etc.

Air pollutants frequently cause tip burn on conifers as do certain soil-applied herbicides and excess fertilizer (Figure 6). Freezing may have a similar effect. All needles at a specific growth stage are usually affected, and usually the same length on each needle is affected. Affected tissue is usually reddish brown, and the margin between it and healthy tissue is sharp.

Damage caused by nonliving factors usually results in a sharp margin or edge between affected and healthy tissue. If bark and wood are cracked, suspect winter injury (Figure 7). In this case die-

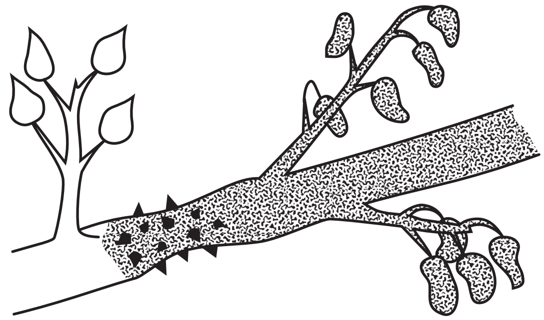


Figure 5.—Shoot dieback caused by a fungal infection.

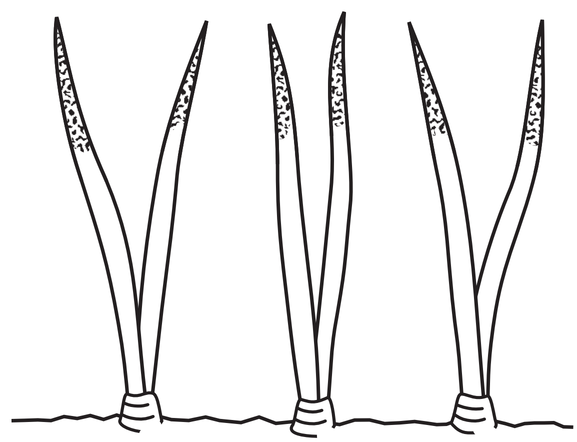


Figure 6.—Uniform death of needle tips.

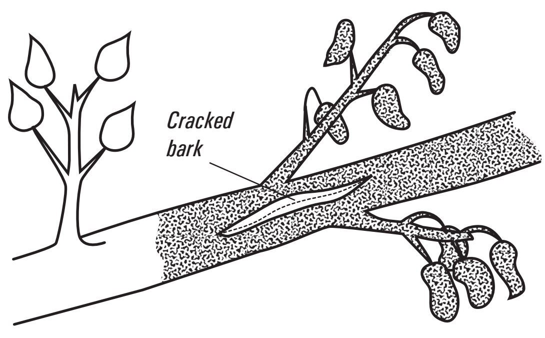


Figure 7.—Shoot dieback caused by winter injury.

back is often gradual rather than sudden unlike damage caused by most other nonliving factors (see the following section).

Development of damage over time

Another clue for distinguishing between living and nonliving factors is to observe the development of the pattern over time.

Sudden decline (nonliving factors)

Sudden decline is generally caused by a nonliving factor such as a toxic chemical or extreme weather. These factors cause damage at a specific time rather than progressively. For example, all affected leaves might die immediately after a phytotoxic chemical application. If branches die suddenly, especially if affected branches are concentrated on one side of the plant, suspect weather, animal damage, or chemical drift.

If a nonliving damaging factor is not removed, damage will intensify. For example, if a toxic chemical remains in the soil or air, plant damage within the contaminated area will continue to develop. Damage will not spread to uncontaminated areas, however.

Sudden decline can be associated with living factors when a plant is weakened by disease or insects and then subjected to an otherwise survivable stress (e.g., Phytophthora root rot followed by a normal summer drought period).

Gradual decline (living factors)

The gradual decline of an entire plant or a major portion of it is usually caused by a living factor such as Armillaria root rot, Verticillium wilt, or root weevils. However, it also can result from marginally survivable conditions such as nutrient-deficient soil.

Living organisms multiply and grow with time; therefore, they rarely afflict all of the host plant or plants at one time. Damage generally appears first on one part of a plant and then spreads. Likewise, it progresses from plant to plant. For example, gradual shoot decline with retention of dead leaves usually indicates damage by a living factor.

Distinguishing among living causes of damage

To identify which type of living factor damaged a plant, closely examine symptoms and signs. Symptoms are the modified appearance of the affected plant—for example necrotic tissues, chlorosis, cankers, galls, or leaf distortion. Signs are direct evidence of an actual organism. Examples include insects, fungal mycelia, spores, egg masses, insect frass, mite webbing, etc. Signs can be clues for identifying the specific organism that produced the damage. A combination of both symptoms and signs is preferred for a definitive diagnosis of disease and insect/mite damage.

See Chapter 4, *Disease*.

Symptoms and signs of disease

Differentiating between bacterial and fungal pathogens, especially those that cause leaf spots, is not always clear cut, but certain symptoms are distinctive. Table 1 lists key distinguishing characteristics of fungal and bacterial leaf spots.

Fungal diseases

The best clue to a fungal disease is the presence of fungal mycelia and fruiting bodies. Fruiting bodies range in size from microscopic to easily detectable with the naked eye. They are found within the leaf spot or stem rot area on an infected plant. Each type of fungus has its own morphological characteristic structures which are used by plant pathologists for identification.

Fungal leaf spots and stem rots are characterized by various symptoms: dry texture, concentric rings, and discoloration. Spots generally have distinct margins. They vary in size and are usually round and occasionally elongated (Figure 8).

Concentric rings result as the mycelium grows outward from the point of initial infection (much like crocheting a doily). Leaf color ranges from tan (died first) in the center to darker brown (recently dead) to very dark. The outer ring may have a light yellow chlorotic edge where the infection is advancing. Margins of fungal leaf spots and stem rots can be brightly discolored.

Table 1.—Symptoms and signs of fungal and bacterial leaf spots.

Abnormality	Fungal	Bacterial
Water soaking	Not common	Common with the rotting of thick and succulent leaves and with the initial appearance of angular leaf spots
Texture	Usually dry; may be papery	Some dry, some slimy to sticky; may be papery when dry
Odor	Usually none	Usually none. Foul (putrid to earthy, acrid) odor usually associated with the rotting of fleshy plant parts
Pattern	Irregular to circular; may have concentric rings; dark lesion margins	Irregular to angular; often restricted by large veins
Disintegration	Uncommon	Common with rotting
Color changes	Common: red, yellow, purple halos; dark lesion margins	Less common, but may have irregular, yellow halos
Pathogen structures	Common: mycelia, spores, spore structures	Wet or dried slime at the edge of canker or leaf spot

Bacterial diseases

Bacteria enter plant tissues through wounds or natural openings in leaves, stems, roots, or fruit. Once they enter a plant, they reproduce rapidly and may release enzymes and toxins that kill plant cells.

Bacterial galls

Crown gall bacteria genetically engineer their host plant to make galls and amino acids, thus giving the bacteria a place to live and the chemicals they need to grow and reproduce. The galls are characterized by hard, unspecialized plant cells. When young, galls resemble a head of cauliflower, but they harden with age.

Bacterial leaf spot

These bacteria usually enter through leaf stomata. A common symptom is a water-soaked appearance. Holding an infected leaf to light usually reveals the

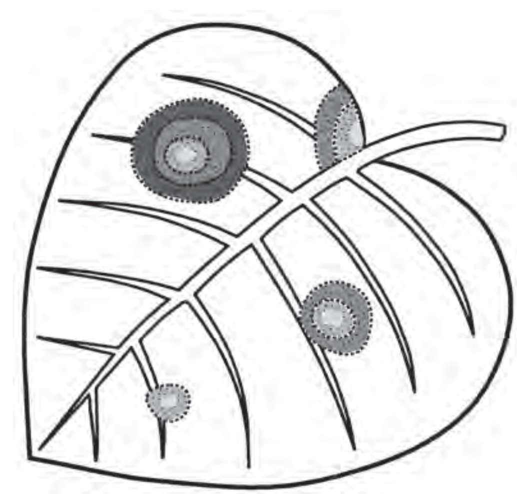


Figure 8.—Fungal leaf spots.

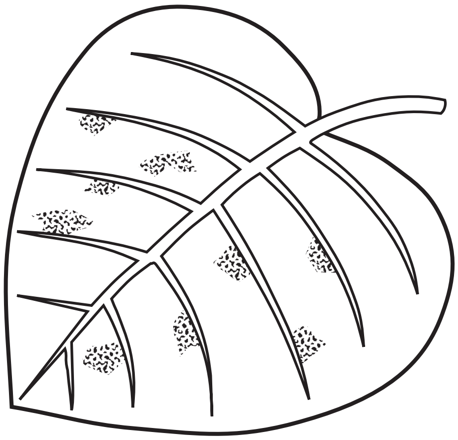


Figure 9.—Bacterial leaf spots.

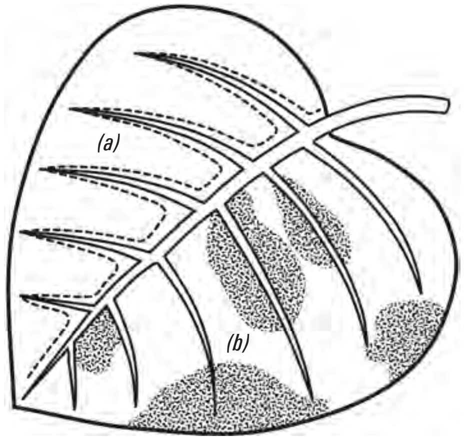


Figure 10.—Typical signs of viral infection: (a) vein banding; (b) mosaic.

water soaking. The tissue may become translucent, papery, and tan when dry.

Initially, bacterial leaf spot symptoms are confined between leaf veins, resulting in discrete, angular spots with straight sides (Figure 9). Many bacterial leaf spots such as Xanthomonas leaf spot on philodendron (also called red edge disease) expand until they reach a large leaf vein. The vein frequently inhibits the bacteria from spreading farther.

The color of bacterial leaf spots is usually uniform although a chlorotic halo often surrounds a spot. Spots may enlarge and coalesce. In the final stages, cracks may form in the plant tissue, and disintegration follows. Some lesions exude bacteria-filled fluid.

A few bacterial leaf blights, particularly on thick or spongy-textured leaves, are slimy and may have a rotten odor.

Vascular wilt

In some cases, bacteria plug a plant's vascular water-conducting tissue. The result is yellowing, wilting, browning, and the death of leaves, stems, and roots.

Viral diseases

Viruses are submicroscopic entities that infect individual plant cells. Viruses are *obligate parasites*; they can replicate only within a host's cell. As a virus proliferates, it moves on to infect other cells.

Because a virus commandeers its host cell to manufacture viruses identical to itself, the cell is unable to function and grow normally. Chlorophyll production may cease, causing chlorosis or necrosis. In some cases, cells may grow and divide rapidly; in others, they may grow very slowly or stop dividing, causing distortion or stunting.

The symptoms of most viral diseases fall into four categories:

- *Lack of chlorophyll in normally green organs—Vein clearing* in which veins look somewhat translucent or transparent but interveinal tissue remains green is a common first symptom of some viral diseases. In *vein banding* a dark green, light green, or yellow band of tissue appears along the veins (Figure 10a). In contrast, when leaf veins remain green and interveinal tissue becomes chlorotic, the cause may be the deficiency of a nutrient such as iron. Virus-infected foliage may also be mottled green and yellow, mosaic, ringed, or a rather uniform yellow (Figure 10b).
- *Stunting or other growth inhibition*—As chlorophyll is lost, reduced photosynthesis leads to shorter internodes,

smaller leaves and blossoms, and lower yields.
- *Distortions*—Strangely formed leaves and flowers, witches' brooms, or rosettes result from nonuniform or uncontrolled growth.
- *Necrotic areas or lesions*—Viruses require their host's survival for their own procreation. Thus, they rarely cause death, and necrosis is usually confined to discrete areas of the plant.

These symptoms can be valuable clues for virus identification but are easily confused with symptoms of nutritional disorders, chemical injury, or damage caused by mites or insects. However, virus-infected plants may be next to healthy plants, unlike the pattern seen with nutritional disorders or chemical injury.

In addition, because of their extremely small size, viruses are not visible to the unaided eye. Virus particles are detectable only through an electron microscope or with special stains and a compound microscope. For this reason, laboratory tests are frequently required to confirm a viral diagnosis.

Viruses are transmitted from plant to plant by insects, mites, fungi, nematodes, rubbing, abrasion, grafting, or other mechanical means. They are occasionally transmitted in seed.

Nematodes

Nematodes are microscopic roundworms that damage plant tissues as they feed. Many feed on or in root tissues. A few feed on foliage or other aboveground organs.

Root nematodes

Aboveground symptoms caused by root-infesting nematodes result from damaged root systems. Moisture and nutrient stress and general stunting are common. Root-lesion nematodes (*Pratylenchus* spp.) and burrowing nematodes (*Radopholus similis*) destroy root tissues as they feed. Root-knot nematodes (*Meloidogyne* spp.) inject growth-regulating substances into root tissues, stimulating the growth of large, tender cells that become permanent feeding sites. As root tissues grow around these sites, they form visible swollen galls or knots. Other root nematodes stunt growth, apparently by killing root meristems.

Shoot nematodes (Aphelenchoides spp.)

Shoot (foliar) nematodes feed inside leaves between major veins, causing chlorosis and necrosis.The tissue first collapses in wedge-shaped areas between the larger veins and then changes color. Injury is most often seen at the base of older foliage.

Symptoms and signs of insect pests

See Chapter 3, *Entomology*.

The location and type of feeding damage are the most important clues in identifying an insect pest. Knowing an insect's life cycle (complete or simple metamorphosis) is also important when attempting to identify an insect or design a control program.

Feeding habits

Insects can be distinguished by their method of feeding: chewing/rasping or sucking.

Use the following clues to determine the cause of chewing/rasping damage:
- If the entire leaf blade is consumed and only the tough midvein remains, the culprit may be caterpillars, canker worms, or webworms.
- Distinct portions of the leaf may be missing. Black vine weevil adults cut distinct notches from leaf margins, leafcutter bees cut circular holes from margins, and beetles, chafers, weevils, and grasshoppers cut small, randomly scattered holes.
- Damaged (especially skeletonized) leaf surfaces may indicate slugs, beetle larvae, pearslugs (pear sawfly larvae), elm leaf beetles, or thrips.

- Leaves tied with silken threads or rolled into tubes often harbor leafrollers or leaftiers (e.g., omnivorous leaftiers).
- If there is a discolored or swollen area on a leaf, hold it up to the light to look for insects or frass in the damaged area. The culprit may be leafminers, which feed between upper and lower leaf surfaces (e.g., cottonwood, birch, and elm leafminers).
- If petioles are weakened and leaves fall in early summer, suspect petiole and leaf stalk borers (e.g., maple petiole borers), which burrow into petioles near leaf blades or bases. Cut open a petiole to look for a small moth or sawfly larva.
- If a twig's bark is girdled (cut, removed, or clamped all the way around), the culprits may be vine weevils or twig-girdling beetles.
- If there is a general decline in a plant or specific branch, examine it closely for holes in the bark, frass, or pitch. These signs are caused by borers, which feed under the bark in cambium tissue, solid wood, or xylem tissue. Examples are mountain pine beetles, European elm bark beetles, and raspberry crown borers.
- The general decline of a plant, along with chewed roots, may indicate root-feeding larval stages of weevils, beetles, and moths (e.g., sod webworms and root weevils).

Sucking insects not only damage plants directly by feeding but sometimes inject toxic substances that cause symptoms ranging from simple stippling of leaves to extensive disruption of an entire plant. Insects that secrete phytotoxic substances are called *toxicogenic* (toxin-producing). The resulting plant damage is called *phytotoxemia* or *toxemia*.

Spotting or stippling results when chlorophyll is destroyed locally at the feeding site but toxins do not diffuse throughout the leaf. Aphids, leafhoppers, and plant bugs commonly cause this type of injury.

Severe toxemias develop when toxic saliva causes leaves to curl and pucker around an insect. Severe aphid infestations may cause this type of damage.

In some cases, toxic effects spread throughout the plant, resulting in reduced growth and chlorosis. This condition is known as *systemic toxemia*. Psyllid yellows of potatoes and tomatoes, scale insects, and mealybug infestations may cause systemic toxemia.

Look for these clues when determining the cause of sucking damage:

- General (uniform) stippling, flecking, or chlorotic patterns on spruce needles are usually caused by adelgid damage. Lace bugs may be the cause on other plants.
- Random stipple patterns on leaves are caused by leafhoppers and mites.
- Leaf and stem distortion accompanied by off-color foliage is the result of aphids. Distortion is often confused with injury from growth-regulating chemicals.
- Galls (swellings on leaf or stem tissue) may be caused by various insects. Examples are aphids, wasps, midges, mossyrose gall wasps, and poplar petiole gall midges.
- Twigs that look like they've been split by a sharp instrument are the result of egg laying (*oviposition*) by sucking insects such as treehoppers.
- The general decline of an entire plant or plant part, as indicated by poor color, reduced growth, or dieback, may be the result of root, stem, or branch feeders such as scales or mealybugs.

Insect life cycles

Knowledge of life cycles assists in identifying damaging insects. There are two types of insect life cycles: incomplete and simple (also known as gradual or incomplete).

In a *complete life cycle,* the immature stage is a larva (a worm-like or grub-like creature that may feed on plants). It then becomes a pupa, a relatively inactive stage often enclosed in some form of cocoon. Finally, it emerges as an adult which is completely different in appearance from the larval stage. With these types of insects, the larval stage is usually the most damaging. Examples are butterflies, moths, weevils, beetles, and flies.

In a *simple life cycle*, insects resemble adults as soon as they hatch except that they are smaller and wingless. As an insect grows, it sheds its skin (*molts*), leaving cast skins as a diagnostic sign. With each molt, wing buds become more noticeable. Plant bugs, leafhoppers, and grasshoppers are examples of insects with simple life cycles.

Symptoms and signs of other animal damage

A variety of other living organisms can damage plants. For example:

- *Arachnids*—Arachnids have eight legs (insects have six) and sucking mouthparts. Spider mites are an example. They have a simple life cycle and often cause leaf stippling. Damaged leaves then turn pale on the underside. Severe infestation causes leaf bronzing and death. Foliage may appear dirty due to the presence of small, fine webbing mixed with eggs and frass on the undersides of leaves. Eriophyid mites, on the other hand, cause distorted new growth, rolled leaf margins, and swollen veins. These symptoms are often confused with damage from growth regulators.
- *Crustacea*—Sowbugs and pillbugs usually feed on decaying vegetation. Unless populations are high, they are not considered damaging to live plants.
- *Mollusca*—Slugs and snails feed on low-growing foliage and fruit, causing skeletonization or destruction of soft tissue. Look for slime trails on foliage and the surrounding soil.
- *Miscellaneous animals*—Millipedes (arthropods) feed on decaying plants. They have many small legs, are brownish or white in color, and vary in size from ½ to 2 inches long. They are not considered injurious to live plants.
- *Small mammals*—Chewed bark and cambium tissue on small trees and shrubs is most frequently caused by mice, rabbits, squirrels, or possibly beavers. Look for teeth marks.

See Chapter 23, *Vertebrate Pests.*

- *Large mammals*—Cattle, goats, deer, and horses tear or cut branches.
- *Birds*—Missing flower petals or punctured bark may be caused by yellow-bellied sapsuckers. They make even rows of holes in tree trunks.

Distinguishing among nonliving causes of damage

Uniform patterns of damage indicate that a nonliving factor is the probable cause. There are three broad categories of nonliving factors:

- *Mechanical* factors include abrasion and bruising from construction or maintenance equipment, handling during transplanting, or lawn mowers.
- *Physical* factors include environmental or weather changes such as extremes of temperature, light, moisture, or wind.
- *Chemical* factors include pesticide applications, aerial and soil pollutants, and nutritional disorders.

Additional clues, as discussed below, will help determine which of these is the cause of damage.

Mechanical factors

First, consider whether there has been recent excavation, construction, or paving on the site. Then examine the damaged plant. Close examination often reveals whether stems or roots were broken or girdled and whether leaves were bruised, punctured, or broken. For example, if stems break because a plant is dropped during transplanting, rapid wilting will occur above the break. Living factors such as pathogens and insects seldom cause sudden plant death.

Physical (environmental) factors

Primary sources of diagnostic information for damage caused by physical factors are damage patterns and weather records.

Temperature extremes

Hot or cold temperature extremes can damage plants. In both cases, recognizable damage patterns are likely to occur.

Heat damage is most likely to occur in the early afternoon when the sun is in the southwest quadrant of the sky. Therefore, damage occurs primarily on outer, unshaded leaves on a plant's southwest side. Leaves shaded by other leaves or those on the northeast side may be undamaged.

The most severe damage occurs on plant parts farthest from water-carrying roots, stems, and leaf veins. Thus, leaves on the outer perimeter of the plant, leaf tips, leaf margins, and interveinal areas are most commonly damaged and turn brown. This damage pattern is likely to occur uniformly over many plants in an area.

Cold damage occurs on the least hardy plants and is most severe on the least hardy tissues of those plants. Plants vary in their hardiness (cold tolerance). By checking how low the temperature dropped and knowing the indicator plants for various USDA cold hardiness zones, one can begin to determine whether plant damage was caused by coldness.

As plants acclimate to cooler temperatures in the fall, cold hardiness is achieved first by terminal buds. With time, lower parts become hardy. Branch crotches are often the last tissues to acclimate. If warm temperatures induce deacclimation in early spring, terminals (buds) lose hardiness first.

See Chapter 7, *Woody Plants*.

Thus, the portion of plant damaged indicates whether damage occurred before a plant achieved cold hardiness in the fall or after cold hardiness was lost in the spring. Damage to buds occurs most often in late winter or early spring, while damage to lower plant parts may occur in the fall or early winter.

On a given structure (e.g., leaf or bud), exposed, nonhardy tissues are damaged in a recognizable pattern. For example:

- Spring frost damage may uniformly kill new, succulent growth. New growth emerging after the frost will be healthy. If buds were not killed, new leaves may appear distorted.
- Frost cracks are longitudinal separations of bark and wood that generally occur on the southwest side of a trunk. They are the result of wide day–night temperature fluctuations in winter.
- The dividing cells on outer portions of leaves may freeze while still inside the bud. As a result, distorted or lace-like leaf blades develop.

Generally, root systems cannot survive as low a temperature as can aboveground plant parts. Fortunately, soil temperatures are usually warmer and more stable than air temperatures during winter. Thus, cold damage to roots is primarily a concern with container-grown plants in which soil temperatures fluctuate more than in the ground. Examine the root system to detect damage. Damage generally occurs on the periphery of the root ball (near the container edge). Evidence includes black or spongy roots that lack new growth or new root hairs.

Above-ground symptoms of cold damage to roots generally do not become evident until shoots begin to grow in the spring. At that time, leaf expansion may be incomplete because of restricted water and nutrient uptake by the damaged root system. The result is smaller-than-normal leaves. As air temperature increases, water loss from shoots and leaves may exceed the roots' ability to take up water. As a result, the plant loses leaves or wilts and may die.

Light extremes

Plants can acclimate to various light conditions but need time to do so. They respond adversely to rapid change. A sudden change from low to high light intensity results in destruction of chlorophyll. The result is yellowing and necrosis. Rapid change from high to low light intensity, on the other hand, results in reduced growth and leaf drop. Under low light, new leaves are larger, thinner, and darker green than normal while flowering is reduced, delayed, or absent.

Oxygen and moisture extremes

These factors relate primarily to the root environment where the quantities of oxygen and moisture are inversely related. A waterlogged (saturated) root environment lacks sufficient oxygen for root metabolism and growth. Consequently, less water and nutrients are taken up by plants.

Drought and waterlogging produce many of the same aboveground symptoms. The first symptoms are wilting, chlorosis, and abscission (dropping) of older leaves. Under severe, continuing moisture stress, wilting and necrosis occurs on tips and interveinal regions of recently expanded leaves and new growth.

Chemical toxicities

See Chapter 19, *Pesticides*.

Patterns of chemical injury on individual plants differ depending primarily on whether a chemical causes damage directly on contact or is absorbed and moves throughout a plant.

Direct-contact damage

Direct-contact damage can occur on both foliage and roots.

Shoot/foliage contact

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 typified by chlorotic or necrotic spotting. Spots are usually uniformly and evenly distributed over the leaf surface and are generally all the same size. Color is usually uniform across the spot. The margin between affected and healthy tissue is usually sharp (Figure 11).

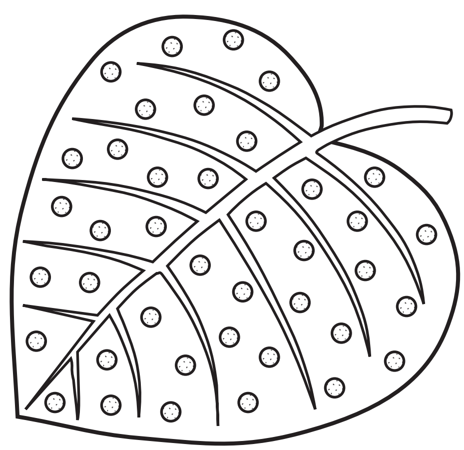


Figure 11.—Foliar chemical spray injury.

If a chemical is applied directly to aboveground parts, one may be able to see the application pattern. 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 is lowest—show damage first.

Examples of shoot/foliage contact chemicals are foliar-applied fertilizers and some agricultural herbicides. Very few, if any, contact herbicides are available to home gardeners.

Root contact

Toxic-contact chemicals in the root zone, including excess fertilizer, result in poor root development. Roots are injured and root tips may be killed.

Aboveground shoots may show water and nutrient stress symptoms like reduced growth, wilting, or chlorosis because the roots are unable to obtain water. In severe cases, wilting can occur even when the soil is wet. Lower leaves generally wilt first followed by the drying of leaf margins.

Herbicides that inhibit root growth include the agricultural herbicides dinitroanilines, DCPA, and diphenamid. Excess nitrogen fertilizer can have the same result.

Keep in mind that many other factors also injure roots or inhibit their growth including nematodes and other pathogens, soil compaction, cold weather, salinity, and nutritional deficiencies or excesses.

Translocated chemical damage

Some chemicals can move throughout a plant after being absorbed. The effects of these mobile chemicals depend on whether they are transported in the phloem or the xylem.

If transported solely in the xylem, chemicals move upward through a plant. These chemicals cause symptoms primarily in older foliage. Examples include urea fertilizer and the agricultural herbicides triazine, alachlor, and metolachlor.

If transported in the phloem, a chemical 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 toxic chemicals occur primarily in a 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 toxic chemicals include the common garden herbicides 2,4-D, dicamba, and glyphosate.

Nutrient deficiencies

Like the effects of toxic chemicals, those of nutrient deficiencies depend on whether the chemical is transported only in the xylem or also in the phloem.

Nutrients that are transported solely in the xylem are immobile in a plant once they have been moved upward from the roots. They cannot be moved through the phloem to new growth if a soil deficiency develops. Thus, symptoms of these *phloem-immobile* chemicals typically develop on new growth. Calcium, iron, manganese, zinc, copper, molybdenum, and, in some plant species, sulfur and boron, are phloem-immobile.

In contrast, if a soil deficiency develops, a *phloem-mobile* nutrient can be withdrawn from older leaves and moved to growing root and shoot tips. Deficiencies of these nutrients are visible first on older leaves. Nitrogen, phosphorus, potassium, magnesium, chlorine, and, in some plant species, sulfur and boron, are phloem-mobile.

For more information

Many other publications on specific insect and disease problems are listed in other chapters.

Other publications

Bennett, W.F., ed. *Nutrient Deficiencies and Toxicities in Crop Plants* (APS Press, St. Paul, MN, 1993). 202 pp.

Borror, D.J., and R.E. White. *A Field Guide to the Insects of America North of Mexico* (Houghton Mifflin Company, Boston, 1970). 404 pp.

Derr, J.F., and B.L. Appleton. *Herbicide Injury to Trees and Shrubs: A Pictorial Guide to Symptom Diagnosis* (Blue Crab Press, VA). 72 pp.

Flint, M.L. *Pests of the Garden and Small Farm: A Grower's Guide to Using Less Pesticide*, Publication 3332 (University of California, Los Angeles, 1990). 276 pp.

Howard, R.J., J.A. Garland, and W.L. Seaman, eds. *Diseases and Pests of Vegetable Crops in Canada* (The Canadian Phytopathological Society and the Entomological Society of Canada, Ottawa, 1994). 554 pp.

Insects and Diseases of Woody Plants (Colorado State University Cooperative Extension Bulletin 506A, Fort Collins, Colorado, 2000). 284 pp.

Johnson, W.T., and H.H. Lyon. *Insects That Feed on Trees and Shrubs*, 2nd edition (Cornell University Press, Ithaca, NY, 1991). 560 pp.

An Illustrated Guide to Plant Abnormalities Caused by Eriophyid Mites in North America, Ag Handbook No. 573 (U.S. Department of Agriculture, Agricultural Research Service, 1982). 178 pp.

The Ortho Problem Solver, 2nd edition (Chevron Chemical Co., San Francisco, 1984). 1,040 pp.

Pirone, P.P. *Diseases and Pests of Ornamental Plants*, 5th edition (John Wiley & Sons, New York, 1978). 566 pp.

Sherf, A.F., and A.A. Macnab. *Vegetable Diseases and Their Control*, 2nd edition (John Wiley & Sons, New York, 1986). 728 pp.

Sinclair, W.A., H.H. Lyon, and W.T Johnson. *Diseases of Trees and Shrubs* (Cornell University Press, Ithaca, NY, 1987). 575 pp.

Sunset Western Garden Problem Solver (Sunset Books, Inc., Menlo Park, California, 1998). 320 pp.

A step-by-step method of diagnosis

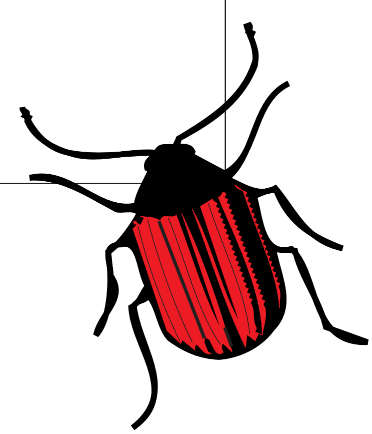
1. **Determine that a real problem exists. Define the problem.**
   A. Identify the plant. Establish what a "normal" plant would look like at this time of year. Describe the abnormality (symptoms and signs).
   B. Examine the entire plant and its community. Locate the primary problem and the plant part where initial damage occurred.

2. **Look for patterns. Is the damage on more than one plant? On more than one plant species?**
   A. A nonuniform damage pattern (irregular or random pattern of damage) is indicative of living factors (pathogens, insects, mites, or other animals).
   B. A uniform damage pattern (e.g., damage on all leaves of a certain age or all plants in an area) indicates nonliving factors (mechanical, physical, or chemical).

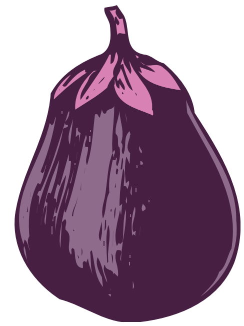
3. **Delineate development of damage over time.**
   A. Progressive spread of the damage on a plant or onto other plants indicates damage caused by living organisms.
   B. Damage that does not spread to other parts of the affected plant or to other plants and a clear line between damaged and undamaged tissues indicate damage caused by nonliving factors.

4. **Gather information to identify possible causes of damage.**
   A. Distinguish among living factors.
      1. Symptoms and signs of pathogens
      2. Symptoms and signs of insects, mites, and other animals
   B. Distinguish among nonliving factors.
      1. Mechanical factors
      2. Physical factors
         a. Temperature extremes
         b. Light extremes
         c. Oxygen and moisture extremes
      3. Chemical factors
         a. Pesticide or pollutant phytotoxicities
         b. Nutritional disorders
   C. Use references. Laboratory analyses may be needed to narrow the range of probable causes.

5. **Synthesize information to determine probable causes.**



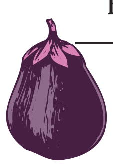
Diagnostic key



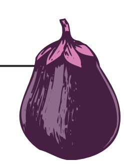
Vegetables—general

- This key is not a comprehensive list of plant symptoms, causes of damage, or management techniques. Refer to this chapter's general discussion of problem diagnosis and to other references for more information.
- Cultural, mechanical, and biological methods are listed first under "Management and comments." Chemical methods are listed last.

Symptoms/Possible causes	Management and comments
Poor fruit yield; fruit may be small and have poor taste.	
Uneven moisture	Water during dry periods.
Poor soil fertility	Test soil; supply nutrients based on results.
Unfavorable environment	Plants need to be adapted to Wyoming.
Plants grow slowly; leaves light green.	
Insufficient light	Thin plants; do not plant in shade.
Cool weather	Growth will improve when weather warms.
Poor soil fertility	Test soil; supply nutrients based on results.
Improper pH	Test soil; adjust pH if possible.
Excess water	Do not over water; improve drainage.
Seedlings don't emerge.	
Dry soil	Water.
Damping-off (fungal disease)	Use sterile pots and planting media; do not over water; allow soil to dry slightly between waterings; treat seed with registered fungicide before planting.
Incorrect planting depth	Plant at correct depth.
Slow germination due to weather	Wait for appropriate weather conditions before planting.
Root maggots	Use floating row cover; apply registered soil insecticide.
Wilted seedlings; seedlings fall over.	
Damping-off (fungal disease)	Use sterile pots and planting media; do not over water; allow soil to drain and dry slightly between waterings; treat seed with registered fungicide before planting.
Cutworms	Use cutworm collars, biological control agent; apply registered soil insecticide.
Root maggots	Use floating row cover; apply registered soil insecticide.



Symptoms/Possible causes	Management and comments
Chewed seedlings.	
Rodents, rabbits, or birds	Place fence around garden.
Slugs	Use slug barrier or bait.
Various insects	Identify insect; use appropriate nonchemical or chemical control.
Wilted plants; bottom leaves may turn yellow.	
Dry soil	Water.
Root rot (fungal disease)	Use sterile pots and planting media; do not over water; allow soil to dry slightly between waterings; treat seed with registered fungicide before planting.
Vascular wilt (fungal disease, mainly affecting tomatoes, potatoes, eggplants, and peppers)	Plant resistant varieties; rotate.
Root-knot nematodes	Plant resistant varieties; rotate; remove diseased plants; fumigate soil.
Various root-feeding nematodes	Submit soil sample for nematode analysis; plant resistant varieties; rotate; remove diseased plants; fumigate soil.
Waterlogged soil	Improve drainage; do not over water.
General leaf yellowing; no wilting.	
Nutrient deficiency	Soil test; supply nutrients based on results.
Insufficient light	Thin plants; do not plant in shade.
Leaves stippled with tiny, white spots.	
Spider mites	Use predatory mites; apply insecticidal soap or registered miticide.
Leaf margins turn brown and shrivel.	
Dry soil	Water.
Wind desiccation	Water as needed.
Fertilizer burn	Test soil for soluble salts; do not over fertilize; flush soil with water.
Potassium deficiency	Soil test; supply nutrients based on results.
Cold injury	Do not plant too early.

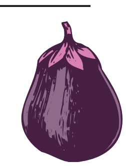


Symptoms/Possible causes	Management and comments
Discrete, brown spots on leaves; some spots may coalesce.	
Fungal or bacterial leaf spot disease	See specific plant listings below.
Chemical injury	Do not apply chemicals that are not registered for use on the plant; apply chemicals at recommended rates and in the right environmental conditions.
White, powdery growth on upper leaf surfaces.	
Powdery mildew (fungal disease)	Use resistant varieties; space plants adequately for better air circulation; remove leaf debris in fall; apply registered fungicide.
Leaves shredded or stripped from plant.	
Hail damage	—
Rodents	Place fence around garden; use traps.
Slugs	Use slug barrier or bait.
Dead tissue drops out after fungal infection	Avoid wetting foliage; space plants adequately for better air circulation; apply registered fungicide before problem reaches this stage.
Various insects	Identify insect; use appropriate nonchemical or chemical control.
Leaves with yellow and green mosaic or mottle pattern.	
Viral disease	Plant resistant varieties if available; plant certified, disease-free seeds or seedlings; control weeds; remove and destroy affected plants.
Leaves curled, puckered, or distorted.	
Herbicide injury (common on tomatoes and cucumbers)	Be careful when using herbicides.
Viral disease	Plant resistant varieties if available; plant certified, disease-free seeds or seedlings; control weeds; remove and destroy affected plants.
Aphids	Pick off, mash, or wash away insects; use biological control agent; treat plant (especially undersides of leaves) with insecticidal soap or registered insecticide.

Symptoms/Possible causes	Management and comments
Tops turn yellow, brown, and die back; reddish-brown, orange, or black pustules appear on stems and leaves.	
Rust (fungal disease)	Plant resistant varieties; cut tops close to ground in fall and destroy; remove and destroy affected leaves; improve air circulation; avoid wetting foliage; apply registered fungicide.
Shoots wilt, turn yellow, then brown; vascular tissue in crown area is reddish brown.	
Fusarium wilt (fungal disease)	Plant resistant varieties; destroy affected plants; rotate for two to four years; fumigate soil.
Verticillium wilt (fungal disease)	Plant resistant varieties; destroy affected plants; rotate for two to four years; fumigate soil.

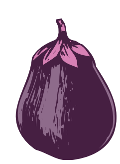
Vegetables—specific

Asparagus	
Small spears.	
Immature plants	Asparagus produces small spears for two or three years after planting.
Plants overharvested during previous year	Do not harvest late into the season; plants can't store enough food for following season.
Poor fertility	Soil test; supply nutrients based on results.
Poor drainage	Do not over water; plant in well-drained area.
Spears crooked.	
Mechanical injury from windblown sand or mishandling	Be careful not to damage emerging spears when harvesting.
Asparagus beetles	Shake foliage over a tray and discard the insects; apply registered insecticide.
Spears turn brown and soft.	
Frost injury	Protect spears with mulch.
Root rot (fungal disease)	Rotate; plant in well-drained area; do not over water; remove plant debris.

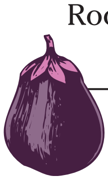


Symptoms/Possible causes	Management and comments
Leaves chewed; slime may be present on leaves; no evidence of insects.	
Slugs (emerge at night and hide during the day)	Use slug barrier or bait.
Spears and leaves chewed or scarred.	
Asparagus beetles	Shake foliage over a tray and discard the insects; apply registered insecticide.
Beans	
Plants wilt/are stunted; leaves may turn yellow.	
Dry soil	Water.
Root rot (fungal disease)	Rotate; plant in well-drained area; do not over water; remove plant debris.
Root-knot nematodes	Rotate; remove diseased plants; fumigate soil.
Poor fertility	Soil test; supply nutrients based on results.
Failure to set pods.	
High temperature causes blossoms to drop	Wait for cooler weather.
Dry soil	Water.
Wet soil causes lack of oxygen to roots	Do not over water; plant in well-drained area.
Mature pods left on vines cause seed production rather than pod set	Pick pods regularly.
Rust-colored powdery spots surrounded by yellow halos on leaves and stems.	
Rust (fungal disease)	Plant resistant varieties; remove plant debris and pods; remove and destroy affected leaves; apply registered fungicide.
Soft, watery spots or white, moldy growth on leaves, stems, and pods; plants wilt and die.	
White mold (fungal disease)	Rotate; remove plant debris; improve air circulation; use registered fungicide.

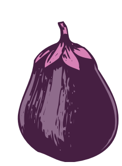
Symptoms/Possible causes	Management and comments
Water-soaked spots followed by irregular brown spots on undersides of leaves.	
Halo blight (bacterial disease)	Delay planting until warm weather; plant disease-free seed; rotate; remove plant debris.
Mottled patterns on leaves; leaves often curl downward, may become chlorotic, soon die.	
Mosaic (viral disease)	Use resistant varieties and certified seed; avoid planting beans near gladioli, which may harbor the disease.
Leaves lose color; undersides appear dusty and webbed.	
Spider mites	Use predatory mites; apply insecticidal soap or registered miticide.
Young leaves curled, distorted, and yellow; clusters of tiny insects on leaves and stems.	
Aphids	Pick off, mash, or wash away insects; use biological control agent; apply insecticidal soap or registered insecticide.
Beets	
Small, circular spots with light centers and dark borders on leaves.	
Cercospora leaf spot (fungal disease)	Rotate; pick off and destroy affected leaves; thin planting; avoid wetting foliage.
Deformed roots.	
Overcrowding	Thin beets early.
Cloddy soil	Prepare soil properly.
Leaves with many small holes.	
Flea beetles	Use floating row cover or biological control agent; apply registered insecticide.
Irregular, tan blotches in leaves.	
Leafminers	Use floating row cover; remove and destroy infested leaves.



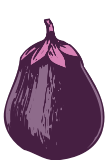
Symptoms/Possible causes	Management and comments
Carrots	
Inner leaves yellow; outer leaves reddish purple; roots stunted and bitter.	
Aster yellows (phytoplasma disease)	Remove and destroy affected plants; control weeds; control leafhoppers with registered insecticide.
Root tops green.	
Roots exposed to sunlight	Cover exposed roots with soil or mulch.
Roots deformed.	
Overcrowding	Thin carrots early.
Cloddy soil	Prepare soil properly.
Root-knot nematodes	Submit soil sample for nematode analysis; rotate; remove diseased plants; fumigate soil.
Excess nitrogen	Do not over fertilize.
Small maggots in roots.	
Carrot rust fly larvae	Rotate; plant resistant varieties; use floating row cover; apply registered insecticide.
Cole crops (cabbage, broccoli, turnips, cauliflower, brussels sprouts)	
Cabbage heads crack.	
Excess water taken up by plant causes head to burst	Harvest heads as soon as mature.
Poor heading.	
Overcrowding	Thin plants early.
Dry soil	Water.
High temperature	Wait for cooler weather.
Poor soil fertility	Test soil; supply nutrients based on results.
Club root (fungal disease)	Check roots for large swellings; rotate cole crops out of affected area for seven years.
Root rot (fungal disease)	Rotate; plant in well-drained area; do not over water; remove plant debris.



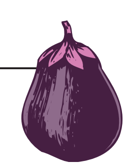
Symptoms/Possible causes	Management and comments
Discolored cauliflower heads.	
Exposure to sun	Tie leaves over heads early.
Plants wilt and turn yellow; roots have large swellings (not to be confused with smaller root knots caused by nematodes).	
Club root (fungal disease)	Check roots for large swellings; rotate cole crops out of affected area for seven years.
Plants stunted and yellow (especially cabbage); roots not discolored.	
Dry soil	Water.
Poor soil fertility	Test soil; supply nutrients based on results.
Cabbage maggots	Use collars, floating row cover, or biological control agent; add a soil insecticide at planting time.
Heads soft and rotted.	
Soft rot of broccoli (bacterial disease)	Grow broccoli varieties that shed water (conical head); provide good air circulation; avoid wetting heads.
Rough, brown, raised areas on undersides of leaves.	
Oedema (physiological problem due to uneven water supply)	Water during dry periods; avoid over watering in cool conditions.
Leaves riddled with shotholes.	
Flea beetles	Use floating row cover or biological control agent; apply registered insecticide.
Leaves chewed.	
Imported cabbage worm, cabbage looper, diamond-back moth	Identify insect; use floating row cover or biological control agent; apply registered insecticide.
Some leaves curled, yellow; clusters of tiny, gray or green insects.	
Aphids	Use floating row cover or biological control agent; apply insecticidal soap or registered insecticide.



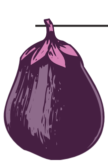
Symptoms/Possible causes	Management and comments
Corn	
Ears not completely filled with kernels.	
Poor pollination	Plant in blocks of three or four short rows rather than a single long one.
White (smooth) or black (powdery) galls on stalks, leaves, ears, or tassels.	
Smut (fungal disease)	Rotate; plant only 1 inch deep to encourage rapid germination; keep soil moist for first four weeks after germination; cut off galls before they turn black; remove plant debris.
Plants stunted; yellow and green striped mosaic pattern on leaves; older leaves pale yellow.	
Maize dwarf mosaic (viral disease)	Control weeds, especially wild grasses; control aphids; destroy affected plants.
Leaves reddish on margins.	
Phosphorus deficiency	Test soil; supply nutrients based on results; avoid planting in very cool soil.
Distorted leaves or stalks; leaves may fail to unfurl or stalk may be bent.	
Herbicide injury	Be careful when applying herbicides.
Caterpillars feeding on tips of ears.	
Corn earworms	Apply mineral oil or registered insecticide during silking to prevent infestation.
Young plants disappear.	
Cutworms	Use cutworm collars or biological control agent; apply registered insecticide.
Birds	Use floating row cover or screen.
Cucurbits (cucumbers, cantaloupes, pumpkins, squash, watermelons)	
No fruit produced.	
Poor pollination	Be patient; male and female flowers are not produced at the same time at first; bee activity may be low due to cool weather; protect bees when using insecticides.



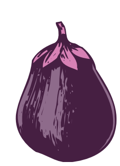
Symptoms/Possible causes	Management and comments
Misshapen or bitter fruit.	
Poor pollination	Be patient; male and female flowers are not produced at the same time at first; bee activity may be low due to cool weather; protect bees when using insecticides.
Dry soil	Water.
Poor soil fertility	Test soil; supply nutrients based on results.
Water-soaked, sunken, brown, or black spot on end of fruit.	
Calcium deficiency, usually caused by uneven soil moisture during blossoming and poor supply of calcium to fruit during early development	Water during dry periods.
Wilted plants.	
Dry soil	Water.
Bacterial wilt	Control cucumber beetles.
Root rot (fungal disease)	Remove old plant debris; rotate; plant in well-drained area; do not over water.
Fusarium wilt (fungal disease)	Plant tolerant varieties if available; rotate.
Circular or irregular spots on leaves and/or fruit.	
Fungal or bacterial disease (any of several)	Plant resistant varieties; space plants properly; control moisture and humidity.
White, powdery growth on leaves; may be on both leaf surfaces.	
Powdery mildew (fungal disease)	Plant resistant varieties; rotate; provide air circulation; control weeds; apply registered fungicide.
Yellow and green mottle pattern on leaves.	
Viral disease	Control weeds before plants emerge; control insects; remove affected plants.
Leaves have strapped appearance, i.e., abnormally narrow with leaf veins stretched out at leaf margins so leaves appear feathery.	
Herbicide injury	Be careful when applying herbicides.



Symptoms/Possible causes	Management and comments
Holes chewed in leaves and stalks; yellow-green beetles with black stripes or spots.	
Cucumber beetles	Use floating row cover or biological control agent; apply registered insecticide.
Squash and pumpkin leaves wilt, eventually become black and crisp; dark gray ½-inch-long bugs present.	
Squash bugs	Hand pick and destroy; use floating row cover; apply registered insecticide.
Lettuce	
Bolting; may taste bitter.	
Weather too hot	Lettuce is a cool-season crop; plant early or late.
Sunken, water-soaked spots appear on lower leaves, which turn brown and slimy; head turns brown.	
Rhizoctonia bottom rot (fungal disease)	Rotate; plant in well-drained area; remove plant debris.
Sclerotinia (fungal disease)	Avoid crowding; plant in well-drained area; remove plant debris.
Stem and lower leaves rotted; dense, fuzzy, gray mold on affected areas.	
Botrytis gray mold (fungal disease)	Rotate; plant in well-drained area; remove plant debris.
Yellow or light green blotches on upper leaf surfaces; white, fuzzy mold on undersides of blotches; spots eventually turn brown.	
Downy mildew (fungal disease)	Rotate; control weeds; apply registered fungicide.
Plants stunted, yellow; youngest leaves curled; head soft.	
Aster yellows (phytoplasma disease)	Remove and destroy affected plants; control weeds and insects.
Mosaic virus	Remove and destroy affected plants; control weeds and insects.
Nutrient deficiency	Test soil; supply nutrients based on results.
Leaf veins and area adjacent to veins turn light yellow, causing a "big-vein" effect.	
Big vein (viroid disease)	Rotate; plant in well-drained area; remove and destroy affected plants.

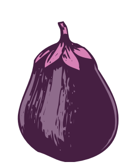


Symptoms/Possible causes	Management and comments
Onions	
White flecks form on leaves and expand into elongated leaf lesions; white-to-purplish mold develops on spots during moist weather; bulb quality poor and often spongy.	
Downy mildew (fungal disease)	Rotate; plant in well-drained area; eradicate wild onions; avoid wetting foliage; apply registered fungicide.
Leaves yellow and die back from tips; bulbs soft and rotted.	
Fungal or bacterial bulb rot	Rotate; plant in well-drained area; remove plant debris; allow tops to die before harvesting; cure bulbs before storing; avoid bruising bulbs.
Tops stunted; roots yellow and eventually become pinkish in color.	
Pink root (fungal disease)	Rotate; plant in well-drained area; plant resistant varieties; fertilize and irrigate properly to maintain optimal growth; remove plant debris.
Plants grow slowly, wilt, and die; white maggots inside bulb.	
Onion maggots	Use floating row cover; destroy infested onions; work registered insecticide into soil.
White streaks or blotches on leaves.	
Onion thrips	Use floating row cover or biological control agent; apply insecticidal soap or registered insecticide.
Peas	
Plants stop producing pods; leaves turn yellow, then brown, and die.	
Hot weather	Peas are cool-season vegetables; plant early in spring; plant heat-resistant varieties.
Root rot (several fungi)	Rotate; plant in well-drained area; do not over water; remove plant debris.
Plants stunted; lower leaves yellow; internal stem tissue brown.	
Fusarium wilt (fungal disease)	Rotate; plant resistant varieties; plant when soil temperature is below 65°F; remove plant debris.

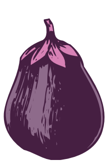


Symptoms/Possible causes	Management and comments
White, powdery mold develops on upper, then lower, surfaces of leaves; leaves and pods may be distorted.	
Powdery mildew (fungal disease)	Rotate; plant resistant varieties; plant early; control weeds; remove plant debris.
Yellowish areas on leaves; blister-like ridges on undersides of leaves and on pods.	
Pea enation mosaic (viral disease)	Plant resistant varieties; plant early before insect vectors are active; control weeds and insect vectors; remove and destroy affected plants.
Yellow and green mottle or mosaic pattern on leaves; plants stunted.	
Viral disease (any of several)	Plant resistant varieties; control weeds and insect vectors.
Peppers	
Large, sunken, tan, water-soaked spot develops on blossom end of fruit; spot turns black, and mold may grow on surface.	
Blossom-end rot, caused by calcium deficiency to developing fruits. Occurs when young fruits receive uneven moisture.	Mulch to conserve water; water during dry periods.
Thin, wrinkled, tan areas develop on fruit and become white and papery.	
Sunscald	Provide shade if hot, sunny weather persists when heavy fruit crop is on plants.
Growth stunted; leaves turn yellow, roll inward, and die.	
Verticillium wilt (fungal disease)	Remove old crop debris; rotate, avoiding tomatoes and potatoes in rotation.
Plants stunted; leaves curled with yellow and green mottle; fruit misshapen with brown streaks, rings, or yellow, green, and red mottle.	
Viral disease (any of several)	Plant resistant varieties if available; control weeds and insect vectors; remove plant debris; wash hands often when working among plants; don't smoke around plants.

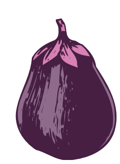
Symptoms/Possible causes	Management and comments
Plants wilt; lower leaves may turn yellow.	
Fungal or bacterial wilt disease	Rotate, avoiding tomatoes and potatoes in rotation; remove plant debris.
Dry soil	Water.
Waterlogged soil	Improve drainage; do not over water.
Root rot (fungal disease)	Rotate; plant in well-drained area; do not over water; remove plant debris.
Potatoes	
Potato tubers are green.	
Exposure to sun	Mound soil up around plants; do not eat green parts of potatoes.
Plants wilt; bottom leaves may turn yellow.	
Dry soil	Water.
Vascular wilt (fungal disease)	Rotate; remove plant debris.
Root rot (fungal disease)	Rotate; plant in well-drained area; do not over water; remove plant debris.
Waterlogged soil	Do not over water.
Brown, corky scabs or pits on tubers; plants do not wilt.	
Scab (fungal disease)	Use certified seed potatoes; use tolerant varieties; provide adequate water when tubers are forming (July).
Tubers show irregular white or brown cavities when cut open.	
Hollow heart, caused by plants' growing rapidly	Do not over fertilize; maintain uniform soil moisture.
Tunnels bored just under the skin of tubers; small holes in leaves.	
Flea beetle adults and larvae	Watch for holes in leaves; use floating row cover or biological control agent; apply registered insecticide.
Leaves chewed; fat, red, humpbacked grubs or orange beetles with black stripes present.	
Colorado potato beetles	Hand pick beetles; use floating row cover or biological control agent; apply registered insecticide.



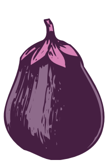
Symptoms/Possible causes	Management and comments
Radishes	
Purple-to-black spots develop on root surface; black discoloration extends inward in radial streaks; roots remain firm.	
Black root (fungal disease)	Plant in well-drained area; rotate; plant resistant varieties; do not over water; remove plant debris.
Leaves riddled with tiny holes.	
Flea beetles	Use floating row cover or biological control agent; apply registered insecticide.
Roots infested with legless white worms.	
Cabbage maggots	Use floating row cover or biological control agent; apply registered insecticide.
Spinach	
Plants bolt.	
Hot weather and long days	Spinach is a cool-season crop; plant in early spring.
Pale yellow spots appear on upper leaf surfaces; grayish-purple mold develops on underside of spots; whole leaves may wither.	
Downy mildew (fungal disease)	Rotate; plant resistant varieties; remove infested plants.
Irregular, tan blotches or tunnels appear on leaves.	
Leafminers	Use floating row cover; remove and destroy infested leaves.
Tomatoes	
Dark brown, irregular spots with target rings, yellow halos develop on fruit; spots are often at stem end and are sunken.	
Early blight (fungal disease)	Rotate; plant resistant varieties; improve air circulation; avoid wetting leaves; remove plant debris; apply registered fungicide.



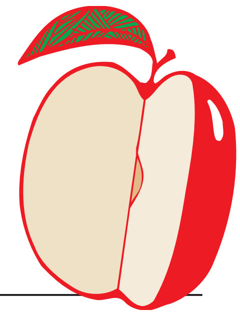
Symptoms/Possible causes	Management and comments
Dark brown, leathery spot on blossom end of fruit; mold may grow on spot.	
Blossom-end rot, caused by calcium deficiency to developing fruits. Occurs when fruits have uneven moisture supply during development.	Mulch to conserve water; water during dry periods.
Extreme malformation and scarring of fruit.	
Catfacing, caused by cool weather or herbicide injury during fruit formation	Protect young plants from cool temperatures; avoid using herbicides nearby.
Yellow-orange blotches that do not ripen at stem end of fruit or white, papery spot on side of fruit facing sun.	
Sunscald	Prevent foliar diseases that cause leaf drop and expose fruits to sun; use cages to confine plants so they will shade themselves better.
Leaves distorted with "strapped" or feathery look (leaves narrower than normal, tips stretched out into thin projections, veins very close together).	
Herbicide injury	Be careful when applying herbicides.
Tobacco mosaic (viral disease)	Plant resistant varieties; wash hands and disinfect tools between plants; don't smoke around plants; remove plant debris.
Note: It may be difficult to distinguish between these two causes based on symptoms alone; however, during the spring lawn weed control season, strongly suspect herbicide injury.	
Leaves roll upward, feel leathery, but remain green; plants are not stunted.	
Excess water	Common physiological disorder after wet periods; do not over water.
Young plants cut off at ground level.	
Cutworms	Use cutworm collars or biological control agent; apply registered insecticide.



Symptoms/Possible causes	Management and comments
Young plants have many tiny holes in leaves.	
Flea beetles	Tomatoes tolerate a lot of flea-beetle damage if they are healthy; when necessary, use biological control agent or registered insecticide.
Tiny, white-winged insects on undersides of leaves.	
Whiteflies	Use yellow sticky boards (smeared with grease) to attract and trap adults; apply insecticidal soap or registered insecticide.



Tree fruits—general



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Symptoms/Possible causes	Management and comments
Premature fruit drop.	
Natural thinning	Many trees produce more fruit than they need and thin themselves naturally.
Spring frost	Frost often kills developing flower buds or fruits.
Poor pollination	Tree may require another tree nearby for pollination; be careful not to kill bees with pesticides.
Environmental stress	Drought, cold, and heat can cause fruit drop.
Various diseases	Contact diagnostic clinic.
Various insects	Identify insects; contact diagnostic clinic.
Few fruits on tree.	
Poor pollination	Tree may require another tree nearby for pollination; be careful not to kill bees with insecticides.
Biennial bearing	Apples and pears naturally bear a heavy crop for one year and few fruits the following year. Thin fruits to counteract this tendency.
Improper pruning	Do not cut off fruit-bearing wood when pruning.
Frost injury	—
Fruits too small.	
Failure to thin	Peaches and apples tend to produce many small fruits. Thin fruits to increase size of remaining fruits.
Poor soil fertility	Test soil; supply nutrients based on results.
Gray-white, powdery growth on leaves; leaves and fruit may be distorted.	
Powdery mildew (fungal disease)	Improve air circulation; apply registered fungicide.

Symptoms/Possible causes	Management and comments
Black, sooty growth on leaves, stems, and/or fruit.	
Sooty mold (fungus that grows on honeydew substance secreted by aphids and other insects)	Identify insects; if aphids, hose down tree with a powerful spray of water; use biological control agent or registered insecticide.
Young leaves curled and distorted; clusters of insects on undersides of leaves.	
Aphids	Encourage predators; hose down tree with a powerful spray of water to remove aphids; use biological control agent or registered insecticide.
Leaves with tiny, white spots, often dirty with webbing.	
Spider mites	Encourage predators; use predatory mites; apply registered miticide.

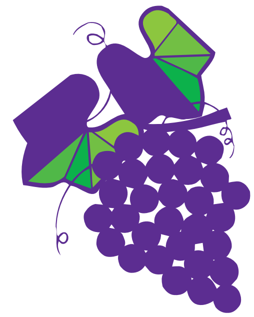
Tree fruits—specific

Apples and pears

Olive-brown, puckered spots on leaves and young fruit; fruit spots develop into brown, corky lesions; mature fruit is distorted.	
Scab (fungal disease)	Plant resistant varieties; rake and destroy fallen leaves; prune for better air circulation; avoid wetting leaves; apply registered fungicide.
Pink-white worms bore into fruit and feed near core.	
Codling moths	Use traps to monitor pest population; apply registered insecticide.
Apples have faint brown streaks in the flesh.	
Apple maggots	Use traps to monitor pest population; apply registered insecticide.

Symptoms/Possible causes	Management and comments
Stone fruits	
Purple spots appear on upper surfaces of cherry leaves; leaves become shotholed and turn yellow; fruit may also be affected.	
Cherry leaf spot (fungal disease)	Rake and destroy fallen leaves and fruits; apply registered fungicide.
Peach leaves puckered, thickened, and curled from time they first appear in spring; leaves red or orange at first but turn yellow; shoots swollen and stunted.	
Peach leaf curl (fungal disease)	Pick off and destroy affected leaves; fertilize the tree; apply registered dormant-season fungicide before buds begin to swell.
Blossoms and young twigs wilt and decay during bloom; sunken cankers with gummy ooze develop on twigs; circular, brown spots on fruit develop tufts of gray spores during moist weather.	
Brown rot (fungal disease common on all stone fruits)	Prune away badly affected twigs; follow stone fruit fungicidal spray program.
Cherry fruits infested with small, white worms.	
Western cherry fruit flies	Use traps to monitor presence of adult flies; apply registered insecticide.

Berries and grapes—general



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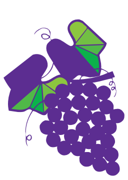
Symptoms/Possible causes	Management and comments
Grayish-white moldy growth on leaves.	
Powdery mildew (fungal disease)	Provide better air circulation and drier conditions; control weeds; apply registered fungicide.
Plants wilt; leaves may turn yellow.	
Dry soil	Water.
Waterlogged soil	Plant in well-drained area; do not over water.
Verticillium wilt (fungal disease)	Rotate; plant resistant varieties; fumigate soil.
Root rot (fungal disease)	Rotate; plant in well-drained area; do not over water; remove plant debris; apply registered fungicide.
Green and yellow mosaic or mottle pattern on leaves; plants may be stunted.	
Viral disease (any of several)	Purchase certified, virus-free plants; remove and destroy affected plants; control insects that spread virus.
Leaves rolled or tied together; small caterpillars feeding inside.	
Leafrollers, leaftiers	Use biological control agent or registered insecticide.

Berries and grapes—specific

Caneberries

Plants wilt; leaves turn yellow at bottom of plant first; stems turn dark blue at base; internal stem tissue may be discolored.	
Verticillium wilt (fungal disease)	Rotate; use certified, disease-free plants, resistant varieties; plant in well-drained area; remove and destroy affected plants.



Symptoms/Possible causes	Management and comments
Plants wilt with symptoms as above, but stem discoloration is not evident.	
Dry soil	Water.
Waterlogged soil	Plant in well-drained area; do not over water.
Verticillium wilt (fungal disease)	Rotate; use certified, disease-free plants, resistant varieties; plant in well-drained area; remove and destroy affected plants.
Root rot (fungal disease)	Rotate; plant in well-drained area; do not over water; remove plant debris; apply registered fungicide.
Ripening berries covered with tufts of gray, green, white, or black moldy growth.	
Fungal fruit rot (any of several)	Pick berries regularly and cool immediately; prune for better air circulation; avoid wetting leaves; control weeds; apply registered fungicide.
White or tan spots with purple borders on canes; canes die back.	
Anthracnose (fungal disease)	Prune out old canes immediately after harvest; thin out weak and unproductive canes; improve air circulation.
Grapes	
Whitish or gray fungus patches on leaves and later on fruit.	
Powdery mildew (fungal disease)	Train and prune for better air circulation; control suckers and weeds; apply registered fungicide.
Leaf resembles a fan; main veins drawn together and teeth along margins elongated; plants stunted.	
Fan leaf (viral disease)	Purchase certified, virus-free stock; do not replant in same location for 10 years unless soil is fumigated; remove and destroy affected plants.
Herbicide injury	Be careful when applying herbicides.

Symptoms/Possible causes	Management and comments
Strawberries	
Gray, fuzzy mold on ripening fruit.	
Botrytis (fungal disease)	Space plants for better air circulation; provide drier growing conditions; do not over fertilize; remove and destroy affected fruits; apply registered fungicide.
Plants wilt; leaves may turn brown at margins; roots and crowns look discolored when cut open.	
Root rot (fungal disease)	Rotate; use disease-free plants; plant in well-drained area; do not over water; remove plant debris.
Malformed berries; looks like several berries have grown together.	
Fasciation, a response to environmental conditions	Common in certain varieties—may be caused by insect activity.

Ornamental trees and shrubs—general

- Most ornamental tree and shrub problems can be diagnosed from this list of general problems; only very common problems specific to certain trees or shrubs are listed under specific plants.
- This key is not a comprehensive list of plant symptoms, causes of damage, or management techniques. Refer to this chapter's general discussion of problem diagnosis and to other references for more information.
- Cultural, mechanical, and biological methods are listed first under "Management and comments." Chemical methods are listed last.

Symptoms/Possible causes	Management and comments
Many small twigs broken off.	
Squirrel damage	Squirrels prune twigs for nest building and sometimes prune more than they need.
Wind breakage	—
Large areas of split bark; no decay evident.	
Frost cracks	Use tree wrap to protect bark from winter sun and temperature extremes.
Sunscald	Thin-barked trees like young ones split when exposed to intense sunlight; use tree wrap or block sun on bright days; avoid heavy fertilization in late summer and fall.
Mechanical injury (e.g., lawn mower injury)	Remove grass from around base of trunk to avoid mowing too closely.
Large areas of split bark; decay evident in wood.	
Secondary decay of any of the wounds described above	Remove loose bark back to live cambium so the tree can heal itself.
Fungal or bacterial canker	Prune away affected parts; apply registered fungicide.
Gray-white, powdery growth on leaves; leaves may be distorted.	
Powdery mildew (fungal disease)	Improve air circulation; control weeds; apply registered fungicide.
Black, sooty growth on leaves and/or stems.	
Sooty mold (fungus that grows on honeydew substance secreted by aphids and other insects)	Identify insects; if aphids, spray plant with a powerful stream of water to wash off insects and mold; apply insecticidal soap or registered insecticide.

Symptoms/Possible causes	Management and comments
Brown, dead areas on leaf margins.	
Leaf scorch, caused by insufficient transport of water to leaves	Scorch is usually caused by weather, but root rots or other root damage can also be involved. Water tree well during dry periods.
Cold injury	—
Chemical injury	Chemical injury to trees is not common but does occur. Be careful when using herbicides.
Interveinal yellowing of leaves; no wilting.	
Nutrient or mineral deficiency	Test soil; supply nutrients based on results.
Iron tied up in soil because of high soil pH	Test soil; supply iron if needed.
Waterlogged soil results in poor transport of nutrients to leaves	Improve drainage; do not over water.
Large, corky galls at base of tree and on roots.	
Crown gall (bacterial disease)	Treat preventively with biological control agent; minimize wounds when pruning; disinfect pruning equipment between trees; improve drainage; consult an arborist about pruning out galls. Trees may live for many years in spite of galls.
Brown, gray, green, or yellow crusty, leaf-like growths on trunk and branches.	
Lichens	Lichens are a combination of algae and fungi; they grow in moist, shady areas and seldom cause damage.
Early leaf drop.	
Environmental stress such as drought, compacted soil, or transplant shock	Provide better growing conditions.
Various insects or diseases	Look for signs of the causal agent; control as needed.

Symptoms/Possible causes	Management and comments
General browning of conifer needles.	
Drought	Water well during dry weather.
Transplant shock	Water regularly after transplanting.
Girdled roots	Be sure main roots are not curled around themselves when transplanted; remove all strings and wraps before planting.
Plant is root bound	Cut container root ball in several places before transplanting.
Dog urine injury	—
Fungal disease	Contact diagnostic clinic.
Yellow and green mottle or mosaic pattern on leaves; leaves may be distorted.	
Viral disease	No controls; removal of plant may be necessary if virus spreads easily.
Sunken cankers on trunk or branches; plant may wilt or show poor growth.	
Fungal or bacterial canker	Prune away affected limb or bark areas.
Oozing sap on trunk.	
Insect borers	Contact diagnostic clinic.
Mechanical injury	Prevent lawn mower or weed trimmer injury.
Leaves chewed or completely eaten.	
Various caterpillars, sawflies, leaf beetles, etc.	Identify pest; use biological control agent; apply registered insecticide while insects are young and before damage is extensive.
Scurfy, scale-like structures tightly attached to leaves, twigs, or branches.	
Various scale insects	Use biological control agent; spray with dormant oil during winter to destroy eggs.
Young leaves puckered, curled, or distorted; clear, sticky substance on leaves; clusters of small insects on undersides of leaves.	
Aphids	Spray plant with powerful stream of water to remove insects; use biological control agent.

Symptoms/Possible causes	Management and comments
Leaves off color with tiny white or yellow spots; may appear dirty due to fine webbing and collected dust.	
Spider mites	Spray plant with powerful stream of water to remove mites; use predatory mites.

Ornamental trees and shrubs—specific

Most ornamental tree and shrub problems can be diagnosed from the list of general problems above; only very common problems specific to certain trees or shrubs are listed below.

Symptoms/Possible causes	Management and comments
Birches	
Leaves sparse, especially at top of tree; swollen ridges in bark.	
Desiccation	Inadequate watering winter and summer; low humidity.
Bronze birch borers	Becoming more of a problem in Wyoming.
Leaves with pale blotches of varying size and shape.	
Birch leafminers	Treat with registered insecticide when first leaves are fully formed.
Dogwoods	
Large, brown, irregularly shaped blotches on leaves; dead leaves hang on through winter.	
Anthracnose (fungal disease)	Prune and destroy affected twigs; rake and burn fallen leaves; avoid wetting canopy; apply registered fungicide.
Native trees die, bark sloughs away.	
Collar rot (fungal disease)	Avoid damaging trunks with lawn mowers, etc.; remove loose bark; avoid wetting trunk.

Symptoms/Possible causes	Management and comments
Leaf petiole curls; leaf curls upward, sometimes discolors.	
Environmental stress	Dogwood leaves may curl from lawn herbicides, too much water, or many other stress conditions.
Junipers	
Entire plant dies.	
Root rot, probably Phytophthora	Remove plant debris; rotate; plant in well-drained area; do not over water.
Twigs die.	
Juniper twig blight (fungal disease)	Prune and burn affected twigs; improve air circulation; avoid wounding twigs or wetting foliage; apply registered fungicide.
Twigs webbed together tightly; affected twigs turn brown in warm weather.	
Juniper webworm	Apply registered insecticide in early spring.
Twigs appear clubby and gall like; entire plant appears more compact than normal.	
Juniper tip midge	Apply registered insecticide.
Maples	
Irregular, brown spots on leaves (on Norway maple, brown areas follow leaf veins); tree otherwise healthy.	
Anthracnose (fungal disease)	Rake and destroy fallen leaves; destroy cankered twigs; apply registered fungicide.
Scorch, caused by hot, dry weather	Water tree well.
Note: Anthracnose can be confused with scorch if leaf spots have enlarged and run together. In early stages, it should be possible to distinguish between the two; scorch is mainly at leaf margins.	

Symptoms/Possible causes	Management and comments
Brown, dry areas on margins of leaves only; tree otherwise healthy.	
Scorch, caused by hot, dry weather	Water well.
Leaves on tree suddenly wilt, may turn yellow and drop off; wilt may occur on one side of tree only; tree may die suddenly or decline over period of years; no external trunk or branch damage evident; some branches may have brown streaks in wood.	
Verticillium wilt (fungal disease)	Avoid heavy fertilizing, which produces soft, succulent growth; prune away dead branches; don't replant the site with a susceptible species; disinfect tools when pruning.
Drought	Water well.
Small, red, green, or black globular growths on upper leaf surfaces.	
Gall mites	No control; harmless in most cases.
Pines	
Rough, elongated, swollen areas develop on trunks and branches; orange-colored spore masses burst through the cankered bark.	
White pine blister rust (fungal disease)	Prune away affected branches; rate planting sites for blister rust hazard; plant resistant varieties in high-hazard sites; don't plant near currants.
Rough, globular galls on trunk and branches covered with orange spores in late spring.	
Western gall rust (fungal disease)	Remove galls where practical.
Chlorotic spots appear on affected needles in fall and winter; far end of needle turns reddish brown while base remains green.	
Red band needle blight (fungal disease)	Prune out dead and dying branches; clean up plant debris under tree; provide good drainage and air circulation; control weeds.
During spring, last year's needles turn yellow, then brown, and drop; football-shaped fruiting bodies form on affected needles.	

Symptoms/Possible causes	Management and comments
Lophodermium needle cast (fungal disease)	Provide good air circulation; control weeds; clean up plant debris under tree; apply registered fungicide.
Needles at tips of twigs turn yellow, become deformed and stunted.	
Eriophyid mites	Apply registered insecticide.
Roses	
Black, circular spots with feathery edges surrounded by yellow halo on leaves; leaves drop.	
Black spot (fungal disease)	Avoid wetting foliage; rake and destroy affected leaves; prune affected canes back to two buds; improve air circulation; apply registered fungicide.
Pustules containing orange or brown, powdery spore masses appear on lower leaf surfaces first and then upper leaf surfaces.	
Rust (fungal disease)	Remove and destroy affected leaves; remove plant debris; apply registered fungicide.
White, powdery fungal growth on young leaves; distortion is common.	
Powdery mildew (fungal disease)	Improve air circulation; control weeds; remove plant debris; use registered fungicide.
Various patterns of yellow and green on leaves including streaks, rings, vein clearing (yellow veins), or blotches.	
Viral disease	Common on roses; these viral diseases generally enter through grafts and are not transmitted from plant to plant; buy healthy plants; maintain vigor by proper care of shrub.
Nutrient deficiency	Test soil; supply nutrients based on results.
Spruce	
Needles turn yellow in late winter and brown as weather warms; drop off in late spring, leaving bare branches.	
Spruce aphids	Apply registered insecticide.
Older, inner needles of branches appear speckled with dull yellowish blotches; later, needles turn brown or purple from tips back and drop; rows of tiny, black specks on needles are visible with a magnifying glass.	
Rhizosphaera needle blight (fungal disease)	Space plants adequately for better air circulation; remove plant debris; avoid wetting foliage; do not prune when foliage is wet; apply registered fungicide.

Annual and perennial flowers—general

- Most annual and perennial problems can be diagnosed from this list of general problems; only very common problems specific to certain flowers are listed under specific plants.
- This key is not a comprehensive list of plant symptoms, causes of damage, or management techniques. Refer to this chapter's general discussion of problem diagnosis and to other references for more information.
- Cultural, mechanical, and biological methods are listed first under "Management and comments." Chemical methods are listed last.

Symptoms/Possible causes	Management and comments
Plants wilt; flowers may drop; leaves may turn yellow.	
Dry soil	Water.
Waterlogged soil	Improve drainage; do not over water.
Transplant shock	Do not transplant during hot, sunny weather; water regularly after transplanting.
Root, stem, or corm rot (fungal or bacterial disease)	Plant in well-drained area; do not over water; destroy affected plants.
Soil-inhabiting insect pests	Look for and identify problem insects; contact diagnostic clinic.
Seedlings wilt; stems turn brown and soft and may be constricted at the soil line.	
Damping-off (fungal disease)	Plant in well-drained area; improve air circulation; allow soil to dry slightly between waterings; apply registered fungicide in early stages.

Symptoms/Possible causes	Management and comments
Plants fail to flower; foliage looks healthy.	
Wrong season	Plants have specific day-length requirements for flowering.
Cool weather	Wait for warmer weather.
Insufficient light	Do not plant sun-loving plants in shade.
Too much nitrogen	Do not over fertilize; nitrogen stimulates foliage growth, sometimes at the expense of flower production.
Immature plants	Biennials and young perennials often do not flower the first year.
Tall, "leggy" plant; stem and foliage pale or yellow.	
Insufficient light	Do not plant sun-loving plants in shade.
General yellowing of leaves; yellowing may be interveinal; plant may be stunted; no wilting.	
Nutrient deficiency	Test soil; supply nutrients based on results.
Viral disease (any of several)	Contact diagnostic clinic.
Grayish-white, powdery growth on leaves.	
Powdery mildew (fungal disease)	Plant resistant varieties; improve air circulation; control weeds; apply registered fungicide.
Pustules containing orange, yellow, or brown powdery substance on leaves.	
Rust (fungal disease)	Plant resistant varieties if available; remove and destroy affected leaves; avoid wetting foliage; remove debris; apply registered fungicide.
Flowers wilt or fail to open; grayish mold appears on flowers in moist weather.	
Botrytis gray mold (fungal disease)	Remove and destroy affected flowers; improve air circulation; apply registered fungicide.
Yellow and green mottle or mosaic pattern on leaves.	
Viral disease (any of several)	Use resistant varieties; control insect vectors; remove and destroy affected plants.
Tiny, white dots (stippling) or white, interveinal areas on leaves.	

Symptoms/Possible causes	Management and comments
Spider mites	Use predatory mites; apply insecticidal soap or registered miticide.
Clusters of insects on stems or undersides of leaves; leaves may be curled or distorted.	
Aphids	Pick off, mash, or wash away insects; encourage insect predators; apply insecticidal soap or registered insecticide.
Leaves chewed or completely eaten.	
Various insects	Contact diagnostic clinic.
Slugs	Look for slime trails; use slug barrier or bait.
Light-colored tunnels or blotches in leaves.	
Leafminers	Remove and destroy affected leaves. Contact diagnostic clinic.
Tiny, white-winged insects on undersides of leaves.	
Whiteflies	Use yellow sticky traps; apply insecticidal soap or registered insecticide.
White, cottony masses on leaves or stems.	
Mealybugs	Use biological control agent; apply registered insecticide.

Annual and perennial flowers—specific

Most annual and perennial flower problems can be diagnosed from the list of general problems above; only very common problems specific to certain flowers are listed below.

Chrysanthemums	
Flowers greenish instead of normal color; upper branches of flowering stem are yellowish and upright.	
Aster yellows (phytoplasma disease)	Control insect vectors; destroy affected plants.
Yellowing and wilting of foliage; leaves die from base of plant upward; discolored brown areas in stems.	
Verticillium wilt (fungal disease)	Use resistant varieties if available; obtain cuttings only from healthy plants; rotate; remove and destroy affected plants early.

Symptoms/Possible causes	Management and comments
Geraniums	
Corky, raised spots on lower leaf surfaces.	
Oedema, a physiological problem associated with over watering	Do not over water.
Plants wilt; brown or black rotted area evident at base of stem; brown spots may be present on leaves.	
Fungal or bacterial root or stem rot (any of several)	Plant in well-drained area; do not over water; remove dead plants.
Iris	
Leaves turn yellow and wilt; if pulled gently, leaves detach from plant; soft, slimy, smelly rot at base of plant.	
Bacterial soft rot (bacterial disease)	Dispose of affected plants and rhizomes; divide plants frequently to avoid overcrowding; avoid wounding rhizomes; dry rhizomes in sun before replanting.
Small, brown spots with water-soaked edges; spots may run together; leaves may die.	
Leaf spot (fungal disease)	Improve air circulation; remove and destroy affected plant parts; apply registered fungicide.
Marigolds	
Leaves yellow; plants wilt and die.	
Fusarium wilt (fungal disease)	Improve soil drainage and air circulation; rotate; destroy affected plants; drench beds with registered fungicide.
Wet, cold soils	Delay planting until conditions are right.
Leaves discolored and look dusty with tiny webbing.	
Spider mites	Wash off foliage with water frequently; use predatory mites; apply insecticidal soap or registered miticide.
Leaves reddish, smaller than normal.	
Lack of nutrients	Provide nitrogen fertilizer.
Cold temperatures	Wait for warmer weather.

Symptoms/Possible causes	Management and comments
Narcissus (daffodils)	
Water-soaked areas that enlarge and wither on flower edges; later, small, elongated spots that turn brown on leaves; leaves may die.	
Fire (Botrytis) (fungal disease)	Rotate out of area for two years; improve air circulation; remove and destroy affected parts; apply registered fungicide.
Spots appear on top 2 to 3 inches of leaves as they emerge; leaves die.	
Leaf scorch (fungal disease)	Rotate to new planting site each year; apply registered fungicide.
Leaves have light green, grayish-green, or yellow stripes or mottles.	
Yellow stripe (viral disease)	Control insect vectors; remove and destroy affected plants.
Flowers smaller than normal; white streaks or blotches may appear.	
White break (viral disease)	Control insect vectors; remove and destroy affected plants.
Plants smaller than normal; fewer flowers than normal; plants die.	
Narcissus bulb flies	Dig and inspect bulbs at least every two years; discard those that are infested.
Peonies	
New shoots wilt and turn black; flowers, buds, leaves, and stems turn brown and leathery; gray, fuzzy mold may appear in wet weather.	
Botrytis blight (fungal disease)	Prune out affected parts; improve air circulation; remove plant debris; do not use mulch in spring when plants are emerging; apply registered fungicide.
Frost damage	Provide cover.
Tulips	
Stems are very short and flowers bloom at ground level.	
Warm spring and/or inadequate winter cooling	After digging bulbs, chill them in refrigerator before replanting.

Symptoms/Possible causes	Management and comments
Light or dark spots on leaves and flowers; spots enlarge to form large, gray blotches; fuzzy, brown or gray growth appears on spots during wet weather; leaves and stems distorted.	
Botrytis blight (fungal disease)	Rotate; improve air circulation; destroy affected plants; apply registered fungicide.
Flowers streaked, spotted, or mottled in an irregular pattern; leaves may also be streaked or mottled.	
Viral disease (any of several)	Many of the stripes in tulips are caused by viral diseases, but some may be desirable; either destroy the affected plants or put them far enough away from others to prevent the spread of disease; control insect vectors.
Thrips (tiny insects that feed on emerging flowers)	Use biological control agent, insecticidal soap, or registered insecticide.
Zinnias	
Off-color lesions near base of plant followed by white, cottony growth on stems; plant wilts and dies.	
Stem rot (fungal disease)	Space plants for better air circulation; remove and destroy affected plants; apply registered fungicide.
Plants wilt; no sign of root rots or stem disorders.	
Dry soil	Supply moisture.
Soil too wet	Improve drainage; do not over water.

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Integrated Pest Management

14

All gardeners experience pest problems from time to time, and pest management can be a real challenge. Insects, plant diseases, weeds, slugs, and other animals can cause significant plant damage. How one reacts to a pest problem depends on the value of the affected plants, the cost of treatment, the toxicity of available controls, and one's personal gardening philosophy.

Many gardeners are concerned about the use of pesticides. Some pesticides, if not used, stored, and disposed of carefully, can harm the applicator, the environment, children, pets, or other nontarget organisms.

These concerns can be met by implementing integrated pest management (IPM) practices in one's garden. Thoughtful, well-researched pest management choices will reward the gardener, the environment, and the beneficial organisms that share the space.

Topics in this chapter

- What is IPM?
- Developing an IPM program
- Cultural methods
- Physical methods
- Biological methods
- Chemical methods

What is IPM?

Integrated Pest Management (IPM) is a strategy to prevent and suppress pests with minimum impact on human health, the environment, and nontarget organisms.

Steve Dreistadt, University of California

Integrated pest management has been used in commercial agriculture since the 1970s. Many of the principles that guide farmers in making pest management decisions can be used by gardeners as well.

IPM is a systematic approach to pest management that focuses first on preventing problems. It involves monitoring pest populations, identifying pests, and choosing a combination of tactics to keep pest populations at an acceptable level. Tactics may include

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cultural, mechanical, biological, and chemical methods of pest management. IPM stresses trying the least toxic methods first.

Developing an IPM program

Monitoring

Don't wait for trouble to happen. Regularly check plants for signs and symptoms of pest damage. During the height of the growing season, check each plant two or three times per week.

See Chapter 3, *Entomology,* Chapter 4, *Disease,* and Chapter 13, *Diagnosing Problems*.

Because many pests prefer sheltered sites, inspect the undersides of leaves and the inner parts of plant canopies. Occasionally, check plants at night with a flashlight.

Look closely at any plant that is missing leaves, flowers, or fruit. Also look for plants whose color, texture, or size looks unusual. Compare each plant to others of the same variety and to what it looked like in previous years during the same season.

Take notes on findings. Record the date, damage present, and any pests seen. In subsequent years, such records will help one know when to look for signs and symptoms of specific pests and how to recognize them when they are seen.

Several tools will help with monitoring. A 6–15X hand lens can be very useful when checking for spider mites, fungal fruiting bodies, and other small signs and symptoms. Plastic bags and glass jars are good for collecting pests and examples of damage. A flashlight is another useful tool because many pests are active at night.

Some insect pests can be dislodged by laying a sheet below an infested plant and gently shaking the plant. Other insects can be monitored with traps. See "Physical methods" later in this chapter for more information.

Identifying pests

Most plant problems in home gardens are due to a nonliving factor such as poor growing conditions, temperature extremes, poor water management, soil compaction, or mechanical injury. In the face of a suspected plant problem, one's first step is to rule out these factors as the cause.

The next step is to find the pest itself or typical signs and symptoms associated with it. Correctly identifying a pest is half the battle and can require some detective work. Remember that many organisms do no damage, and many others are beneficial. Make sure the organism identified is actually the one doing the damage and not just one that happens to be present.

Many resource materials can help with pest identification. An experienced Master Gardener or Cooperative Extension Service agent can provide assistance.

Don't stop with correct identification. Learn all about the pest's life cycle. Try to determine at which point the pest is most susceptible to control measures. For example, an insect may be soft bodied as a larva and hard bodied as an adult. Typically, soft-bodied insects are controlled more easily than hard-bodied ones. Also, it usually is easier to control relatively immobile insects than those that fly. Thus, the timing of controls may be critical.

Similar principles apply to weeds. For example, seedlings are often controlled more easily than mature weeds.

Establishing a tolerance level

Establish an acceptable injury level by considering how much damage both the gardener and the plants can tolerate. A small amount of plant damage is not inherently undesirable. For a pest's natural enemies to survive, they must have a pest population on which to feed.

A meticulous gardener may not be willing to tolerate much damage and will thus be aggressive in monitoring and managing pests. Less meticulous gardeners are willing to accept more damage. The amount of time, energy, and money one is willing to invest in pest management also will affect one's tolerance level.

Also consider how much damage each plant can tolerate. Some food plants can tolerate quite a bit of defoliation without exhibiting decreased yields. Likewise, significant defoliation can occur on some ornamental plants without causing permanent damage. Seedlings are less able to withstand pest damage than are mature plants. Use references and experience to help determine whether a plant is likely to withstand pest damage.

Developing a pest management strategy

After a pest has been identified and its damage determined to be unacceptable, develop a pest management strategy. The strategy may involve the use of more than one tactic. The rest of this chapter focuses on tactics for managing insects, diseases, and other pests.

Evaluating results

The evaluation of results is an important and often overlooked part of a pest management program. Did the strategy work? Was the pest controlled to one's satisfaction? These questions can be answered by continuing to monitor plants carefully. Again, record observations for future reference.

Cultural methods

Some cultural pest management methods prevent pest problems by keeping plants healthy and growing vigorously. Others directly tackle specific pest problems.

Choosing resistant or tolerant varieties

The selection of plants strongly influences what pests are likely to be encountered. When possible, choose plants that are not prone to serious pest problems.

Most garden plants are available in more than one variety (*cultivar*). Some varieties are genetically *resistant* to attack by certain diseases and insects. A plant's level of resistance is determined by its physical characteristics or chemical composition. Other varieties can tolerate a lot of damage without a significant decrease in appearance or yield. These plants are termed *tolerant*. Some of the most common garden problems such as black spot on roses, scab on apples, cytospora on cottonwoods, and fusarium on tomatoes can be avoided by choosing resistant or tolerant varieties.

Some plants have natural resistance or tolerance. In other cases, plant breeders produce resistant or tolerant plants. Thus, new varieties are introduced continually. Consult seed and plant catalogs, nurseries, and county extension offices for suggested varieties.

Putting the right plant in the right place

Place plants in an environment where they will grow well. A few plants will grow in a wide variety of environments, but most require fairly specific conditions. Consider neighboring plants, soil pH, moisture, drainage, and exposure to sun and wind when choosing plants for a specific site.

Many gardeners make the mistake of going to a nursery and choosing the most beautiful plant regardless of whether they

See Chapter 22, *Landscape Design*.

have an appropriate place for it. It is much wiser to analyze the conditions of a planting space and then select a plant that will thrive in those conditions.

Starting with healthy transplants

Buy only plants that are free of pests, wounds, and symptoms of insect or disease problems. Choose healthy-looking plants with good color. Container plants should be in a sterilized potting medium and should be well rooted but not potbound.

Give plants a good start by planting them properly. Planting techniques for specific types of plants are discussed in other chapters of this handbook. Space plants according to their mature size. Crowded plants invite pests.

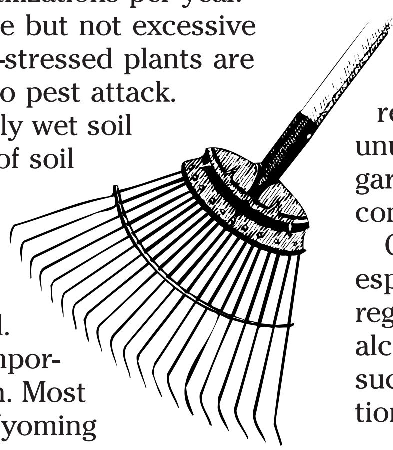
Keeping plants healthy

Plants growing well are less likely to suffer a pest attack than are stressed plants and are also better able to withstand pest damage if an infestation does occur.

Know plants' nutrient needs and fertilize accordingly. An under-fertilized plant is stressed and vulnerable to pest attack, and an over-fertilized plant may have excess succulent growth that can invite disease and insect pests. Some landscape plants require very little, if any, fertilization. Others, especially those that flower or fruit heavily, may require several fertilizations per year.

See Chapter 2, *Soils and Fertilizers*.

Provide adequate but not excessive irrigation. Drought-stressed plants are more susceptible to pest attack. Plants in excessively wet soil suffer from a lack of soil oxygen and are vulnerable to attack by root-disease organisms that prefer wet soil.



Soil pH also is important to plant health. Most soil pH levels in Wyoming are above 7, so purchase plants accordingly.

Adding organic matter to soil helps retain water and nutrients in sandy soil and improves drainage in clay soil. It also encourages beneficial soil micro-organisms. These microbes break down organic matter and make nutrients available to plants. There is also evidence that microbes and fatty acids in compost can suppress certain soilborne diseases.

Keeping gardens clean

Proper sanitation can prevent many pest problems. Many pests live and breed in crop debris, so promptly remove any vegetation that isn't serving a purpose. Remove all unused fruit immediately.

Remove pest-infested leaves and fruit as soon as they are seen. If an annual plant is badly infested with insects or disease, remove the entire plant. Prune out diseased and dead branches of woody plants. Do not add disease or insect-infested plant parts to a compost pile. Destroy them instead.

See Chapter 15, *Composting*.

Keep gardens as weed-free as possible during the growing season. Weeds harbor insects and diseases in addition to competing with garden plants. They provide food, shelter, and a place to breed for insects, slugs, and diseases. Cutworms, earwigs, flea beetles, thrips, aphids, and leafhoppers are common pests associated with weedy areas.

Eliminate hiding places for slugs by removing boards, plastic sheeting, unused plant pots, and plant debris from gardens. Regularly check for pests under containers and in other hiding spots.

Clean gardening tools, especially pruning tools, regularly. Use rubbing alcohol, a disinfectant such as Lysol, or a solution of one part bleach to

See Chapter 5, *Weeds*.

nine parts water. If pruning diseased plants, be sure to disinfect the tools between each cut.

Rotating annual plants

When the same plants are grown in the same soil each year, insect and disease populations build up. Many pests overwinter in soil and move to a specific type of host plant in the spring. By growing different plants in different places each year, one can deprive pests of their hosts. This technique works best for annual flowers and vegetables since they are replanted each year.

Since insects and diseases often infest members of the same plant family, it is best to rotate to a member of a different family (Table 1). A more extensive list of plant families is found in Chapter 10, *Plant Disease.*

See Chapter 4, *Disease*.

A similar principle holds true for perennials. If removing a perennial plant because of a soilborne insect or disease, plant something from a different family in its place.

Companion planting and intercropping

Companion planting involves growing two or more specific types of plants together in the hope that the combination will discourage disease and insect pests. For example:

- One plant can act as a "trap" and draw pests away from the other.
- One plant may produce a repellent or toxic substance that discourages or harms pests.
- One plant may provide habitat for natural enemies of an other plant's pests.

All of these interactions can and do occur. Unfortunately, relatively little research has been done on these topics, and many claims of positive results have not been substantiated.

Experiment in the garden and take careful notes. Over several seasons, certain plants may have fewer pests when grown close to another specific type of plant. Keep in mind that even if a particular combination of plants reduces pest problems, competition between the plants may decrease crop yields.

Intercropping involves mixing plants to break up pure stands of a single crop. The physical separation of individual plants of one type by those of another may interrupt the movement of insects and diseases. However, although this patchwork planting approach may discourage pests that feed on a narrow range of plants, it may encourage generalist feeders such as cutworms, thrips, and aphids.

Table 1.—Plant families for rotations.

Plant family*	**Representative members**
Apiaceae	Carrot, celery, fennel, parsley, parsnip
Asteraceae	Chicory, endive, lettuce
Brassicaceae	Bok choy, broccoli, brussel 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 found in Chapter 10, *Plant Disease.*

Physical methods

See Chapter 10, *Vegetables*.

Physically blocking, removing, or trapping pests can be very successful and causes little disruption of a garden's ecosystem.

Hand picking

Hand picking large, clearly visible, or slow-moving insects and slugs can reduce pest populations in small plantings. For example:

- Pick off large beetles and caterpillars. (Make sure they are really pests.) Crush the insects or drop them into a container of soapy or oily water.
- Rub off scale insects with a fingernail or a plastic scrub pad.
- Shake insects such as thrips or beetles onto a sheet and destroy them.
- Remove and destroy entire leaves infested with leafminers.

These techniques require careful observation of affected plants, including the undersides of leaves. Hand pick most species every few days to keep damage at an acceptable level.

The best time to collect most insects is in the early morning when temperatures are cool and insects are sluggish. Use a flashlight at night to find slugs and other pests that feed at night and hide during the day.

Spraying with water

A forceful stream of water can dislodge, injure, or drown small, soft-bodied pests. This technique is useful for aphids, mites, and mealybugs. The water must hit the pests directly, so one may need to spray the undersides of leaves. Spray early in the day so plants have a chance to dry before evening. It may be necessary to spray every few days to remove returning pests.

Pruning

If pests are concentrated at one or two sites on a plant, it may be possible to prune them out. For example, aphids often cluster on new growth. Tent caterpillars and fall webworms gather in webs; prune them out and burn the entire web, if necessary. Remove cane borers in raspberries and roses by pruning the affected canes while the insects are inside. Cankers on landscape and fruit trees can sometimes be removed by pruning as well.

See Chapter 16, *Pruning*.

In addition, regular pruning makes a plant less dense, which allows beneficial insects to locate their prey more easily. It also improves air circulation, which decreases the incidence of foliage diseases.

Before pruning for pest control, evaluate whether potential pest damage is greater than potential pruning damage.

Using barriers

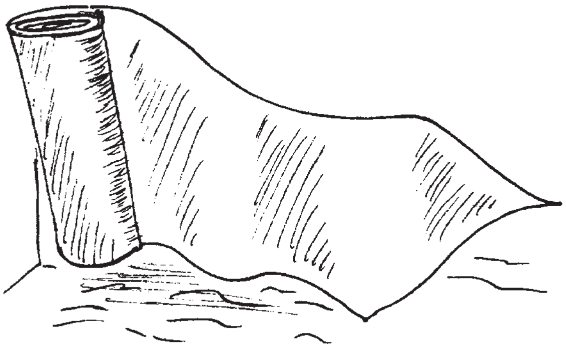
Row covers, plant cages, plant collars, sticky barriers, metal barriers, and diatomaceous earth physically shield plants from insect and slug damage.

Row covers

Row covers are sheets of synthetic material that cover an entire row of plants or individual plants. Originally designed to extend the gardening season by retaining heat, they also keep insect pests away from plants. They can exclude migrating pests such as root maggots, cucumber beetles, flea beetles, whiteflies, aphids, leafminers, and cabbage loopers.

Row covers should allow air, water, and light to reach plants. Apply them before seedlings emerge or when setting out transplants.

Floating row covers are among the easiest to use. Simply place them over plants, leaving enough slack to allow for



plant growth. Bury the edges to make certain insects can't enter.

Check under covers frequently for intruders. Pests that do get in are protected from their natural enemies and can cause a lot of damage. Remove covers if it gets too hot underneath, if plants require insect pollination, or when plants are large enough to withstand some insect damage.

Plant cages

Protective cages can be made by attaching screen or row cover material to wood, wire, or PVC-pipe frames. These cages should last several seasons.

Another way to make a cage is to shape a piece of screen into a cone and staple the edges together. Place cones over seedlings until plants are large enough to tolerate some damage.

Always sink cages about 1 inch deep in the ground.

Plant collars

Collars can 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 each tube 1 inch deep.

To protect against root maggots, cut tar paper into disks at least 3 inches in diameter, cut a slit in each disk for a plant stem, and slip each disk around a seedling so the tar paper lies on the soil surface. Flies are then unable to lay eggs next to the seedlings.

Sticky barriers

Sticky materials 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 a plant, first wrap the stem or trunk with a 3 to 4-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.

Metal barriers

A garden bed, container, or group of plants can be edged with strips of copper (or a combination of copper and zinc) to repel slugs. When these pests try to cross a copper strip, they are repelled by a chemical reaction that occurs between the copper and their slime. The strip should be at least 6 inches wide to keep large slugs from "hopping the fence."

Diatomaceous earth

Another barrier to insects is diatomaceous earth, which is made of the fossilized remains of diatoms (tiny algae). This material has microscopic, sharp edges that cut an insect's cuticle (outer "skin") and cause dehydration and death. It also can be used to combat slugs.

The main drawback to diatomaceous earth is that it is not effective after it becomes wet, so its use is limited in moist areas. It can be used as a dust on plants if overhead irrigation is not used. Always wear a dust mask when handling diatomaceous earth.

Vacuuming

Commercial growers have used this technique successfully for many years. It works best with insects such as whiteflies and spider mites that congregate in groups and do not scatter when disturbed. Use a hand-held, 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 it overnight if possible, and then discard it.

Mulching

Many disease organisms (*pathogens*) overwinter in the soil. When the weather warms in the spring, they become infectious and can be splashed or blown onto plants by rain or wind. A layer of new mulch laid down in early spring can protect emerging plant tissue from these organisms. For example, this technique can protect roses from the pathogens that cause black spot.

Rototilling

Although rarely used strictly for pest management, tilling does help control certain pests such as slugs, symphylans, and cutworms. Tilling kills some bugs, buries some so deeply they can't crawl back to the surface, and exposes others to predators and extreme weather conditions.

Trapping

Many pests can be attracted to and caught by traps. Some traps kill large numbers of pests. Others are used as monitoring devices; by knowing when a pest is present, one can time control measures effectively.

Traps are unlikely to completely rid a garden of a pest species. They are simply a way to reduce pest populations. They can easily be used in conjunction with other techniques.

Colored sticky traps

Some insects are attracted to certain colors. Take advantage of this fact by placing colored, adhesive-coated traps near a pest infestation. The insects are attracted by the color and then caught in the adhesive. Yellow traps attract whitefly adults, winged aphids, psyllids, fungus gnats, and some species of thrips. Blue traps attract some species of thrips. Red spheres attract apple maggots.

Sticky traps are available in most garden centers, or they can be made at home. To make a flat sticky trap, paint a piece of ¼-inch plywood or other flat surface the appropriate color. For sphere traps, use a commercial trap or paint a croquet or tennis ball. Be sure to use waterproof paint.

Cover the painted trap with adhesive. Use a commercial adhesive, motor oil, petroleum jelly, or a 50/50 mixture of petroleum jelly and dish soap. All of these adhesives can be cleaned off with vegetable oil.

Set the trap on a pole near infested plants or hang it from a branch of an infested plant. Place the trap as close to the infestation as possible. To catch a maximum number of insects, check the trap every few days and renew the adhesive as needed. If using the trap to monitor a pest's emergence or peak flight, check the trap as often as necessary to adequately interpret changes in the pest population.

Rolled newspapers

Moist, rolled newspapers can trap earwigs, sowbugs, and pillbugs. In the evening, lay the traps on the soil surface where pests are numerous. The next morning, tap the pests out of the traps into a dish of soapy water.

Codling moth traps

A band of corrugated cardboard around a tree trunk will capture codling moth larvae in the fall as they travel down the tree looking for a place to spend the winter under loose bark or fallen leaves. Wrap a 2-inch-wide band of large-core corrugated cardboard around the trunk at least 18 inches above the ground. Place the band on the smoothest bark possible so larvae can't get under the band. The corrugations should be vertical (parallel to the tree trunk). When larvae move down the tree, they will enter and remain in the corrugations. Replace the band weekly.

See Chapter 12, *Fruit Trees*

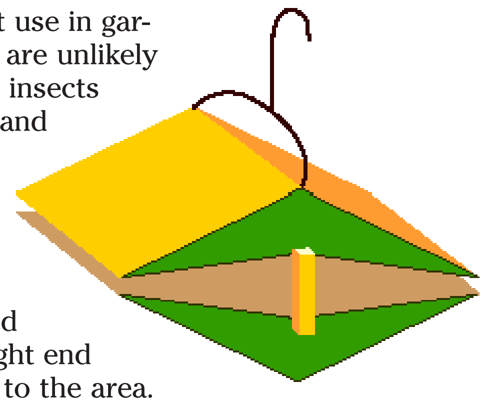
Slug traps

Wyoming gardeners have used slug traps for years. These traps consist of a covered container filled with bait. One can buy slug traps at garden centers, but recycled pint plastic containers with an entrance hole cut in the side work just as well. Fill the traps with beer or commercial bait to the level of the entrance hole and place them on the ground. Remove dead slugs every couple of days. Renew the bait as needed.

Pheromone traps

Some traps are baited with *pheromone* (a chemical that usually attracts a single species) and coated with adhesive to trap pests. Often the pheromone is a synthetic version of the chemical used by females to attract males. Consequently, many pheromone traps capture only male insects.

Pheromone traps are used extensively in commercial agriculture to help farmers detect the presence of a pest species and to time other control measures. This is probably their best use in gardens as well. They are unlikely to capture enough insects to prevent mating and egg laying.



If a gardener has never had a particular pest, do not use the pheromone trap designed for it; the pests might end up being attracted to the area.

Light traps

There are a number of light traps also known as "bug zappers" on the market. These traps are not effective in controlling pests and actually end up killing far more beneficial and innocuous insects than pests.

Biological methods

In a well-balanced ecosystem, insect pest populations are kept in check by natural enemies such as other insects, birds, bats, snakes, frogs, toads, and even fish. Disease organisms are often kept under control by competition from other microorganisms. Even weeds have natural enemies: insects and other animals.

Biological controls can be used to help keep pest numbers low. Don't expect natural enemies to keep a garden pest free, however. Usually some pests need to be present for natural enemies to survive.

Beneficial insects

Most insects are not pests. Only those that feed on desirable plants or transmit disease cause problems for gardeners. Many insects are very useful, and it is worth learning to recognize them. Most good insect references include pictures and descriptions of beneficial insects.

Table 2.—Beneficial insects and the pests they control.

Predators	Pests controlled
Big-eyed bugs	Aphids, leafhoppers, lygus bugs (nymphs), spider mites
Green lacewings	Aphids, leafhoppers, plant bugs (immature), spider mites, thrips
Hover flies (syrphid flies)	Aphids
Lady beetles	Aphids, mealybugs, scales, spider mites
Minute pirate bugs	Aphids, spider mites, thrips, immature stages of many small insects
Parasitoids	**Pests controlled**
Hymenoptera parasites (e.g., Ichneumonids, braconids, and chalcids)	Aphids (larvae), cutworms, loopers, omnivorous leaftiers, oriental fruit moths, tortrix moths
Tachinids	Codling moths, Colorado potato beetles, corn earworms, cutworms, grasshoppers, hornworms, imported cabbage worms, plant bugs, tussock moths, others

See Chapter 3, *Entomology*.

There are three types of beneficial insects: pollinators, predators, and parasitoids.

Insect *pollinators* include several bee and fly species. In home gardens, honeybees (Figure 1), bumblebees, and syrphid flies are the most important pollinators, but many other minor pollinators also play a part.

Predatory insects eat large numbers of other insects. Some are predaceous as both adults and larvae, some are predaceous only as larvae, and some are so only as adults. Many predatory insects feed on only certain types of insects (e.g., lady beetles eat mostly aphids) while others feed on a wide variety of insects. Common predaceous garden insects include lady beetles, praying mantids, green and brown lacewings, ground beetles, minute pirate bugs, damsel bugs, and syrphid fly larvae. See Figure 2 for examples. Spiders, predaceous spider mites, and centipedes are also important predators in a garden ecosystem.

Parasitoids are insects that live on or in a host insect, feed on the host, and usually kill it in the process. Most parasitoids are small, stingless wasps or flies that lay their eggs in or on specific host insects. The eggs hatch, and the larvae feed on the hosts. These insects are not easily seen, but research shows they have an important impact on pest insect populations. Figure 3 illustrates some typical parasitoids of Wyoming.

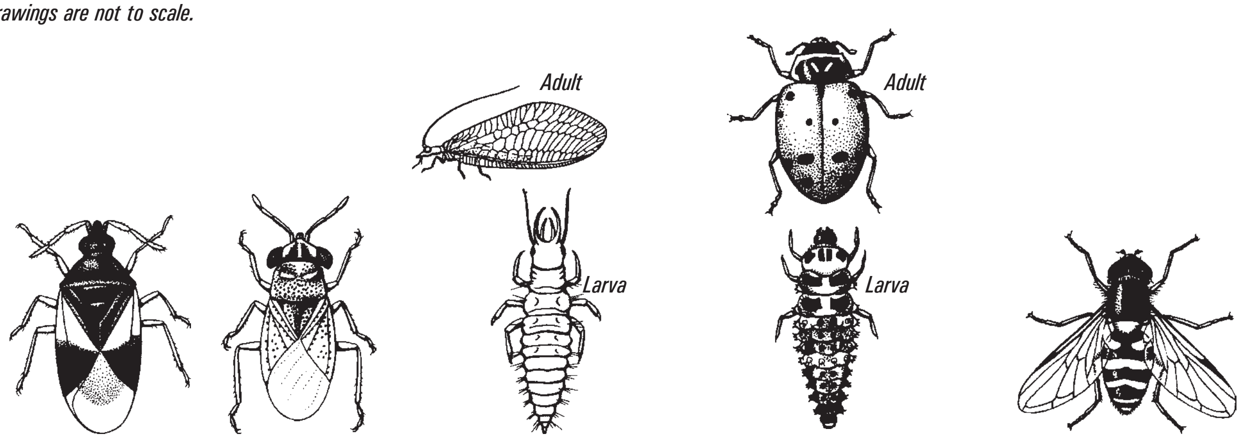
See Table 2 for a list of beneficial insects and pests they control.

Protecting beneficial insects

All beneficial insects are susceptible to insecticides. Most insecticides available to home gardeners are broad spectrum, meaning they kill a wide range of insects including beneficials. If using an insecticide, take the following measures to protect beneficial insects:

Figure 1.—Honeybee. (Reprinted with permission from Ralph E. Berry. Insects and Mites of Economic Importance in the Northwest, *2nd edition, 1998. 221 pp.)*

Drawings are not to scale.



Minute pirate bug
1/8 inch
black and white markings

Big-eyed bug
1/8–1/4 inch
buff gray or black

Green lacewing
3 1/4 inches
green to yellow green with transparent wings

Lady beetle
1/8 inch
red orange
usually with black spots

Hover fly (syrphid fly)
1/2 inch
yellow, black, or white bands

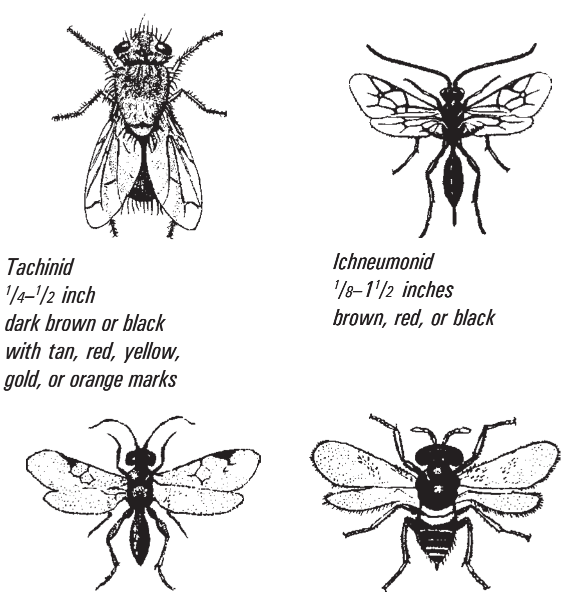
Figure 2.—Common beneficial predatory insects of the Pacific Northwest. (Reprinted with permission from Ralph E. Berry. Insects and Mites of Economic Importance in the Northwest, *2nd edition, 1998. 221 pp.)*

- Choose the least toxic pesticide that will be effective. See "Chemical methods" later in this chapter for more information.
- Spot spray only infested plants.
- Do not spray plants in bloom.
- Spray early in the day when many insects are less active.

Creating habitat for beneficial insects

Invite beneficials to a yard by providing them with food. Pollinators are attracted by a wide variety of blooming plants. Many adult predators and parasitoids feed on nectar and pollen in addition to pest insects. Most are quite small and can reach the nectar and pollen of only small flowers. The flowers that attract them are sometimes referred to as *insectary plants*. Table 3 is a list of common insectary plants for Wyoming.

By scattering insectary plants throughout a garden and landscape, one can attract beneficial insects. Or consider reserving a garden bed or border for insectary plants. Blends of insectary plant seeds are available.



Tachinid
1/4–1/2 inch
dark brown or black with tan, red, yellow, gold, or orange marks

Ichneumonid
1/8–1 1/2 inches
brown, red, or black

Braconid
1/16–1/2 inch
black or dark brown

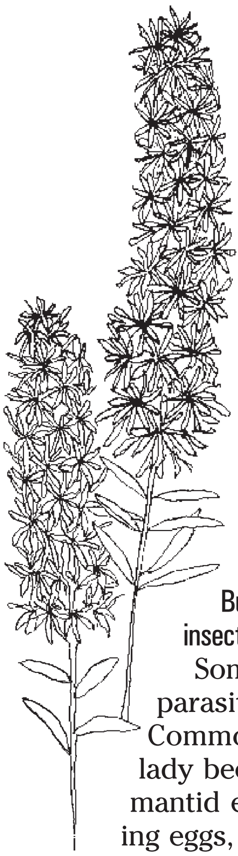
Chalcid
up to 1/8 inch
metallic blue or green

Figure 3.—Common beneficial parasitoids of the Pacific Northwest. (Reprinted with permission from Ralph E. Berry. Insects and Mites of Economic Importance in the Northwest, *2nd edition, 1998. 221 pp.)*

Table 3.—Garden flowers that attract beneficial insects.

Common name/Botanical name*	Predators attracted	Parasitoids attracted
Apiaceae (carrot family)		
Angelica (*Angelica spp.*)	Lacewings, lady beetles	—
Anise (*Pimpinella anisum*)	—	Wasps
Blue lace (*Trachymene coerulea*)	—	Wasps
Caraway (*Carum carvi*)	Bugs, hover flies (syrphid flies), lacewings	Wasps
Coriander (*Coriandrum sativum*)	Hover flies	Tachinids, wasps
Dill (*Anethum graveolens*)	Hover flies, lady beetles	Wasps
Lovage (*Levisticum officinale*)	—	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, soldier 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	—
Fabaceae (legume family)		
Alfalfa (*Medicago sativa*)	Bees, bugs, lacewings, lady beetles	—
Clover (*Trifolium* spp.)	Bees, bugs, lacewings, lady beetles	—
Hydrophyllaceae (waterleaf family)		
Fiddleneck (*Phacelia spp.*)	Bees, bugs, hover flies	—
Polygonaceae (buckwheat family)		
Buckwheat (*Eriogonum* spp.)	Hover flies	—

*This list includes only some of the many plants whose pollen and nectar attract beneficial insects.



Many nonflying predators such as ground beetles and spiders need a place to hide from their enemies. Groundcovers and coarse mulches such as bark dust and straw provide this habitat.

Beneficial insects also need water. If there is no overhead irrigation, sprinkle the plants lightly early in the morning to provide water.

Buying and releasing beneficial insects

Some insect predators and parasitoids can be purchased. Common examples include lady beetle adults, praying mantid egg cases, green lacewing eggs, and parasitoid wasp pupae.

In general, releasing large numbers of beneficial insects has not proven to be an effective method of pest control in home gardens, especially in the case of adult lady beetles. These insects tend to move around and often end up migrating out of the garden. This is less of a problem with lacewings and *Trichogramma*, which are released as eggs, and with mites.

It can be complicated to meet beneficials' needs well enough to keep them in a garden. All beneficials require a reliable food source, and some require a very specific food. Some beneficials also need specific temperature and humidity conditions.

Greenhouses, which provide a controlled, closed environment, often provide the best conditions for the release of beneficials. A number of insects and mites are available for use against greenhouse pests such as whiteflies, thrips, and spider mites. If trying this method of control, make sure to order insects from a reliable source that can provide instructions for maximum success.

Microorganisms

Several microorganisms can be used to keep pest populations in check. As research continues, more products containing viruses, fungi, bacteria, protozoans, and parasitic nematodes will become available.

Bacillus thuringiensis (B.t.)

This bacterium contains a toxin that poisons some insects. When ingested by a susceptible insect, it paralyzes the creature's gut, causing the insect to stop feeding and eventually die.

B.t. has two important advantages over conventional insecticides. First, it affects only a narrow range of insects, thus sparing most beneficials. Second, it is nontoxic to humans, plants, and other animals and has no adverse environmental effects. *B.t.* is registered for use on all plants and can be used up to the harvest date on edible plants.

There currently are three strains of *B.t.* available to gardeners:

- *B.t. kurstaki* is active against lepidopterous larvae (butterflies and moths) such as cabbage loopers. Do not use it on plants that provide habitat for desirable butterflies and moths. A few insects have developed resistance to this strain.
- *B.t. israelensis* is active against mosquito and fungus gnat larvae but is not harmful to other aquatic organisms.
- *B.t. san diego* is active against Colorado potato beetles and elm leaf beetles.

Other *B.t.* products are in development.

A pest must ingest *B.t.* to be killed. Apply *B.t.* when young larvae are feeding since they eat the most and are most easily killed. Thoroughly cover all plant surfaces. Many insects feed on the undersides of leaves, so make sure to spray or dust there as well. Apply *B.t.* on an overcast day or late in the day because it breaks down in sunlight. Most formulations are effective for only a few days, so repeat applications may be necessary.

Parasitic nematodes

These microscopic roundworms kill all stages of certain soil-dwelling insects. They enter an insect through body openings and release a toxic bacterium as they feed. The host insect dies within a few days. When applied properly and at the correct time, parasitic nematodes are active against more than 200 insect species including root weevil larvae, cutworms, and pest beetle grubs.

In order for nematodes to be effective, the soil temperature should be at least 55°F. Thus, they may not be effective against early season pests.

The soil must be moist for nematodes to be active. Water thoroughly before applying and lightly after applying. Keep the soil moist but not soggy for several weeks. Do not apply it in direct sunlight because ultraviolet light kills nematodes. Dusk or dawn applications are ideal.

Nematodes are usually sold on a sponge, in a gel, or on another absorbent material. Mix them with water and apply them to the ground with a watering can or sprayer.

Parasitic nematodes do not adversely affect humans, plants, or earthworms. However, they kill some soil-dwelling beneficial insects.

Parasitic nematodes have a finite shelf life, so make sure to check the expiration date. They also have a short-term effect in the soil. Several weeks after application, nematode activity drops off considerably.

Other microorganisms

Other beneficial microorganisms are used regularly in commercial agriculture and will eventually wbecome available to home gardeners. *Beauveria bassiana,* a fungus that kills aphids, thrips, and other soft-bodied insects, is available to home gardeners. Several products containing microorganisms are available to prevent plant diseases. Expect to see more in the future.

Other animals

Certain species of birds, bats, snakes, frogs, and toads also eat insects. Garter snakes, frogs, and ducks are predators of slugs and are particularly welcome in moist areas.

Beneficial animals can be encouraged to live in a garden by meeting their habitat needs. Water features (especially those with circulating water), plants that provide food and cover, grassy areas, and bird feeders all attract these predators.

Chemical methods

Chemical methods of pest control raise concerns about human safety, toxicity to nontarget organisms, runoff, leaching, disposal problems, and possible residue on food crops. Thus, consider chemical controls only if other techniques do not result in adequate pest control. Some chemical controls can be used in concert with other techniques.

When choosing a chemical, always make certain it is labeled for the plant on which it will be used. Choose the chemical that meets the following criteria:

- Least harmful to the environment
- Least toxic to the applicator
- Most specific to the pest
- Least harmful to beneficial organisms

Labels give a general idea of toxicity by the use of signal words. Pesticides labeled “Caution” are the least toxic, those labeled “Warning” are more so, and those labeled "Danger–Poison" with a skull and crossbones are the most toxic. Other sources of information about pesticides include agricultural chemical references, IPM reference books, county extension offices, and the National Pesticide Telecommunications Network. (See "For more information.")

Insecticidal soap

Sodium or potassium salts of fatty acids are the active ingredient in insecticidal soap. Soap kills insects primarily by damaging their cuticles. It is useful against soft-bodied pests such as aphids, thrips, whiteflies, spider mites, scales, leafhopper nymphs, and some caterpillars.

Insecticidal soap is virtually nontoxic to humans and biodegrades rapidly. It may kill predatory insect larvae that are feeding on pests when soap is applied. Otherwise, it is safe for most beneficials.

Insecticidal soap must contact pests directly to kill them. It is effective only while still wet; there is no residual activity after it dries. It usually does not kill insect eggs, so repeat sprays are often necessary to control newly hatched pests.

Soap can damage certain plants. Use it according to label directions and do not use it on water-stressed plants or if the weather is very hot. Another way to avoid damage is to spray plants, let the soap dry, and then rinse it off with a spray of water.

There are many homemade recipes for insecticidal soap made from liquid dishwashing detergent. These sprays are risky to use because different detergents have different concentrations of active ingredient. If spray is too concentrated, it may harm plants. It is best to use a commercial product that has been tested thoroughly on a variety of plants.

Horticultural oils

Horticultural oils are made from petroleum products, vegetable oil, or fish oil. They kill pests and their eggs by suffocation. Oil sprays can control aphids, scales, whiteflies, mealybugs, spider mites, caterpillars, adelgids, and leafhoppers. They can also protect plant tissue from pathogen entry. Because oils kill on contact, good spray coverage is essential.

See Chapter 19, *Pesticides*.

Horticultural oils are nontoxic to humans and wildlife although they can cause eye and skin irritation. They degrade rapidly, mostly through evaporation.

Oil sprays fall into two categories: dormant oils and summer oils. *Dormant oils* are heavier and are used on woody plants during the dormant season to kill overwintering pests and eggs and to protect against disease. *Summer oils* are lighter and more refined. They can be used year round because they are less likely to damage plants. *Ultrafine oils* are highly refined summer oils and are least likely to cause damage.

See Chapter 12, *Fruit Trees*

To prevent plant damage when using oils, carefully follow label directions, especially dilution rates. Do not use on water-stressed plants or if relative humidity is high. Do not use when the air temperature is below 40°F or above 90°F. Do not use oils on blue evergreens because they break down these plants' waxy coating and turn them green.

Botanical insecticides

Botanical insecticides are derived from plant material. Most botanicals are less damaging to the environment than synthetic insecticides because they break down to nontoxic compounds rapidly, usually within a day or two of application. Thus, there is less chance for environmental contamination or residues on food crops.

Botanicals are not necessarily less toxic to humans, however. Some, such as nicotine sulfate and rotenone, are more toxic than common synthetic garden insecticides. Other botanicals such as azadirachtin (neem extract) are nontoxic to humans and other nontarget organisms.

Because botanicals break down so rapidly, it is important to time applications carefully. Apply the chemical when and where it will reach the greatest number of pests.

Inorganic fungicides and insecticides

A number of mineral-based compounds are toxic to insects and plant disease pathogens. For example, sulfur is both an insecticide and a fungicide. It protects many plants from foliage diseases such as powdery mildew, black spot, and scab. It is also used as an insecticide against thrips and aphids and is a powerful miticide. It is not toxic to humans. Do not use sulfur in conjunction with horticultural oil sprays or when the air temperature is above 85°F. Under these conditions, it can cause plant damage.

See Chapter 4, *Disease*.

Copper is another broad-spectrum fungicide used on fruits, ornamentals, and a few vegetables. Copper-based fungicides protect plants against a wide array of fungal and bacterial diseases. Copper is toxic to fish and earthworms.

Synthetic insecticides, fungicides, and molluscicides

Many garden pesticides are produced synthetically. Common synthetic products include insecticides such as carbaryl, malathion, and acephate; fungicides such as captan, chlorothalonil, and triforine; herbicides such as glyphosate, 2,4-D, and dichlobenil; and molluscicides such as metaldehyde.

See Chapter 19, *Pesticides*.

Toxicity and the potential for environmental damage from these products vary widely. Evaluate each pesticide on its own merits and drawbacks.

When considering using a chemical to control a pest, carefully evaluate the situation and try cultural, physical, and biological controls first. Chapter 19, *Understanding Pesticides,* contains a checklist of things to consider before deciding to use a pesticide.

If a chemical is necessary, spot spray infested plants with the least toxic effective chemical. Read the product label carefully and follow all suggested safety practices.

For more information

University of Wyoming Cooperative Extension Service publications

Landscape Pests: Integrated Pest Management Strategies for Controlling the Dastardly Dozen (B-1035)

Other publications

On line at www.uwyo.edu/ces/plantsci.htm

Books

Berry, R. *Insects and Mites of Economic Importance in the Northwest,* 2nd ed. (published by the author, Corvallis, OR, 1998). 221 pp.

Dreistadt, S.H., J.K. Clark, and M.L. Flint. *Pests of Landscape Trees and Shrubs: An Integrated Pest Management Guide*, Publication 3359 (University of California Division of Agriculture and Natural Resources, Davis, 1994). 327 pp.

Flint, M.L. *Pests of the Garden and Small Farms: A Grower's Guide to Using Less Pesticide,* Publication 3332 (University of California Division of Agriculture and Natural Resources, Davis, 1990). 276 pp.

Olkowski, W., S. Daar, and H. Olkowski. *Common-sense Pest Control: Least Toxic Solutions for Your Home, Garden, Pets, and Community* (The Taunton Press, Newtown, CT, 1991).

Sunset Books. *Sunset Western Problem Solver* (Menlo Park, CA, 1998). 320 pp.

Other resources

National Pesticide Information Center
Oregon State University

Divider goes here

Composting

15

Gardeners have long made and used compost to improve garden soil. Today, they also compost plant and vegetable matter because it is an important way to reduce the amount of waste that is burned or dumped in landfills. Yard wastes and vegetable scraps can make up as much as 20 percent of household garbage. Composting can effectively recycle that waste.

Topics in this chapter

- The science of composting
- Managing the decay process
- How to make compost
- Using compost
- Composting food wastes
- Health and safety questions
- Composting and the environment

The science of composting

The cycle of growth and decay

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 die, they become raw materials for the composting (decay) process.

Microorganisms, fungi, insects, worms, mites, and other creatures (Figure 1) convert the carbon from dead plants into energy for their own growth, releasing carbon dioxide into the air (Figure 2). Similarly, they recycle nutrients from decaying plants into their own bodies and eventually back into the soil. Other plants and microorganisms use the carbon and nutrients released by the composting process, and the cycle begins again.

See Chapter 2, Soils and Fertilizers.

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.

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 Wyoming by Karen L. Panter, Cooperative Extension Service horticulture specialist, University of Wyoming.

Fast (hot) composting

One can manipulate the decay process 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.

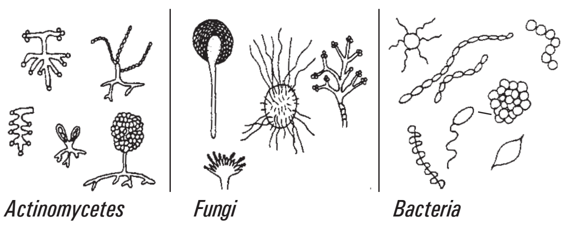


Figure 1.—Primary groups of microorganisms involved in composting (magnified more than 1,000 times). (Reprinted by permission from On-Farm Composting Handbook, *NRAES-54, Natural Resource, Agriculture, and Engineering Service, Cooperative Extension, Cornell University, 1992.)*

One byproduct of microbial activity is heat. When conditions are favorable for high-temperature microorganisms, compost piles heat rapidly to 120° 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, lower-temperature microorganisms, worms, insects, and other invertebrates complete the decay process.

Slow (cold) composting

If ideal conditions are not maintained for hot composting, microorganisms still break down wastes. Decay is slower, cooler, and less effective at killing weed seeds and pathogens.

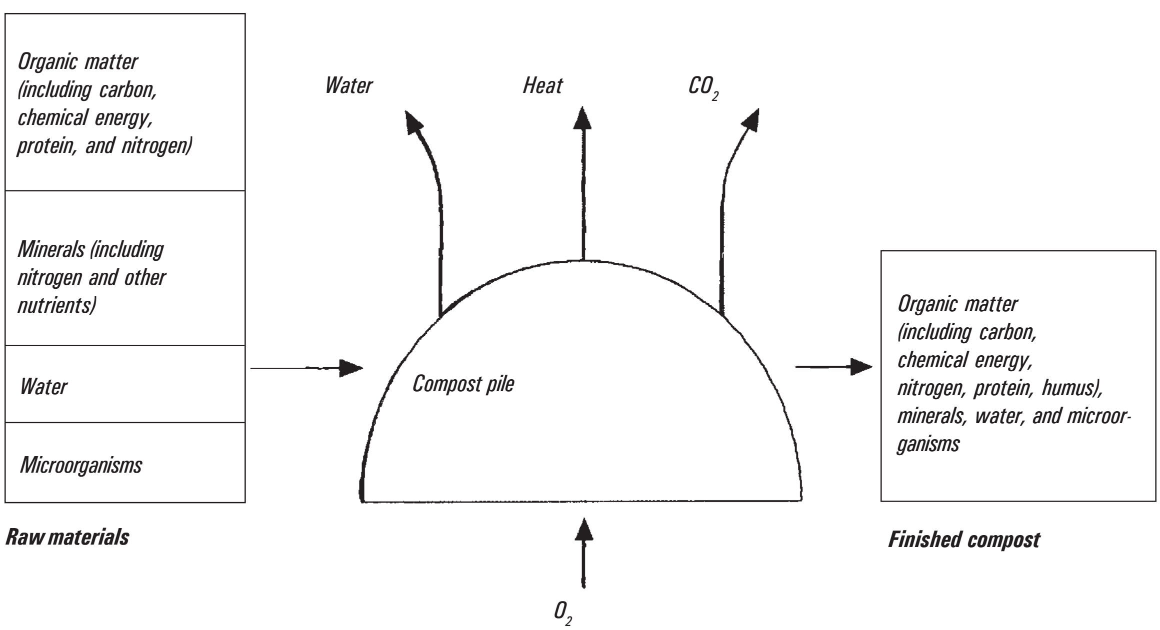


Figure 2.—The composting process. The amounts of carbon, chemical energy, protein, and water in the finished compost are less than in the raw materials. The finished compost has more humus. The volume of the finished compost is 50 percent or less of the volume of raw material. (Reprinted by permission from On-Farm Composting Handbook, NRAES-54, Natural Resource, Agriculture, and Engineering Service, Cooperative Extension, Cornell University, 1992.)

Managing the decay process

One can affect the speed of the composting process and the quality of finished compost by managing the factors described below.

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 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 piled without bulking agents, these materials are usually too wet and dense to allow much air into the compost pile. When one opens the pile, 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.

Table 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
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

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.

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 size of $^1/_8$ to $^1/_2$ inch in diameter.

Woody branches that have not been ground often make it difficult to turn a pile. They also decompose very slowly. Grinding or chipping woody branches or piling them separately might help.

Mixing

Layering is one way to build a pile. However, if all of the materials are on hand when building the pile, 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 of the pile where anaerobic conditions are likely to occur.

Pile size

The pile must be big enough to hold heat. A hot pile decays much faster than a cold pile. Small piles are usually colder because they have small cores that hold less heat. Small piles also dry out faster. A pile of about 1 cubic yard is big enough for year-round composting, even in cold-winter areas.

Moisture

All materials in the pile must be moist but not soaking wet. Check moisture when turning the pile. The mixed material should feel moist, but one should not be able to squeeze water out of it with one's hands. In Wyoming's climate, one will need to add water.

Aeration

The microorganisms responsible for fast decomposition need oxygen. 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 aeration. Turning the pile or adding more bulking agents improves aeration.

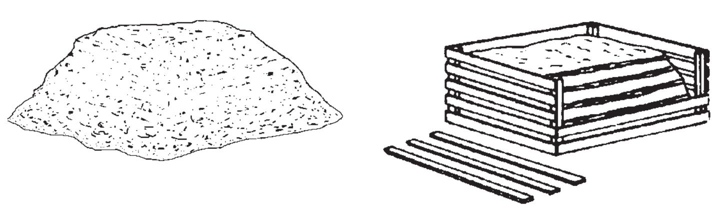


Figure 3.—Some people compost in open piles; others prefer using bins.

Microorganisms

Raw materials used to form a compost pile usually contain all the microorganisms needed to make compost. It is not necessary to add soil or compost starters with special microorganisms. The best source of microorganisms (if needed) is finished compost.

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. Additional fertilizer from any source (organic or inorganic) is usually not needed.

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.

Compost additives such as blood meal and bone meal are simply organic fertilizers; they do not contribute anything magic to the compost pile.

How to make compost

One does not need a bin or other container to make compost. Piles work well. However, some people prefer containers 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 3).

Slow (cold) composting

Employing slow composting is an easy and convenient way to turn yard wastes into a useful soil amendment. It is often 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 1).

Add fresh wastes by opening the pile, placing the wastes in the center, and covering them. This 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, one may need to screen the pile or use another method of composting these wastes.

One option is to bury vegetable and fruit wastes directly in the garden. Dig a hole or trench about a foot deep, add a few inches of wastes, mix them 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 or green cone (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 putting seeds in the compost pile, be prepared for more weeding.

Fast (hot) composting

If one creates and maintains 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.

Building the pile

1. Collect enough material to make a pile at least 1 cubic yard in volume. (An open pile 5 feet wide at the base by 3 feet high holds about a cubic yard.) Use roughly two parts bulking agent to one part energy material (see Table 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 a drop of water can barely be squeezed out, 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 the moisture until the pile is built.

Turning the pile

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 its initial mixing, a regularly turned pile usually stays hot (120° 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.

See Chapter 2, *Soils and Fertilizers*.

Temperatures during curing are 80° to 110°F. The compost is ready to use when at least eight weeks have passed since the 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. Cover the pile or build a larger pile during wet periods.
- 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 hold heat better.

Sometimes there may be several problems to overcome. If the pile won't heat, all is not lost. The pile will eventually break down by the slow method.

Using compost

The best part about compost is the benefit it provides to a garden. Mix compost with soil to add organic matter or use it as mulch.

Amending soil

Well-decomposed, earthy composts are good soil amendments. They make soil easier to work with and create a better medium for plant growth. Mix 1 to 2 inches of compost into the soil before planting a vegetable garden, lawn, flower bed, or cover crop.

Mulching

Composts applied to the soil surface help 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 mulching perennial plantings, choose compost made from woody bulking agents; it decomposes slowly, resists compaction, and slows weed establishment.

Composting food waste

Composting kitchen scraps in an outdoor bin sometimes attracts pests. Some people prefer using worm composting or green cones, as described below.

Worm bins

Many food wastes can be composted in worm bins. Examples include fruit and vegetable peels, grains, pasta, baked goods, coffee grounds, and even coffee filters. Do not add meat products.

Place worm bins where temperature and moisture can be controlled. An ideal temperature range for worms is from 55° to 77°F. Worms also need a moist environment. Air circulation is a must in and around a worm box. Choose a location that is convenient for maintaining the box.

The size depends on how much waste is generated per week. A box measuring 1 foot by 2 feet by 3 feet can handle 6 pounds of kitchen wastes per week, which is about average for a family of four to six.

Starting a worm bin

Most worm bins are made from plywood. Worms avoid light, so the container should be dark inside and have a good lid. The lid should cover the top but does not need to attach securely to the container.

Health and safety questions

Are there any plant materials to keep out of a compost pile?

Keep diseased plants and seed heads of weeds out of a 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. Western redcedar, often used for fence posts because of its resistance to decay, can break down slowly in compost piles.

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 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. *Therefore, exclude fresh manure from compost that will be used on fresh garden crops.*

Keep dog, cat, and pig manure out of a 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 for people.

Are herbicides a problem in compost?

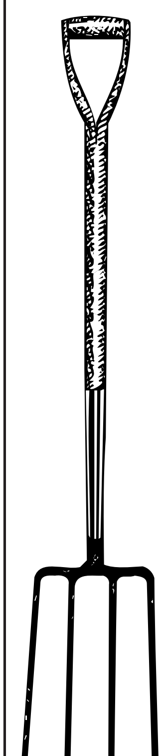
On rare occasions, herbicides from compost have harmed plants grown in soils amended with the compost.

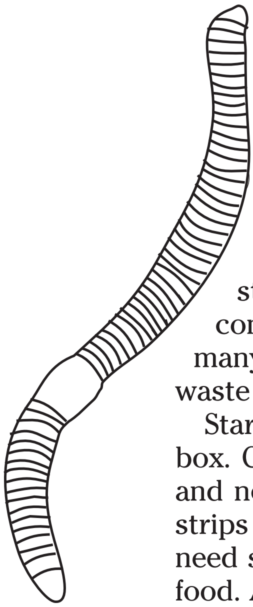
See Chapter 5, *Weeds*.

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 are also 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 residues are composted or to use herbicides that break down quickly.

If one suspects there are herbicides in a compost pile, let the pile sit for a year or more, allowing more time for breakdown and binding.





There should be air holes somewhere on the container—either on the lid, sides, or bottom (if the container is not sitting directly on the ground). If using a plastic bin, be sure to add both drainage and aeration holes. Never use a container that has been used for storing toxic chemicals. Worm bin construction plans are available from many extension offices or county solid waste departments.

Start by putting bedding in the worm box. Corrugated cardboard, newsprint, and newspaper shredded in 1-inch-wide strips make excellent bedding. Worms need some grit for breaking down their food. Add a little topsoil for this purpose. Put the worms in the bedding with their first feeding.

Moisture

In order to survive, worms require 75 to 90 percent moisture content in both their bodies and their bedding. To achieve this percentage, add 3 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 some in one's hand. If a few drops of moisture are released by squeezing, the bedding is sufficiently moist. If five or more drops are produced, 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. Earthworms only live in furrows in the soil.

Number of worms

The number of worms required depends on the daily weight of food waste added. Since worms can eat their own weight in food in 24 hours, measure worms by weight rather than number. Two pounds of worms are needed for each pound of kitchen waste added per day (a ratio of 2:1). For example, if producing $3^1/_2$ pounds of kitchen waste per week ($^1/_2$ pound per day), use 1 pound of worms. Calculate as follows:

$3^1/_2$ pounds of kitchen waste per week
÷ 7 days in a week
= $^1/_2$ pounds of waste per day (average)

$^1/_2$ pounds of waste per day
x 2 pounds of worms for each pound of daily waste
= 1 pounds of worms

Red worm sources

Check with a local extension office. Many garden supply companies also carry worm-composting equipment and supplies.

Worm bin management

Adding waste

It is a good practice to vary the location of where wastes are buried in a worm box. A worm box 2 feet by 2 feet has approximately nine locations for burying kitchen wastes. That gives nine feedings before having to bury again at the first location.

Grinding is not necessary because kitchen wastes break down very quickly. Do pulverize egg shells, however.

Leaving the box untended

If one needs to be away from home, he or she should feed the worms a little extra before going and leave them undisturbed. They can go three weeks or a month without feeding. If going away for a longer time, make arrangements with someone to feed the worms.

Changing the bedding

After many weeks the bedding will disappear as worms and microorganisms decompose the material. The color of the bedding also becomes darker. As these things happen, the favorable environment for the worms decreases. Large amounts of accumulated castings might become harmful to the worms since castings of one worm are toxic to other worms. Decide when to change the bedding based on the condition of the bedding and the quantity of worms in the box.

Population control

Worms multiply fast. Avoid overpopulation. Use extra worms to start a new worm box or give them to someone else who is starting a worm composting box.

Odor and pest control

Control odors by not overloading the box with waste, keeping out inappropriate waste, and providing adequate fresh bedding. Do not fill the bin with a lot of food waste until the worm population is established. Never add cheese or other animal products to any type of composting system.

Fruit flies are more of a nuisance than a serious problem. Minimize fruit flies in a worm bin by completely covering fresh food waste with several inches of bedding and by covering the bedding with a sheet of newspaper, cardboard, or plastic tucked in around the edges.

Rodents can be a problem. The easiest way to keep animals from entering a worm bin is to keep the lid shut and meat wastes out. If there are signs of 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 worm bin lid latched or well secured if raccoons or other wildlife are problems.

Green cones

Green cones are another convenient way to compost food scraps. The green cone composting process is anaerobic (occurring without air). The cone is a plastic, rodent-proof composting unit with an attached underground basket.

Commonly asked questions about worms

Can a worm see?

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 a worm's mouth?

A 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 its 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 can worm compost be used?

Use worm compost like any other compost. Sterilizing is not necessary.

Check with a local health department or solid waste management department to determine whether green cones can be used in a particular area. Some counties may not allow the use of green cones while others may have specific rules regarding siting or installation. Some areas may require a minimum of two units to handle a typical family's amount of food waste.

Proper installation is essential to keep green cones rodent proof. Make sure the unit purchased has complete installation and use directions. Select a convenient, sunny location. Preferably, install green cones away from a home on well-drained soil. Although green cones are most successful in sandy or loamy soils, they can be used on heavy or shallow soils as well.

Remove enough soil to create a hole for the underground basket. In heavy or shallow soils, remove an additional 4 to 6 inches of soil and replace it with rocks or sand to improve drainage. Place the green cone basket in the hole, replace the soil around the basket, and screw the cone to the basket.

Add food scraps to the unit through the top. Be sure to close the lid to keep down odors and flies. Remove the plastic bar across the opening to allow easier access. Add a thin layer of leaves or sawdust if odors or flies become a problem. No additives are required to speed up the composting process.

Over time, the green cone basket should contain dark, moist compost. The speed at which compost is produced depends on the kind of food waste added, soil drainage, soil texture, and time of year. On the average, a green cone used by two people should be harvested after 6 to 12 months.

Spring and fall are the best times to harvest the compost. To harvest, unscrew the cone section from the basket and take the compost and any uncomposted food out of the basket. Bury the compost in the garden at least 8 inches deep as a soil enhancer. The compost may be smelly, but this is a quick and easy way to harvest. After harvesting, replace the cone section on the basket.

Occasionally, food may rise into the cone section. However, the food waste volume will decrease with time. If the cone section is constantly full, consider using two green cones or burying a portion of the waste.

Using two green cones makes composting even easier. Simply use the first cone until the cone section is about half full. Then switch to the second unit and let the first one sit idle to allow the food to decompose and settle back into the underground basket. By the time the second cone is half full, the first one should be ready to harvest. Because this method allows food scraps to be composted more efficiently and completely than with one cone, one can use the harvested compost directly in the garden as a mulch or top dressing or dig it into the soil.

Troubleshooting green cone problems

- Control odors by removing excess or inappropriate waste and adding a thin layer of leaves or dried grass.
- Never add cheese or other animal products of any type to compost systems.
- Fruit flies are more of a nuisance than a serious problem. Minimize fruit flies by adding a thin layer of leaves or sawdust.
- Rodents can be a problem. The easiest way to keep animals from entering a green cone is to keep the lid shut and meat wastes out. One also can cover the underground basket with wire mesh hardware cloth to prevent pests from entering.

Composting and the environment

Backyard composting reduces the flow of wastes to landfills or burn piles and produces valuable organic matter for the soil at the same time. The composting process is fueled by the solar energy captured in plant tissue. The benefits are the same whether composting in carefully tended hot piles or in neglected slow piles. Backyard composting is a simple yet important way to improve communities and the environment.

For more information

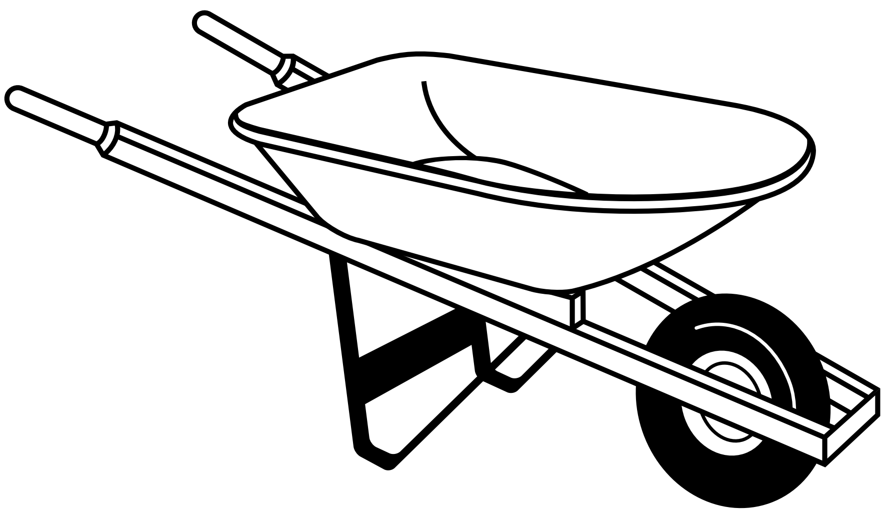
UW Cooperative Extension Service publications

Backyard Composting: Simple, Small-scale Methods (B-974R).

Other publications

Rangarajan, A., E.A. Bihn, R.B. Gravani, D.L. Scott, and M.P. Pitts. *Food Safety Begins on the Farm: A Grower's Guide* (Cornell Good Agricultural Practices Program, Cornell University College of Agriculture and Life Sciences, 2000).

Rynk, R., On-Farm Composting, NRAES-54 (Natural Resource, Agriculture, and Engineering Service, Ithaca, New York, 1992). 186 pp.



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Pruning

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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 is frequently done in rose gardens, but it is used haphazardly elsewhere. Most often it is performed on ornamentals only when a shrub or tree begins to encroach on its neighbors, a walkway, or a building.

Pruning is often thought of as a way to make a barren tree fruitful. If carried out correctly, it eventually will. 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.

Topics in this chapter

- Reasons for pruning
- Tools
- Basic pruning techniques
- Espaliering
- Shade trees
- Fruit trees
- Shrubs
- Rose bushes
- Vines and groundcovers

Reasons for pruning

The reasons for pruning can be grouped under the following four categories:

- To train a plant
- To maintain plant health
- To improve the quality of flowers, fruit, foliage, or stems
- To restrict growth

Adapted from *The Virginia Master Gardener Handbook*. Edited by Ray McNeilan, Extension agent emeritus, Multnomah County, Oregon State University. Edited for Wyoming by Mark Hughes, Community Forestry Coordinator, State of Wyoming.

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 the growth of most lateral buds below the tip and reduces the 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. It 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 where it attaches to another branch rather than removing it entirely.

Leader—The uppermost portion of a scaffold limb. The terminal is the tip (apex) of the leader.

Root sucker—A shoot that arises from a root system.

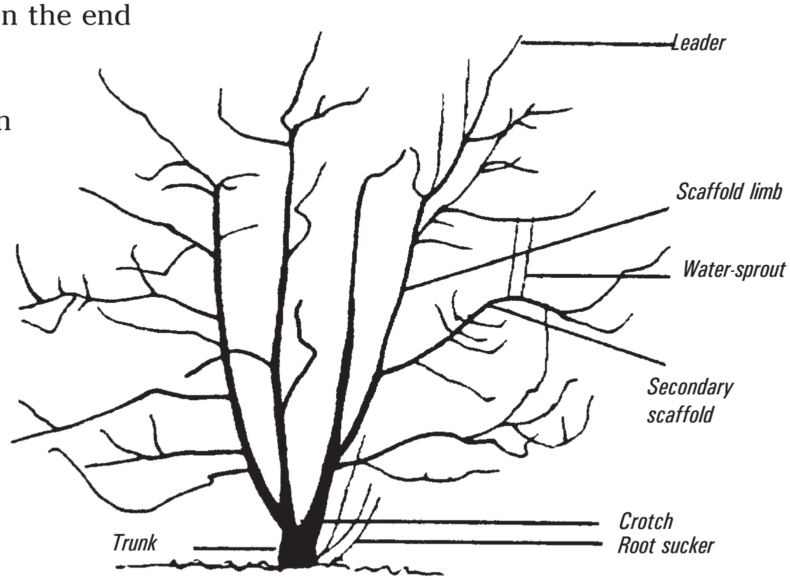
Scaffold limb—A large limb that forms the framework of a tree.

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—Removal of 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.



Training a plant

Prune trees and shrubs after transplanting only to remove dead, broken, crossing, and 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 properly pruned nursery-grown plants are used. Excessive pruning at transplanting, according to research, reduces plant size and does not aid in survival.

Pruning should, however, 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* (the uppermost portion of a scaffold limb). Pruning the leader is, however, appropriate for some naturally low-branched trees or if a multiple-stemmed plant is going to be developed. Trees with a central leader such as linden or green ash 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 are usually removed over a period of years, beginning in the nursery and continuing for several years after transplanting, until the desired height is reached.
- For greatest strength, branches selected for permanent *scaffolds* (the framework of a 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.

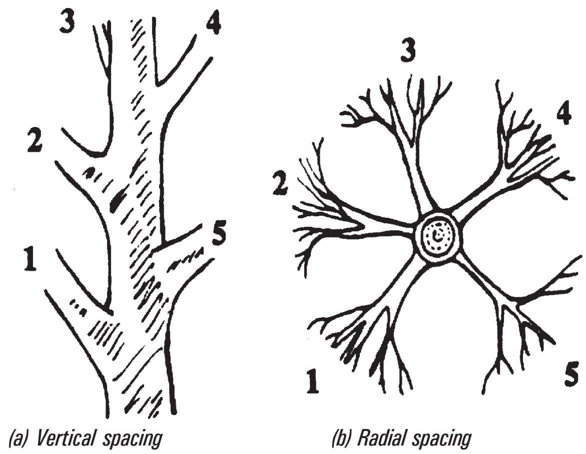


Figure 1.—Proper vertical spacing (a) and radial spacing (b) for scaffold branches.

- For shade trees, choose branches for major scaffolds that are at least 8 inches apart vertically (preferably 20 to 24 inches). See Figure 1a. Closely spaced scaffolds have fewer lateral branches. The result is long, thin branches with poor structural strength.
- Five to seven scaffolds should fill the circle of space around a trunk (Figure 1b). This arrangement prevents one limb from overshadowing another, thus reducing competition for light and nutrients.
- Remove or prune shoots that are too low, too close, or too vigorous in relation to the leader and scaffold branches.

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 can be an entry point or buildup chamber for insects or fungi that could spread to other parts of a 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

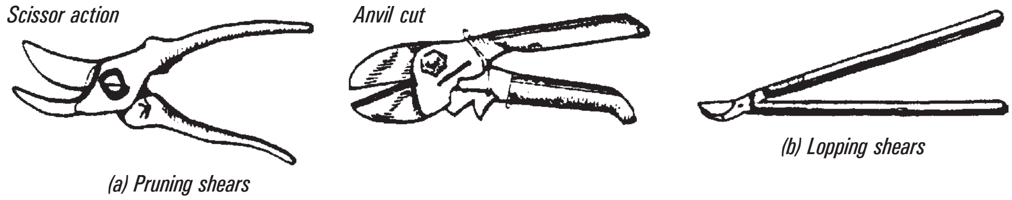


Figure 2.—Pruning shears (a) and lopping shears (b).

solution after each cut to prevent the transfer of disease to healthy stock.

Keeping a shrub or tree from growing too dense can help prevent disease. Evergreen shrubs in particular usually benefit from occasional thinning. This thinning allows light and air to penetrate throughout the shrub, resulting in the even growth of healthy foliage.

Improving flowers, fruit, foliage, and stems

The more flowers and fruit a plant produces, the smaller those items are as is evident on an unpruned rose bush or fruit tree. Pruning reduces the amount of wood and diverts energy into the production of larger though possibly fewer flowers and/or fruit. Most flowering shrubs bloom either on last year's growth or on new growth. Properly timed pruning increases the production of flower-bearing wood.

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.

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.

Tools

Hand shears

Hand pruning shears are good for branches up to ½ inch in diameter. Using them to cut larger branches risks making a poor cut and/or ruining the shears.

There are two styles of hand shears: scissor-action types and anvil-cut types (Figure 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 are not recommended because they tend to crush woody plant tissue.

Lopping shears

Lopping shears have long handles and are operated with both hands (Figure 2b). Even the cheapest can cut ½-inch diameter material. The better ones can slice through branches 2 inches or more thick, depending on species and condition. For example, pin oak wood is tougher than that of linden, and dead wood is tougher until decay sets in than live wood.

Pole pruners

Pole pruners have a hooked blade above and a cutting blade beneath (Figure 3). The blades are on a pole and are operated by pulling a long piece of cord downward.

The poles can be in sections which either fit together or telescope. They can be

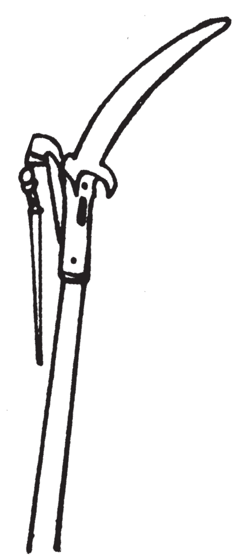


Figure 3.—Pole pruner.

made of several materials. Wooden poles are heavy. Aluminum poles are light but can conduct electricity if they touch an overhead wire. Poles made of fiberglass or a plastic compound are probably best. Poles can be fitted with saws, but these are usually frustrating to use.

Pole pruners can be dangerous because material that is cut overhead can fall on the operator if it isn't caught on other branches. Use caution 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 4). Heavy-duty shears with one serrated blade are good for difficult jobs.

Power hedge shears are also available. For home use, electric models are most common.

Saws

There are many makes and models of hand-pruning saws (Figure 5). The fineness of the cutting edge is measured in points (teeth per inch). Average saws are about 5½ to 6 points. An 8-point saw is for delicate, close work on small shrubs and trees while a 4½-point saw is 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. However, a fixed-blade saw with a leather scabbard is safer.

Saw blades can either be 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 and coarse on the other. These saws are 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.

Figure 4.—Hedge shears.

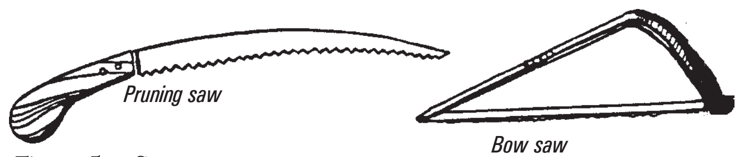


Figure 5.—Saws.

Chain saws 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 very large branches.

Caring for tools

Clean and oil tools regularly by wiping an oily cloth on blades and other surfaces. Keep cutting edges sharp. Several passes with a good oilstone usually suffice. 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 cut wires with pruning tools.

Basic pruning techniques

Types of pruning cuts

To simplify pruning, remember that there are only two types of cuts: heading cuts and thinning cuts. Figure 6 shows the effect of each.

Heading involves cutting off part of a shoot or limb (Figure 6a). It increases the number of new shoots and stiffens branches, holding them in position.

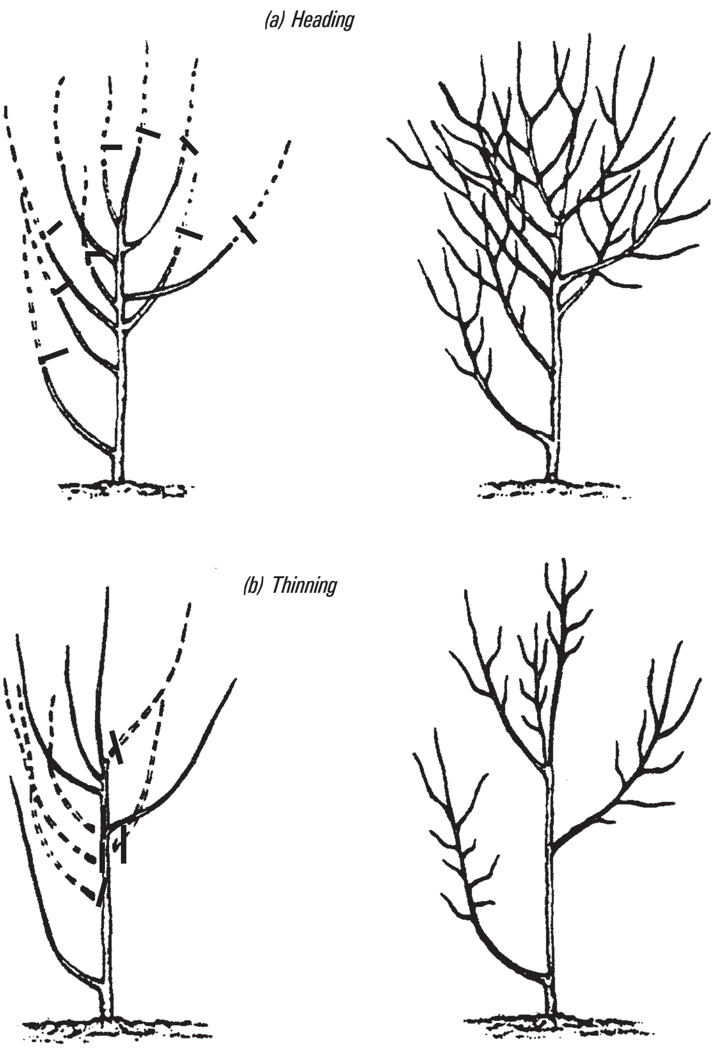


Figure 6.—Heading cuts (a) increase the number of new shoots formed and stiffen the branches, holding them in position. Thinning cuts (b) reduce the number of new shoots and direct growth.

Thinning removes undesired wood (Figure 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, one can remove considerable growth without changing a plant’s natural appearance or growth habit. Thus, one 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 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 that has a diameter of at least one-half that of the branch to be removed (Figure 7).

Make slanting cuts when removing limbs that grow upward; this technique prevents water from collecting in the cut and expedites healing.

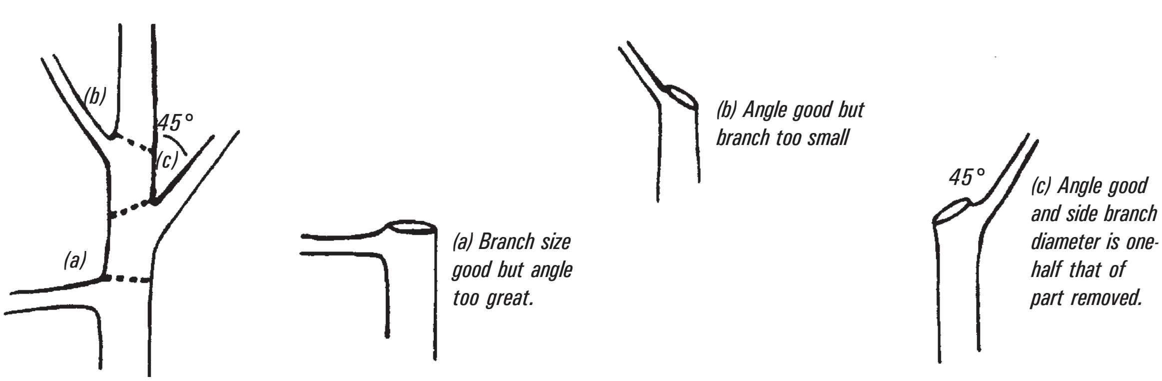


Figure 7.—Proper branch selection: (a) Angle is too great. (b) Branch is too small. (c) Angle is good and branch is large enough.

Thick, heavy branches

Remove thick, heavy branches flush with the *collar* at the base of the branch, not flush with the trunk (Figure 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 regardless of whether a 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 9:

1. Undercut the bottom of the branch about one-third of the way through, 6 to 12 inches out from the trunk (Figure 9a). If there is a danger that the branch will damage lower limbs or objects on the ground, rope it and support it.
2. Make a second cut from the top, about 3 inches farther out from the undercut, until the branch falls away (Figure 9b). If the branch was roped for support, carefully lower it to the ground after the second cut.
3. Cut back the resulting stub to the branch collar (Figure 9c).

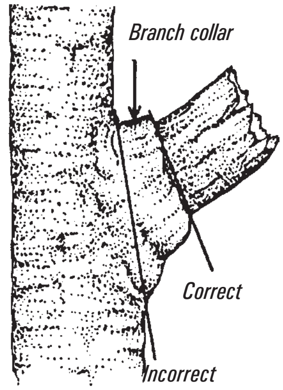


Figure 8.—Remove branches flush with the collar, not flush with the trunk.

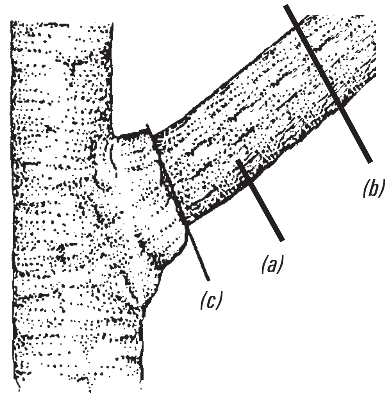


Figure 9.—Pruning a large branch: (a) Undercut one-third of the way through the branch. (b) Cut through until the branch falls away. (c) Cut back to the collar.

Topping

Topping is described as the indiscriminate cutting back of tree branches to stubs or to other lateral branches not large enough to become leaders. Topping is also called "heading," "tipping," "hat racking," and "rounding over."Topping trees is never recommended. It removes the central leader of a tree, exposing a cut surface to the elements. It also weakens trees and makes them unsightly.

This practice frequently removes 50 to 100 percent of the leaf-bearing crown of a tree. Removing this much foliage stresses a tree and may starve it. Latent buds may be induced to grow, often forming multiple shoots below each cut. The stress leaves a tree vulnerable to insects and diseases.

Topping can also lead to decay because a tree may not be able to heal the wound properly. It often leads to tree sunburn since the interior portion is now exposed to high sunlight when previously it was in almost 100 percent shade. Topped trees are also more hazardous because the new shoots arise from the outer layers of branches, making them subject to easy breakage. Topping is also unsightly and expensive.

See Chapter 7, *Woody Plants*.

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 prune plant roots 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, prune its roots a year or so before digging it. In fall, sever half of the roots to 1 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 that will eventually be dug. 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 of 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, one must dig a root ball 4 to 6 inches larger than the root-pruned area to produce newly developed roots.

Root pruning is also used to force a vigorously growing fruit tree, wisteria vine, or flowering dogwood into bloom. 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.

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 a 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 10). Apples, pears, plums, and some shrubs such as pyracantha adapt well to this system. A plant is usually supported by a wall, fence, or wire trellis. Training to a 4-tier cordon or 4-wire trellis is relatively easy.

One can construct a simple 4-wire trellis using 8-foot posts. Space the posts 12 feet apart and set them 2 feet in the ground. Run wires through the posts at heights of 18, 36, 54, and 72 inches. Plant two

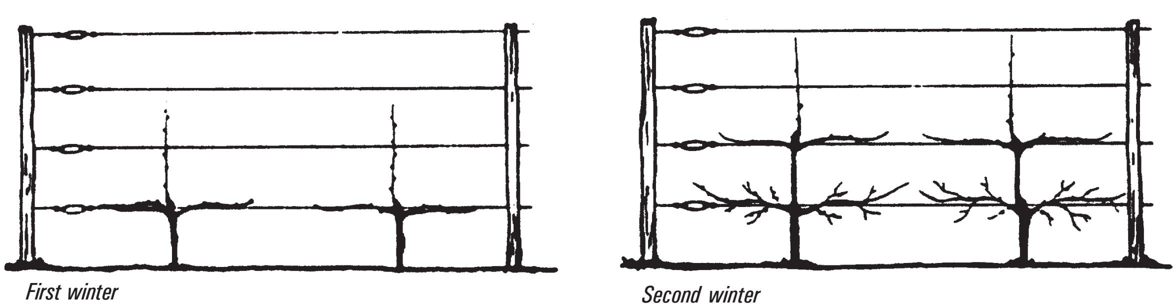


Figure 10.—Training a tree with an espalier system.

unbranched whips of the desired plant 6 feet apart between the two posts.

Before growth begins the first spring, cut off each whip just above the highest bud 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.

Loosely tie the two scaffold shoots 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 the end of the shoot is tied in a non-horizontal manner, 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, the fruit trees should be producing well.

In the years to follow, do all pruning during spring and summer. When new spring growth is about 2 inches long, cut it off. Remove about one-fourth of the previous season's growth. Do not prune the scaffolds' terminals.

On August 1 or as soon as new growth reaches 10 to 12 inches in length, cut it back to two or three buds. Repeat this process 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 are generally pruned only for sanitation, safety, or size restriction.

One can prune shade trees at any time of the year. Late-winter pruning is often 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 elms, maples, and birches 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 may also cause fewer suckers or *water sprouts* to grow. (A water sprout is a long shoot that grows in an undesirable location on a trunk or major limb.)

Fruit trees

See Chapter 12, *Fruit Trees*.

The basic objectives in directing and guiding the growth of young fruit trees are to encourage early fruit production and to develop an optimum tree structure for supporting future crops. One can meet these objectives by maintaining a proper balance between vegetative and potential fruiting wood. The pruning of mature trees is aimed at producing a new growth of fruiting wood. This section discusses the pruning of various types of fruit trees.

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.

The pruning of a mature apple tree is greatly affected by early training. Thus, it is 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 11. Upright or vertical limbs (Figure 11a) produce their longest shoots near their tip and tend to exhibit high vegetative vigor. Often, fruits hang down against these limbs and rub them. Horizontally oriented limbs (Figure 11b), on the other hand, 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 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 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 12b). In this condition,

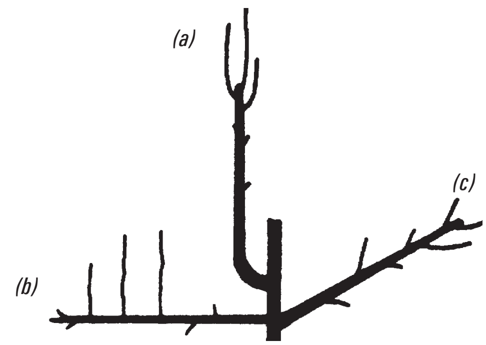


Figure 11.—Possible limb orientations: (a) Vertical; (b) horizontal; (c) 60° from vertical. The 60° limb is ideal.

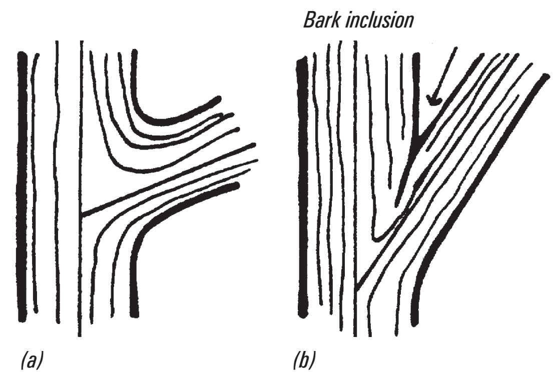


Figure 12.—Strong, wide crotch angle (a) and narrow crotch angle with bark inclusion (b).

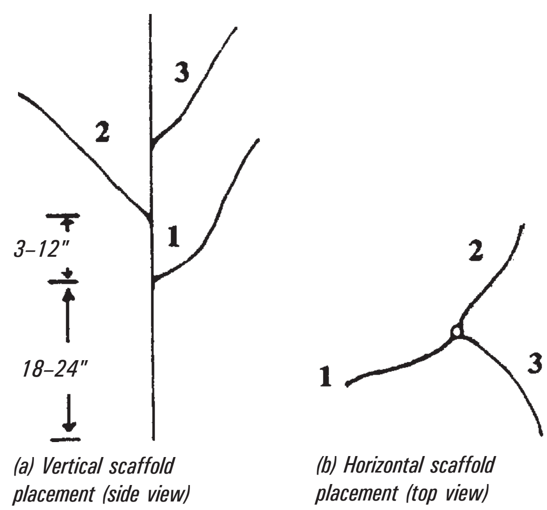


Figure 13.—Selecting well-spaced scaffolds. Scaffolds should be spaced 3–12 inches apart vertically (a) and as equally as possible around the trunk (b).

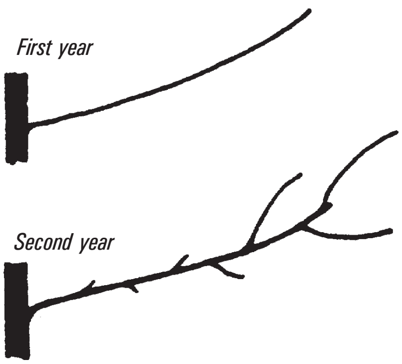


Figure 14.—Natural branching of a shoot.

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 a gardener will 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 a tree is branched, head it back to a strong bud to stimulate the 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, one can select two to four good scaffolds (Figure 13). They should be evenly distributed and not directly above one another. Vertical spacing between scaffolds can vary from 3 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).

Spread or remove limbs with crotch angles 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. Weight down the shoot with something light like a a fishing weight. Remove undesirably located shoots at this time.

First dormant season

If shoots to be retained as scaffolds haven't yet been selected, they should be earmarked 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 have not been selected as scaffolds. Head the central leader to maintain dominance and induce branching; cut it back 3 to 5 inches above the point of the next tier of scaffolds.

Scaffolds usually do not need to be headed; generally shoots branch naturally in their second season (Figure 14). The scaffolds simply need to be spread to encourage uniform branching. Often, however, a scaffold exhibits excess vigor and upsets the balance of a tree's growth. In this case, head it to shorten and stiffen it. One 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 center of the tree. Select and train the new tier of scaffold limbs. Choose limbs that are well spaced in relation to lower scaffolds.

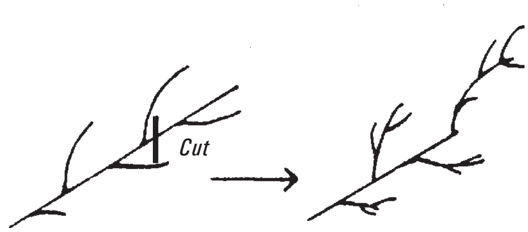


Figure 15.—Shorten limbs with thinning cuts.

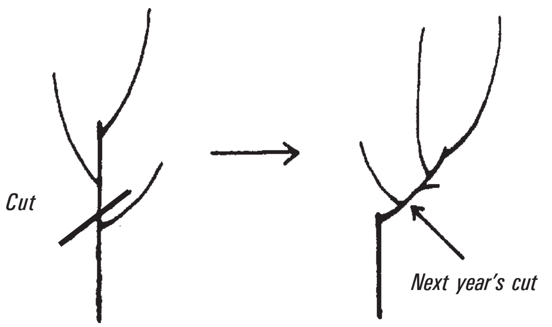


Figure 16.—Prune to a lateral to maintain height.

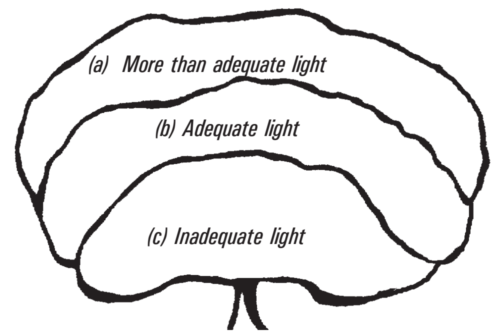


Figure 17.—Light distribution zones in a large apple tree.

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 the vertical spot.

Maintain a conical tree shape with upper branches shorter than lower ones. Always prune the top portion of a tree more heavily than the lower. After the third year, shorten the upper scaffolds with thinning cuts (Figure 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 is desired, cut it back each year to a weak lateral on the central leader (Figure 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 the new growth of fruiting wood. To bear fruit, spurs must be at least 2 years old. After several years of production, however, they lose vigor.

Good fruiting wood requires moderate vigor and exposure to good light. Fruiting may be poor if vigor is too high or too low. Excessive vigor can be the result of inadequate fertilization, no pruning, excessive cropping, or the shading of fruiting wood.

Light is the energy source that produces a fruit crop. Good light exposure is necessary for development of flower buds as well as fruit of optimum size, color, and sugar content. Bearing wood that is

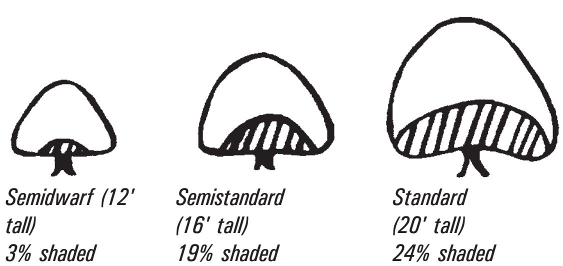


Figure 18.—The shaded area increases as tree size increases.

Figure 19.—Tree shape influences shaded areas.

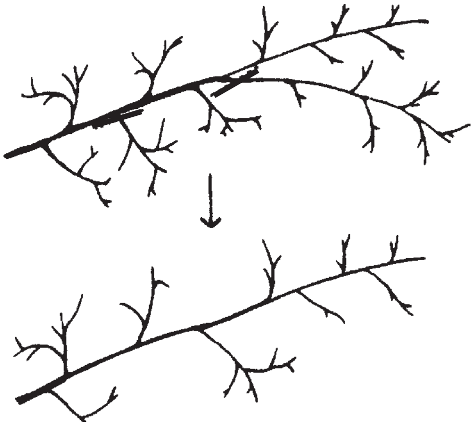


Figure 20.—Thin out low-hanging branches.

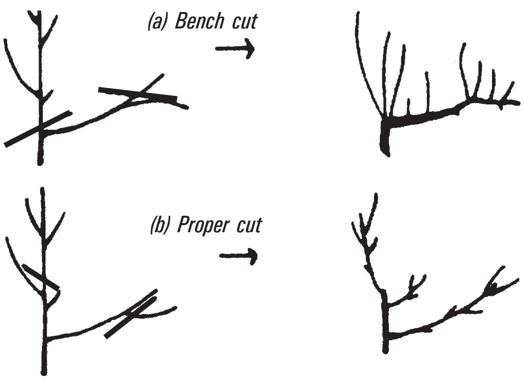


Figure 21.—Bench cuts (a) and proper cuts (b).

shaded is low in vigor and produces small, poorly colored fruits.

A typical tree canopy is composed of different layers or zones with respect to light exposure (Figure 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 18). Trees with wide tops and narrow bottoms also have a high percentage of shaded area (Figure 19).

Use thinning cuts to maintain good light exposure in the tree 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. For this situation, make thinning cuts throughout the tree, especially in the upper, outer portions. This procedure will open up the tree canopy as well as 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 the horizontal area) (Figure 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 21). Such cuts result in weak limbs and an umbrella shape that encourages water sprouts.
- 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 one's gardening experience.
- The excess vigor that can result from severe pruning can decrease fruit quality. The effect is much the same as from excessive nitrogen application. 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 is often 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 a tree to recover. Heading, especially of 1-year-old shoots, induces masses of shoots to grow close to the cuts. These abundant shoots can shade and weaken the inner areas of a 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. Thus, always combine a pruning program with a good fertilization program.

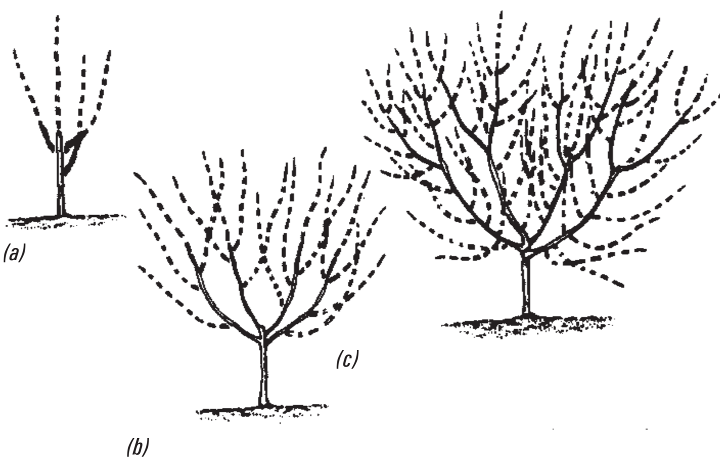


Figure 22.—Pruning to a vase shape: (a) At planting time, head the tree about 18 to 30 inches above ground. Choose two or three scaffold branches and head the selected scaffolds to 3 to 6 inches. (b) In the first dormant season, head the scaffolds 24 to 30 inches away from the trunk. Thin all vigorous 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.

Plum trees

Training young trees in a vase shape

At planting, head prune and plum trees at 18 to 24 inches. 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.

Pruning bearing trees

Prune plum trees to lighten the ends of heavily bearing branches in order to prevent breakage. Cut back annual shoot growth, being careful not to cut away long-lived fruiting spurs. These trees bear on 1-year-old shoots as well as on 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 remaining will become fruiting wood.

Sour cherry trees

If a sour cherry tree has no strong branches at the time of planting, head it to

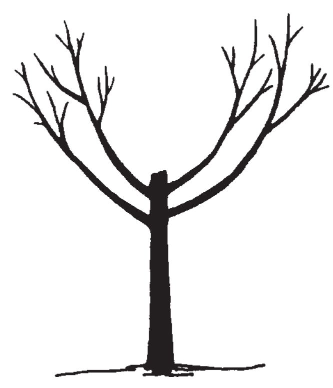


Figure 23.—A vase-shaped tree has an open center and outward-growing branches.

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, 4 to 6 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 3 to 4 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. Renew fruiting wood. Sour cherries bear mostly on 2 to 5-year-old spurs.

Shrubs

Prune both evergreen and deciduous foliage shrubs in late winter before new growth starts. Minor corrective pruning can be done at any time. Specific pruning situations are discussed next.

Deciduous shrubs

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 and 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 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 26). Some thinning may be necessary to shorten long branches or maintain a symmetrical shape.
- 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 the pruning of flowering shrubs to minimize the disruption to blooming. Spring-flowering shrubs bloom on last season's growth (Table 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 2). Prune these shrubs in late winter to promote vigorous shoot growth in the spring.

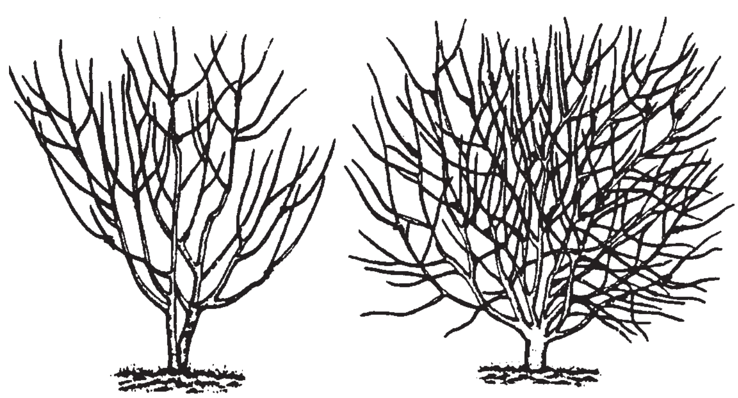


Figure 24.—Training a cherry tree: (a) Without proper training, this sweet cherry tree is too tall and sparsely branched. (b) Heading all the shoots of a young sweet cherry tree produces more branches and a lower tree.

Table 1.—Shrubs that bloom on last season's growth.

Botanical name	Common name
Daphne spp.	Daphne
Forsythia spp.	Forsythia
Lonicera spp.	Honeysuckle
Philadelphus spp.	Mockorange
Rosa spp.	Rambling rose
Spiraea spp.	Early white spirea
Syringa spp.	Lilac
Viburnum spp.	Viburnum
Weigela florida	Old-fashioned weigela

Table 2.—Shrubs that bloom on the current season's growth.

Botanical name	Common name
Buddleia davidii or *globosa*	Butterfly bush
Caryopteris x *clandonensis*	Bluebeard
Rosa spp.	Bush rose
Spiraea bumalda	Anthony Waterer spirea
Symphoricarpos	Coralberry and snowberry

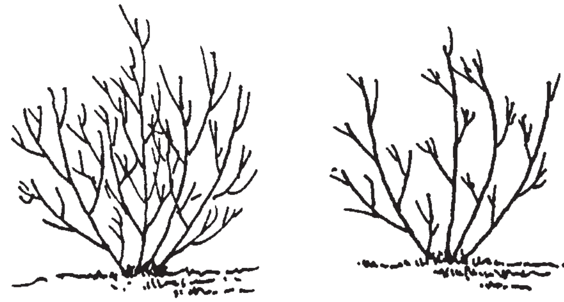


Figure 25.—Thinning a shrub.

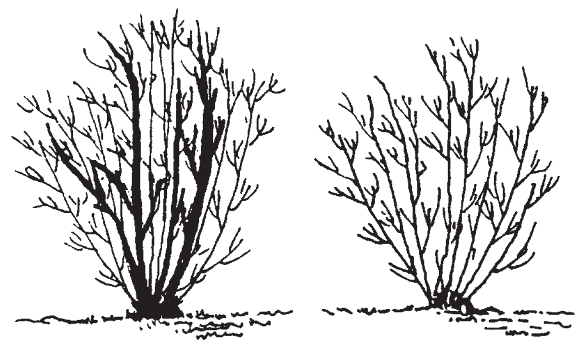


Figure 26.—Gradual renewal of a shrub. (Dark branches in the left-hand illustration are removed.)

Evergreen shrubs

Most evergreen trees and shrubs are sold B and B or in a container. Unlike deciduous shrubs, they require little pruning at planting time.

A thinning-out type of pruning is the best way to prune most mature evergreen shrubs. Some evergreens can be sheared to achieve a stiff, formal appearance. However, they will still need to be thinned 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.

The establishment of a deciduous hedge begins with the selection of nursery stock. Choose young trees or shrubs 1 to 2 feet high, preferably multiple stemmed. Cut the plants back to 6 to 8 inches to induce low branching. Late in the first season or before bud break in the second, prune off half of 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 get 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 27). After the hedge reaches the desired dimensions, trim it 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 it 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 are often shaped with flat tops and vertical sides (Figure 28a and b). This unnatural shaping is seldom 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 28c and d). This shape aids in shedding snow, which otherwise can break branches. Also, by trimming the top narrower than the bottom, sunlight can reach all of the leaves.

Before shaping a hedge, think about the plant's natural shape. For example, common buckthorn, a spreading plant, is easily shaped to a Roman arch (Figure 28c). Naturally conical arborvitae does particularly well in a Gothic arch shape (Figure 28d).

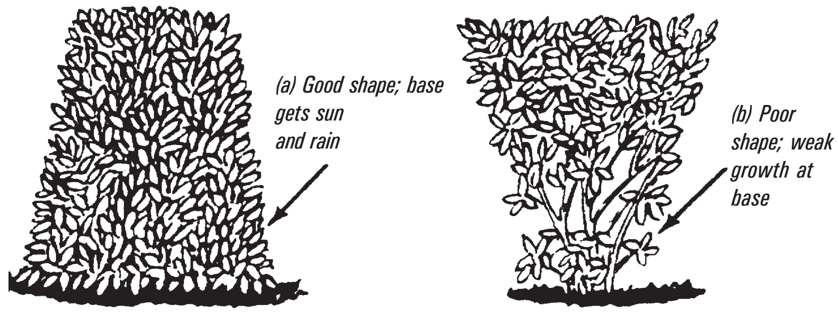


Figure 27.—Correct (a) and incorrect (b) hedge pruning.

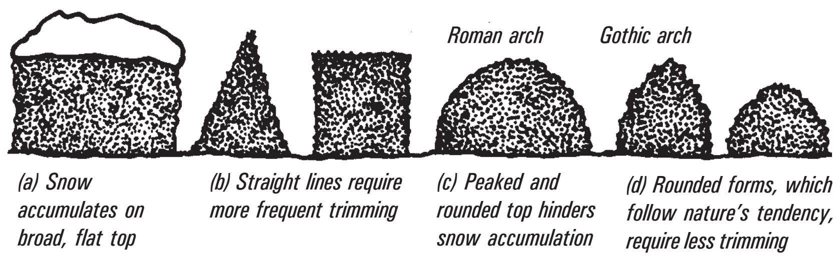


Figure 28.—Improper (a and b) and proper (c and d) hedge shapes.

Two questions often arise: "How often should this hedge be trimmed?" and "When should I trim?" The answers depend on the kind of shrub, the growing season, and the degree of neatness desired.

In general, trim before new growth begins to shade lower leaves. Trim slow-growing plants when new growth is more than 3 or 4 inches long. Shear faster growing evergreens before new growth exceeds a foot in length.

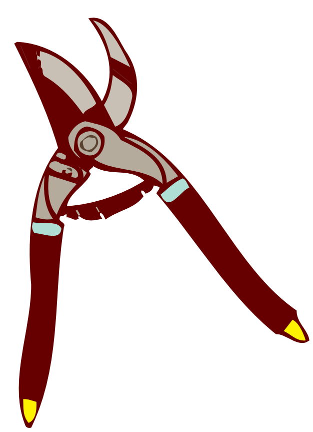
What can be done with a large, overgrown, bare-bottomed, and misshapen hedge? If it is deciduous, the answer is fairly simple. In the spring before leaves appear, prune to 1 foot below the desired height. Then trim carefully for the next few years to give it the shape and fullness desired. Occasionally 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.

Tools for pruning hedges

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. Hand shears work on any type of hedge while electric trimmers do poorly on large-leafed and wiry-twigged varieties and sometimes jam on thick twigs. Hand shears are also 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 for creating an informal look. Use loppers and/or a pruning saw to remove large individual branches. Chain saws are not recommended for use on hedges.



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, making the plant healthy and attractive and resulting 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 one prunes 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. If canes are large, loppers and a small saw with a pointed blade are helpful. Use loppers to reach in and cut out large dead canes.

Remove all dead and diseased wood by cutting at least 1 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 do so 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

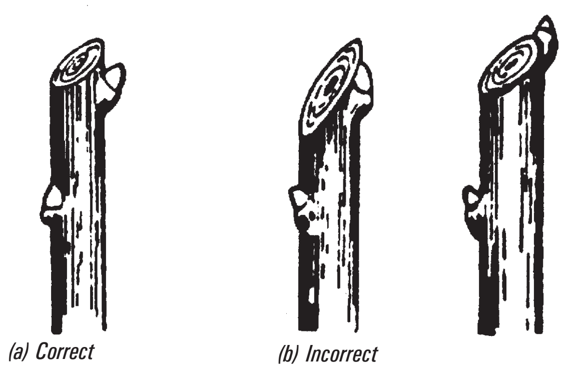


Figure 29.—Proper pruning angle (a) and improper angles (b).

taller growing Hybrids and most Grandifloras may be left at 2 feet.

Make cuts at a 45° angle above a strong outer bud (Figure 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 6 to 10 inches of the base of the budded top in order to encourage rounded, compact, vigorous new growth.

Miniature roses

Miniatures are 6 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 2 inches across. They often produce pliable canes 10 to 15 feet long in one season. Ramblers produce best on 1-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.

Large-flowering climbers

Climbing roses have large flowers more than 2 inches across borne on wood that is 2 or more years old. Canes are larger and sturdier than those of Ramblers. 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 3 to 6 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. The timing is less critical than for flowering vines.

Groundcover plants require very little pruning. Continually remove dead or damaged stems.

For more information

UW Cooperative Extension Service publications

Landscaping: Recommended Trees for Wyoming (B-1090)

Landscaping: Recommended Shrubs for Wyoming (B-1108)

Other publications

Brickell, C. *Pruning* (Simon and Schuster, New York, 1988). 96 pp.

Deaton, C., and M. MacCasky. *All About Pruning* (Ortho Books, 1978). 96 pp.

Gilman, E.F. *An Illustrated Guide to Pruning* (Delmar/Thomson Learning, Albany, New York, 2002). 330 pp.

Gilman, E.F. and S.J. Lilly. *Best Management Practices: Tree Pruning* (International Society of Arboriculture, Champaign, Illinois, 2002). 35 pp.

Sunset Western Garden Book (Sunset Publishing Corporation, Menlo Park, California). 768 pp.

Tree-Pruning Guidelines (International Society of Arboriculture, Savoy, Illinois, 1995). 14 pp.

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Yards and Water Quality

17

Simple things to do to prevent water contamination

People generally view gardening as a wholesome activity that enhances the environment. But pesticides, fertilizers, and erosion from gardens and landscapes can contaminate lakes, streams, rivers, oceans, and groundwater. Since the quality of water resources affects quality of life, it is important to learn how gardening practices can contribute to water contamination and how to reduce the threat to water quality.

The nation has long been aware of contamination from *point* sources such as factories and municipal sewage systems. Recently, there has been more awareness 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.

Thousands of homes in Wyoming 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 and rivers. On the other hand, nitrate (from fertilizers and manure) and some pesticides can leach through the soil to contaminate groundwater (Figure 1).

Added up, these small amounts of contamination form a sizable problem. Only when individuals take responsibility and make wise choices can nonpoint contamination be controlled.

Topics in this chapter

- Landscape design
- Soil and fertility management
- Using garden wastes
- Watering
- Pest management

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 Wyoming by Karen L. Panter, Cooperative Extension Service horticulture specialist, University of Wyoming.

See Chapter 2, *Soils and Fertilizers*.

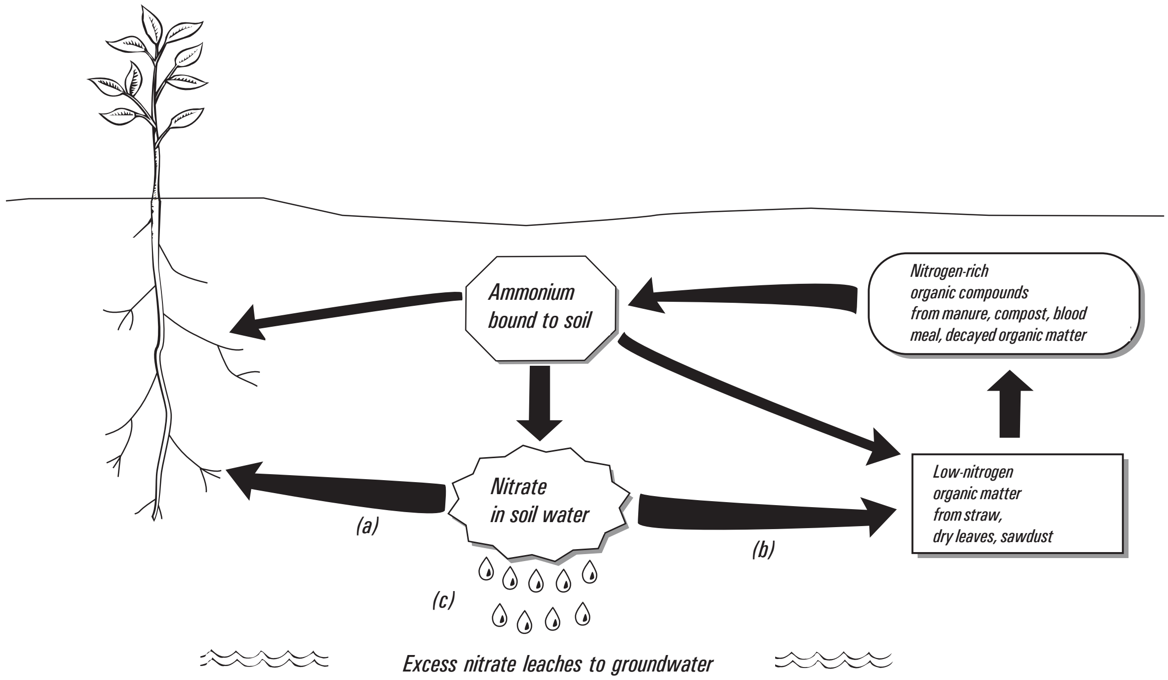


Figure 1—Nitrogen cycle in the soil. All of the arrows represent biological processes in the soil. These steps proceed more rapidly when the soil is warm and there is adequate moisture but the soil is not saturated. Note that there are three possible fates of nitrate:
(a) It is taken up by plants, if they are present.
(b) It is used by microbes to help break down coarse organic matter such as dry leaves.
(c) Any 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 2, Soils and Fertilizers.*)*

Why be concerned?

Clean water is essential for human health, wildlife, recreation, and industry. Water contamination poses many threats. For example:

- Pesticides and nitrates can contaminate drinking water supplies. Nitrate levels as low as 10 parts per million (ppm) in drinking water can cause blue-baby syndrome. While humans more than 6 months old are not seriously affected by nitrate in drinking water, cattle and sheep are.
- Sediment from erosion can ruin aquatic habitats for species that need clear, oxygen-rich water. Residues from lawn and garden fertilizers, especially those containing significant amounts of phosphorus, can over stimulate aquatic plant growth in shallow lakes, making water unsuitable for fish and wildlife. Contamination of water by toxic chemicals can reduce fish populations or make them unfit for human consumption. These problems concern not only those who fish for sport but also 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 can also protect water quality.

For gardeners, the keys to protecting water quality are:

- Reducing the amount of potentially dangerous substances introduced to the environment.
- Minimizing the amount of water that runs off their 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. For example, pavement and gravel allow much more runoff than a landscape of trees or grass (Table 1). On the other hand, a "perfect" lawn often involves more reliance on chemicals than do other types of landscapes.

See Chapter 22, *Landscape Design*.

Table 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).

What can be done

- Select plants adapted to the environmental conditions (sun, moisture, soil, and temperature) of the site to ensure healthy plants and reduced maintenance.
- Replace turf in inappropriate areas (dense shade; steep slopes; narrow, hard-to-irrigate areas; soil compacted by heavy traffic) with plants, mulches, or paving materials that require less irrigation, fertilizer, and pesticides.
- Use porous paving materials (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 underlain by a gravel or tile drainage system. Consult a soils 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.

See Chapter 2, *Soils and Fertilizers*.

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 2 feet.

Drainage also affects the potential for water contamination. A coarse-textured mineral soil such as sand drains rapidly but 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.

However, a dense clay soil drains slowly, thus increasing surface runoff.

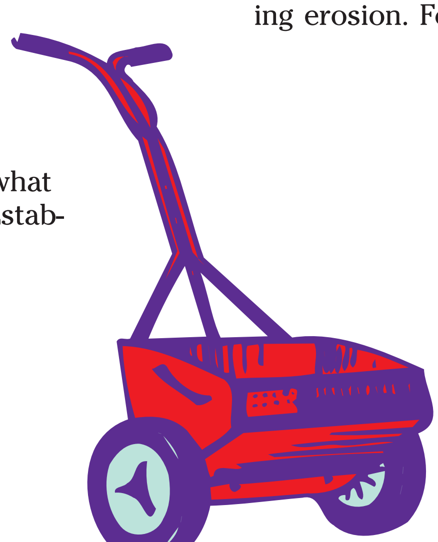
Fertility refers to the presence of minerals necessary for plant life. Unfortunately, the fertility of garden soils is often less than ideal for plant growth. Gardeners usually compensate by adding fertilizers, either from synthetic or natural sources. Overapplication of any fertilizer or manure can result in excess nutrients being carried into lakes and streams or leaching into groundwater. Overfertilization also wastes money, damages plants, and can encourage weeds.

Beating rain 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 can be done

There are several things to do to reduce the likelihood of fertilizers contaminating groundwater and surface water. For example:

- Have 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. A Cooperative Extension Service office can provide names of soil testing labs.
- Use only the amount of fertilizer recommended; more is not better.
- Fertilize according to what 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 using 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 annual and herbaceous perennials 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 clay 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. Low-growing junipers, thyme, and grasses are a few examples.
- Protect existing vegetation where high water velocities are expected. For example, use a concrete splashblock at rain gutter outlets, or place large, rough-edged stones at drainpipe outlets.
- Grow cover crops in vegetable gardens during winter to reduce erosion, trap nutrients, and add organic matter to the soil.

Using garden wastes

Gardening creates wastes such as 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 aquatic 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.

See Chapter 15, *Composting.*

What to 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.
- Since nutrients are likely to leach from compost piles, locate piles away from bodies of water or 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.
- Composting diseased plant materials, annual weeds that have flowered, or perennial weeds is not recommended.

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. For example, 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 the water runs too long. Watering efficiently will reduce water bills while protecting water quality.

Hand watering, with either a hose or a watering can is generally appropriate only for containers or small beds. Hand watering lawns and planting beds usually does no more than wet the soil surface.

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 also is 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 soaked several times a month during the summer. Many drought-resistant plants require minimal watering once they are established.

A bluegrass lawn in Wyoming uses about 2 inches of water per week during hot, dry weather. Watch for signs that indicate the lawn needs watering: gray-green grass, turf that does not spring back when walked on, and blades of grass rolled lengthwise.

Adjust the amount of water applied according to soil type. Use small cans to measure the amount of water sprinklers apply. Turn off the water at the first sign of soil saturation or runoff.

See Chapter 8, *Lawns.*

What to do

- Select plants that need minimal water. Many native plants and other species adapted to dry summers require little irrigation.
- Decrease the amount of lawn. Turf may require more irrigation than a landscape of established trees, shrubs, and groundcovers, depending on the grass type used.
- Increase a lawn's drought tolerance through good cultural practices (soil preparation, dethatching, aeration, fertilization, and proper mowing frequency and height).
- Store runoff from the roof in a rain barrel. Mount a hose tap at the bottom so to use the water in the garden.
- Divide the 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, light irrigations. They tend to encourage shallow rooting and make plants more susceptible to drought stress.
- Apply water slowly (generally not more than 1/2 inch per hour).
- Adjust sprinkler patterns and output to avoid runoff.
- Use soaker hoses or drip irrigation rather than sprinklers where possible.
- If watering 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 plants often to catch problems before they become serious. Detecting and dealing with insect and disease problems early can reduce or eliminate the need for pesticides. The objective is to make a garden a healthy place for plants and an inhospitable place for pests.

See Chapter 14, *IPM.*

What to do

- Plant pest-resistant species and varieties of plants. Check with local nurseries, landscapers, extension agents, or Master Gardeners to see whether resistance information is available for the plants being considered.
- 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 (Solanaceae) family. Rotation can reduce insect infestations and the buildup of soilborne diseases.
- Keep gardens clean. Rocks, wood, and debris provide great hiding places for slugs and insects.
- Weed the garden. Weeds can harbor insects and diseases that attack plants.
- Time plantings to avoid peak insect infestations. Often the most destructive phase of an insect's life is brief and predictable. Check with an Extension office to see whether this information is available for specific insect pests.
- Preserve naturally occurring beneficial organisms by minimizing the use of pesticides.
- Properly identify plant problems. Remember that most problems are cultural or environmental and do not respond to pesticide applications. If a problem is caused by a pest, proper identification is important in selecting the safest and most effective management strategy.
- Determine whether a problem really justifies treatment. Many pests cause only cosmetic damage and are not life threatening to plants.
- Try the least toxic management strategies first. Cultural methods are often a good place to start.
- Record observations and the results of treatments for future reference.
- If using pesticides, choose those that pose the least threat to water quality. Examples include pyrethrins, insecticidal soaps, horticultural oils, and *Bacillus thuringiensis* (Bt).
- Apply pesticides when pests are 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 results.
- Apply preventive fungicides only to plants likely to develop disease problems. Better yet, plant disease-resistant species or cultivars.
- If using pesticides, carefully read the label for directions, usage restrictions, and health and environmental precautions.

See Chapter 13, *Diagnosing Problems.*

See Chapter 4, *Disease.*

See Chapter 19, *Pesticides.*

For more information

UW Cooperative Extension Service publications

Backyard Composting: Simple, Small-Scale Methods (B-974-R)

Landscape Pests: Integrated Pest Management Strategies for Controlling the Dastardly Dozen (B-1035)

Low-Maintenance Grasses for Revegetating Disturbed Areas and Lawns (B-1070)

Nontoxic pest control methods

Insects

See Chapter 14, *IPM.*

- Keep gardens 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 are usually ineffective.)
- Use a stream of water or a brush to dislodge insects.
- Hand pick insects from plants.
- Encourage beneficial insects by planting flowers that provide nectar and pollen.

See Chapter 3, *Entomology.*

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 a compost pile.
- Improve soil drainage and aeration.

See Chapter 4, *Disease.*

See Chapter 2, *Soils and Fertilizers.*

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.

See Chapter 5, *Weeds.*

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Plant Identification

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Learning about new plants is an exciting venture. Sometimes people are looking for a plant to fill a certain spot in a garden, sometimes they want to complete a particular color scheme, and sometimes their attention is caught by a magnificent tree, shrub, or perennial in a public or private garden. When coming 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 one's fingers as a test.) Identification may be as complicated as "keying out" an unknown plant to genus and species (more on keying later).

In addition to dazzling family and friends by rattling off names such as *Aesculus hippocastanum*, by identifying a plant one can determine its 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. By knowing a plant's genus and species, one 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.

Topics in this chapter

- Plant names
- Keys
- Practicing plant identification

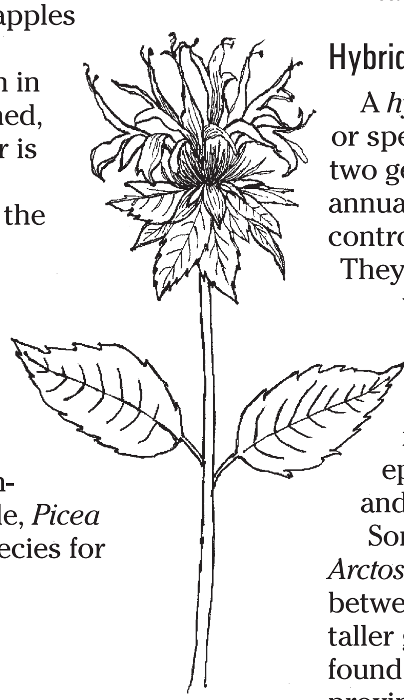
See Chapter 13, *Diagnosing Problems*.

By Marty Wingate, Master Gardener, King County, Washington State University. Adapted for Wyoming by Karen L. Panter, Cooperative Extension Service horticulture specialist, University of Wyoming.

Plant names

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

- *Family*—A broad group of plants with common characteristics. The family name is written in plain text, the first letter is capitalized, and the word ends in "aceae." For example, the maple family is Aceraceae. Some families may be listed using an older style; for example, one may find the daisy family written as either Compositae or Asteraceae. 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 underlined, and the first letter is capitalized. For example, *Picea* is the genus for spruce.
- *Species*—A population of individuals within a genus that are capable of interbreeding freely with one another. For example, *Picea pungens* is the species for blue spruce.



Other terms are also important in plant identification:

- *Specific epithet*—The second word in a plant name. (The word "species" refers to the plant, not the actual word in the name.) The word 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, *Gleditsia triacanthos*, common honeylocust, is further divided into one variety. *G. triacanthos* var. *inermis* is the thornless type while the species *G. triacanthos* has multi-branched thorns from 3 to 6 inches long. The latter is not used for landscape purposes. The word variety can be abbreviated var.; it is not italicized. *Subspecies* (ssp.) is often used in Britain with the same meaning.
- *Form*—A naturally occurring characteristic different from other plants in the same population. For example, the Colorado spruce with the bluest color, *Picea pungens* f. *glauca*, occurs naturally in its native habitat in the Rocky Mountain West.

Hybrids

A *hybrid* is a cross between two varieties or species whether of the same genus or two genera. F_1 hybrids, common among annual vegetables and flowers, are a highly controlled and manipulated type of hybrid. They are a cross between two inbred lines within a species, each of which has been selected and repeatedly inbred for specific traits.

Hybrid names are written with an x 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* x *media*, which is a cross between kinnikinnick (*A. uva-ursi*) and the taller growing *A. columbiana*. *A.* x *media* is found where the two parents grow in close proximity.

Hybridization is common in cultivation as breeders look for better plants for gardens. *Rosa* x *calocarpa* is a cross between *R. rugosa* and *R. chinensis*. Another familiar rose hybrid is *R.* x *harisonii* or Harrison's Yellow Rose. It is a cross between *R. pimpinellifolia* and *R. foetida*.

Occasionally, an *intergeneric* hybrid occurs. Wyoming examples are hard to find, but the Pacific Northwest's leyland cypress was an accidental cross between two species found at a nursery in England. The parents are the Monterey cypress *Cupressus macrocarp* and the Alaskan cedar *Chamaecyparis nootkatensis*. The correct way to write an intergeneric hybrid is to put the x before the genus. Leyland cypress is x*Cupressocyparis leylandii.* (The two generic names were combined.)

Cultivars

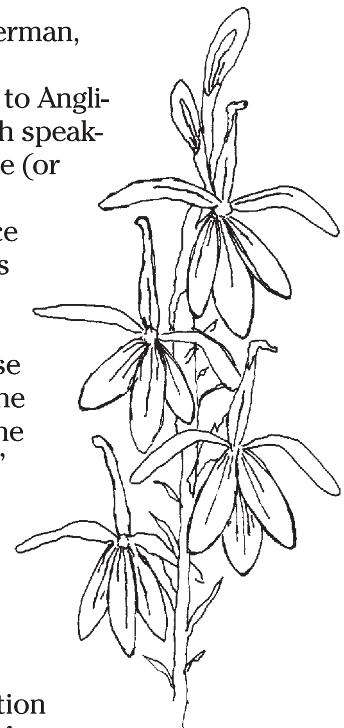
The term *cultivar* is short for "cultivated variety." These are plants within a species that have been selected especially for a particular characteristic and propagated—usually asexually—to continue this characteristic. Bigger blooms, better color, larger fruits, and more compact growth are a few reasons 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. *Penstemon* 'Apple Blossom,' *Malus* 'Spring Snow,' and *Prunus* 'Montmorency' are examples.

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 there are cultivars with Japanese, German, Dutch, or English names.

For awhile, 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 was not only 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

Keys are tools for classification and identification. Keys move from general to more and more specific descriptions (and eventually to identification) by choosing between paired statements. The paired statements have opposite descriptions such as "leaves hairy" and "leaves smooth." Following the one that more correctly describes a specific plant leads to more discrete choices until one arrives at the name of the plant.

Keys are found in many plant identification books. Some include the whole range of flowering plant families; others cover only one genus like 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 1 for a brief example of a key.

Practicing plant identification

Practice—as always—makes perfect. The more people use botanical names for plants, the more quickly they will remember them and not be so self-conscious saying them. Here are some ways to learn and remember:

- Say plant names over and over, using any opportunity that comes along. Repeat the names of plants in a garden even when alone. Say aloud the plants recognized in other gardens.
- Spend a little time each day on plant names. The names and the plants' characteristics should become almost second nature.
- Try to learn the meaning of the names so they make more sense. For example, *Rhus trilobata* is the skunkbush or three-lobed sumac (tri=three; lobata=lobes). *Veronica repens* (creeping veronica) also has its identifying feature in its name: repens means creeping. Another example is *Cerastium tomentosum* or snow-in-summer. The word tomentosum refers to the densely matted hairs on the leaves. Color also plays an important part in plant names. *Acer rubrum* (red maple), *Symphoricarpos alba* (snowberry), and *Ribes sanguineum* (red-flowering currant) are a few examples.
- When looking at plants, note identifying features such as leaf shape and arrangement, growth habit, and flower and/or fruit appearance. All of these aspects help in correct identification.
- Practice during visits to arboreta, nurseries, and public gardens (an enjoyable task in itself!), which often have plant tags or lists of plants.
- Practice using keys such as in *Vascular Plants of Wyoming*.

See Chapter 1, *Botany*.

For more information

UW Cooperative Extension Service publications

Low-Maintenance Grasses for Revegetating Disturbed Areas and lawns (B-1070)

Landscaping: Recommended Trees for Wyoming (B-1090)

Landscaping: Recommended Shrubs for Wyoming (B-1108)

Gardening: Vegetables in Wyoming (B-1115)

Landscaping: Turf in Wyoming (B-1129)

Landscaping: Water-Wise Wyoming Gardens (B-1143)

Gardening: Growing Herbs in Wyoming (B-1144)

Care of Flowering Potted Plants (B-1146)

Landscaping: Herbaceous Perennials for Wyoming (B-1152)

Table 1.—Example of a key.

	I. Leaves opposite	
	1a. Leaves mostly less than 4 cm (1 5/8")	
	2a. Leaf margins toothed	
or *or* *or* *or*	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")	
or	2a. Stems armed (thorny)	*Pyracantha* species
	2b. Stems not armed	
or *or*	3a. Leaves oblanceolate	*Pieris japonica*
	3b. Leaves ovate	*Vaccinium ovatum*
	1b. Leaves greater than 6 cm	
or	4a. Leaves ovate	*Prunus lusitanica*
	4b. Leaves obovate	*Prunus laurocerasus*

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Understanding Pesticides

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Pesticides can be useful when nonchemical methods fail to provide adequate pest control.

Because it is difficult to eradicate an entire population of pests, pesticides are a tool for controlling or managing pest populations at a tolerable level.

The suffix "cide" literally means "kill." The term pesticide refers to a chemical substance that kills pests. Combining the name of the pest (e.g., insect or mite) with the suffix "cide" describes what type of pest a pesticide kills. Thus, it is incorrect to assume that the term pesticide refers only to insecticides. Pesticides include many different types of products with different functions (e.g., insecticides, miticides, and fungicides). Some are listed in Table 1.

Before buying a pesticide, identify the pest and find a pesticide that will control it. Read the label to find out whether the host plant and pest are listed and to make sure the pesticide is not toxic to plants. If there is a choice of products, choose the least hazardous.

Also check safety requirements such as special equipment, protective clothing, restrictions on use, and environmental precautions.

Not all pest problems call for a chemical solution. See "Integrated pest management" later in this chapter for information on other pest control strategies.

Table 1.—Types of pesticides.

Type	Pest controlled
Insecticide	Insects
Miticide	Mites
Nematicide	Nematodes
Fungicide	Fungi
Bactericide	Bacteria
Herbicide	Weeds (also kills other plants)
Rodenticide	Rodents
Molluscicide	Mollusks such as slugs and snails

See Chapter 13, *Diagnosing Problems*.

Topics in this chapter

- Types of pesticides
- Pesticide formulations
- Surfactants
- Pesticide labels
- Application equipment
- Calibrating sprayers and calculating pesticide amounts
- Applying pesticides
- Storage and disposal
- Pesticide toxicity
- Potential environmental hazards
- Home garden versus commercial pesticides
- Integrated pest management
- Pesticides and the law

Edited by Myron Shenk, Extension integrated pest management specialist, Oregon State University. Adapted for Wyoming by Mark Ferrell, Extension pesticide specialist, and Karen Panter, Cooperative Extension Service horticulture specialist, University of Wyoming.

Pesticide terminology

Active ingredient—The chemical in a pesticide formulation that actually kills the target pest.

Attractant—A material that lures pests.

Band—To apply a pesticide in a strip over or along a crop row.

Broadcast—To apply a pesticide uniformly to an entire specific area by scattering or spraying it.

Defoliant—A material that removes or kills leaves and stems.

Dip—To immerse a plant or plant part in a pesticide.

Directed—Aimed at a specific portion of a plant, animal, or structure.

Drench—To saturate the soil with a pesticide.

Foliar—Applied to leaves of plants.

In-furrow—Applied to or in a furrow in which plants are growing.

Phytotoxic—Toxic to plants.

Postemergent—A product applied after crops or weeds emerge from the soil.

Preemergent—A product applied before crops or weeds emerge from the soil.

Preplant—A product applied before a crop is planted.

Repellent—A material that keeps pests away.

Side dress—To apply a pesticide along the side of a crop row.

Spot treatment—To apply a pesticide to a small section or area of a crop.

Surfactant (adjuvant, additive)—A product added to a pesticide to make it more effective.

Types of pesticides

Pesticides can be grouped according to how they work. Many work in more than one way. For example:

- *Contact pesticides* must make direct contact with a pest to kill it.
- *Stomach poisons* kill when swallowed.
- *Systemics* function by entering and becoming distributed within a pest or within plants on which it feeds.
- *Translocated herbicides* move from the point of initial application to circulate throughout a plant. Circulation ensures the death of the entire plant.
- *Fumigants* are gasses that kill when they are inhaled or otherwise absorbed by pests.

Furthermore, pesticides can be divided into two categories:

- *Selective pesticides* kill only certain kinds of plants or animals; for example, 2,4-D kills broadleaf lawn weeds but does not harm most grasses.
- *Nonselective* pesticides kill most plants or animals.

Pesticide formulations

The formulation describes the physical state of a pesticide and determines how it is applied. The chemical in the pesticide formulation that actually kills is termed the *active ingredient*. Other components, which improve efficacy or make the product easier to mix or apply, are termed *inert ingredients*.

Gardeners often attempt to compare a spray with a dust. Note that a dust is a type of formulation, but a spray is not; sprays are one means of applying several different formulations (such as wettable powders or emulsifiable concentrates) mixed with water.

Common pesticide formulations are discussed below.

Emulsifiable concentrates (EC or E)

In these formulations, the active ingredient is mixed with an organic solvent (often a petroleum derivative) and an emulsifying agent. These materials form an *emulsion* when mixed with water for application (i.e., droplets are dispersed throughout the water). ECs are common because they are easy to mix and use. Protect them from freezing temperatures which can break down the emulsifier. One characteristic of many ECs is that they turn water white. They can also cause minor surface bronzing of light-colored fruit. Because ECs are oil-soluble, they penetrate skin more readily than most formulations. Take extra precautions to avoid skin contact with ECs.

Solutions (S)

Solutions are preparations made by dissolving a solid, liquid, or gaseous active ingredient into another substance (usually a liquid) without a chemical change taking place. (Sugar dissolved in water is an example of a solution.) These formulations often are premixed (ready to use directly from the container); others must be mixed with water.

Flowables (F or L)

These formulations consist of very finely ground solid materials (an active ingredient and a carrier) suspended in a liquid. A flowable formulation is mixed with water to form a suspension in a spray tank.

Aerosols (A)

These products are very low-concentrate solutions, usually applied as a fine spray or mist. They are generally sold in aerosol cans and are a convenient but expensive way to apply a pesticide. Some aerosols are dissolved in petroleum distillates and thus are flammable.

Dusts (D)

Dust formulations are made by adding the active ingredient to a fine, inert powder or talc. They are generally used dry. Dusts are more likely to drift than liquid formulations because of their light weight and poor adhering qualities.

Granules (G)

Granular formulations are made by adding the active ingredient to coarse particles (granules) of inert material such as fired clay. They are used dry.

Wettable powders (WP or W)

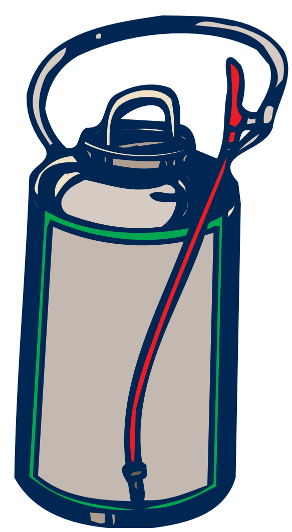
Wettable powder formulations are made by combining the active ingredient with a fine, inert carrier such as talc or silicone. They look like dusts, but they are made to be mixed with water. These formulations are difficult to use because they need continuous agitation to maintain a suspension. When mixing a WP, first mix the measured quantity with a small amount of water to form a slurry. A paper cup and Popsicle stick make good disposable mixing tools. Then add this mixture and the proper amount of additional water to the spray tank. Shake the spray tank frequently to maintain the suspension.

Soluble powders (SP)

A soluble powder formulation contains an active ingredient in powder form that dissolves in water.

Baits (B)

A bait formulation is made by adding the active ingredient to an edible or attractive substance. Baits are often used to control slugs, snails, small ground insects, and rodents.



Surfactants

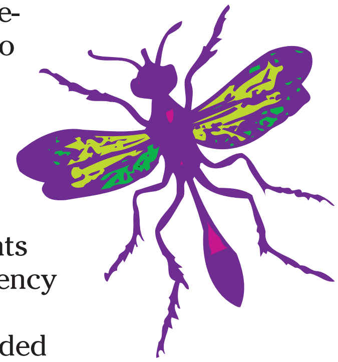
Surfactants (also known as additives or adjuvants) improve pesticide coverage, thus reducing the amount needed and the risk of drift. When added to a pesticide, a surfactant reduces the surface tension between two unlike materials. For example, it may help oil and water mix to form a spray or may help spray droplets stick to a leaf.

Many pesticide products contain surfactants. In other cases, the product label suggests adding a surfactant when mixing the pesticide for spraying. In some cases, surfactants can increase the toxic effects of pesticides. Thus, if the label doesn't recommend addition of a surfactant, don't add one.

Surfactants include activators, compatibility agents, deflocculators, detergents, dispersants, emulsifiers, foam and drift suppressants, and spreading, sticking, and wetting agents. Each of these materials has a different purpose. For example:

- *Suspension agents* help keep a pesticide in suspension.
- *Dispersants* reduce the attraction between like particles, thus enhancing the dispersion of spray.
- *Spreading and sticking agents* increase wetting (or coverage) of leaves, fruits, and stems. These materials are some of the most common surfactants.

When added to a pesticide mix, *spreaders* (also known as wetting agents) increase the area that a given volume of spray will cover. They also improve contact between the pesticide and the plant surface by reducing the surface tension of spray droplets. Most wettable powder insecticides benefit from the addition of a spreader. Overuse of spreaders, however, may cause runoff rather than better coverage.



Stickers (or adhesives) are added to a spray mix to improve the material's adherence (tenacity) to a plant surface. Sticking agents are oily in consistency and increase the amount of suspended solids retained on plant surfaces. Some stickers also protect spray from the effects of wind and rain, thus extending their usefulness. Most fungicides, especially wettable powders, benefit greatly from the addition of a sticker.

Whether a spray rolls off or sticks to a plant surface depends on the physical and chemical properties of the spray mixture and the physical properties of the surface itself. For example, if the plant surface is waxy, spray droplets roll off. Thus, spreading and sticking agents are most useful when spraying the hard-to-wet foliage of plants such as carnations, conifers, euonymuses, gladioli, irises, mahonias, narcissuses, peonies, roses, and yews.

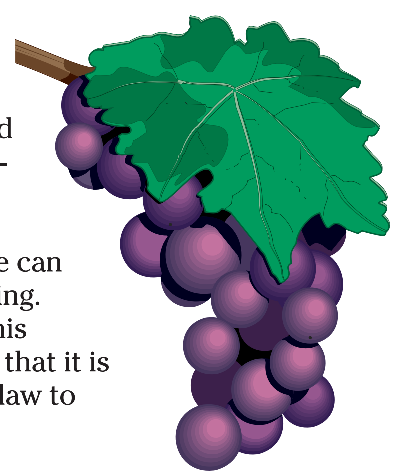
Pesticide labels

All of the printed information on or with a pesticide, including the label, brochures, and fliers from the manufacturer or its agent, is called the *labeling*. The label printed on or attached to a pesticide container tells how to use the product correctly and what special safety measures are needed. Specific parts of a label include the following:

- *Brand name*—Each company uses brand names to identify its products. The brand name shows up plainly on the front of a label.
- *Type of formulation*—Be aware that the same pesticide may be available in more than one formulation.
- *Ingredient statement*—Each pesticide label must list the names and amounts

of active ingredients and the amount of inert ingredients in the product.

- *Common name and chemical name*—Pesticides have complex chemical names derived from their chemical composition. Some are also given a shorter name or common name to make them easier to identify. The same common name or chemical name may be sold under several brand names.
- *Net contents*—This statement tells how much product is in the container. Contents can be expressed in gallons, pints, pounds, quarts, or other units of measure.
- *Name and address of manufacturer*—The producer's or registrant's name and address must be on the label.
- *Registration number*—A registration number must be on every pesticide label. It shows that the product has been approved by the Environmental Protection Agency (EPA) for the uses listed on the label.
- *Establishment number*—The establishment number tells which factory made the chemical.
- *Precautionary statements*—A section with a title such as "Hazards to Humans and Domestic Animals" tells the ways in which the product may harm humans and other animals. It also describes any special steps necessary to reduce hazards such as using protective equipment. Some products inform physicians of the proper treatment for poisoning.
- *Environmental hazards*—The label tells how to avoid damage to the environment. Some examples are: "This product is highly toxic to bees exposed to direct treatment or residues on crops," "Do not contaminate water when cleaning equipment or when disposing of wastes," and "Do not apply where runoff is likely to occur."
- *Physical and chemical hazards*—The label lists specific fire, explosion, or chemical hazards. Examples are: "Do not puncture" and "Do not store near heat or open flame."
- *Signal words and symbols*—Some pesticides may be hazardous to people. Signal words give an idea of the relative toxicity of a pesticide. See "Integrated pest management" later in this chapter for more information about signal words and toxicity ratings.
- *Statement of practical treatment*—If swallowing or inhaling the product or getting it in the eyes or on the skin would be harmful, the label contains emergency first-aid measures and a statement of treatment for medical personnel. The pesticide label is the most important information to take to a physician when someone is poisoned. Without the label, it is difficult for a physician to help.
- *Directions for use*—This section lists the crops, animals, or other sites on which the product can legally be used as well as many of the pests the product will control. It also tells how to apply the product, how much to use, and where and when to apply the material.
- *Preharvest interval*—When a pesticide is used on fruits, vegetables, or other food crops, a certain period of time must pass from the time of application until the crop is safe to pick and use. Known as the preharvest interval and expressed as "days to harvest," this is the time required for the residue to degrade to safe levels. It is often listed as a number in parentheses following the crop name. Do not assume that a residue can be removed by washing.
- *Misuse statement*—This section is a reminder that it is a violation of federal law to



use a product in a manner inconsistent with its labeling.
- *Storage and disposal directions*—Every pesticide should be stored and disposed of correctly. This section tells how to store and dispose of the product.

Always read the label before buying the product, before using, before storing, and before disposal. Buy only as much pesticide as will be needed during the year. Mix only the amount of spray needed for each application.

Application equipment

Pesticide application equipment comes in all shapes, sizes, types, and prices (Figure 1).

Using the same equipment for weed control and insect control is neither safe nor desirable. No matter how well a tank is rinsed after using an herbicide, residue may be left in the tank, gaskets, hoses, and other parts. If the same equipment is used to spray a plant with insecticide or fungicide, the herbicide residue may harm the plant. The wisest policy is to maintain two sprayers—one for herbicides and another for insecticides and fungicides. Label them clearly according to use. Always rinse sprayers after each use. (See "Cleaning equipment" later in this chapter.)

Some common types of application equipment are discussed below.

Proportioners (hose-end sprayers)

These inexpensive, small sprayers are designed to be attached to a garden hose (Figure 1a). A small amount of pesticide is mixed with water and placed in the receptacle. A tube connects this concentrate to the opening of the hose. After the water is turned on, the suction created by the water passing over the top of the tube pulls the pesticide concentrate up and into the stream of hose water. The stream can reach into a tree canopy if water pressure is high.

Some hose-end sprayers control spraying by means of a thumb hole. When the hole is uncovered, the sprayer stops spraying. Others use a trigger device to control spraying.

These sprayers are popular because of their low cost, but they have several potential problems:
- They may distribute spray unevenly.
- They dispense too much spray for many needs and may use excessive amounts of pesticides. Their low price is quickly negated if excessive pesticide is used. However, these sprayers can be appropriate for the soil application of

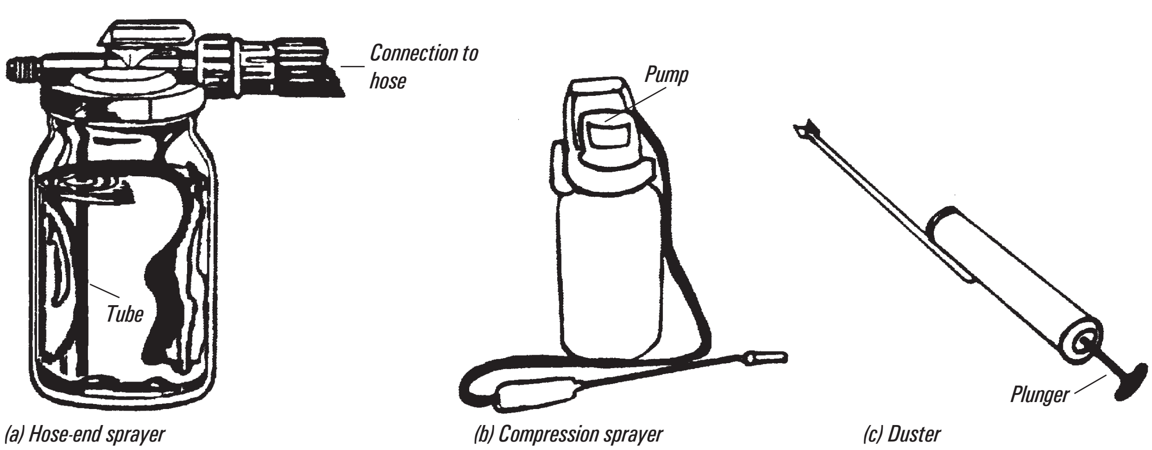


Figure 1.—Types of pesticide application equipment: (a) Hose-end sprayer; (b) compression sprayer; (c) duster.

pesticides in which a high volume of water is needed to move the chemical into the soil.
- Nozzles may clog.
- The metering of concentrate into the stream of water can be inaccurate because it is partially determined by water pressure.

If using a hose-end sprayer, make sure the sprayer or water spigot is equipped with an antisiphon (antiback-flow) device to prevent the back siphoning of toxic chemicals into the water system.

Compression sprayers (knapsack or tank sprayers)

With these sprayers, the spray solution is mixed in a small tank (generally 1 to 5 gallons). A hand-operated pump supplies pressure during application (Figure 1b). Because water weighs approximately 8 ¼ pounds per gallon, small tanks are easier to use than large ones.

A uniform concentration is maintained because the pesticide is mixed with a known quantity of water. However, although these sprayers meter out pesticide more evenly than hose-end sprayers, they do not maintain pressure as evenly unless pumped frequently. Also, frequent agitation of the mixture is necessary when using a wettable powder formulation.

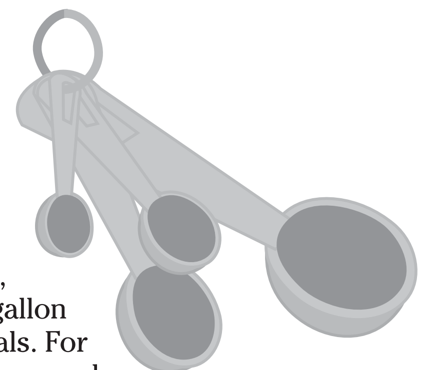
With practice, one can achieve excellent coverage with these sprayers, making them a good choice for treating dwarf fruit trees, vegetables, and ornamentals. The spray will not reach into tall trees, however.

Hand dusters

A duster may consist of a squeeze tube or shaker, a plunger that slides through a tube (Figure 1c), or a fan powered by a hand crank. Uniform coverage of foliage is difficult to achieve with many dusters.

Calibrating sprayers and calculating pesticide amounts

The usual approach to measuring pesticides for spraying is to mix a given quantity of pesticide (e.g., 1 tablespoon) with a given quantity of water (e.g., 1 gallon). This method is acceptable if the label gives recommended rates in teaspoons or tablespoons per gallon. However, some pesticides, usually herbicides and insecticides for lawns, give rates in teaspoons or tablespoons per 100 or 1,000 square feet (similar to fertilizer recommendations).



Be sure to pay attention to this coverage statement. For example, mix 2 tablespoons per gallon of two different chemicals. For product A, the gallon may need to cover 100 square feet (2 tablespoons/100 square feet), while for product B, the gallon should cover 200 square feet (1 tablespoon/100 square feet). If spraying chemical B over only 100 square feet, apply twice as much product as is recommended or required.

To obtain the correct coverage, one must know the sprayer's rate of output. For an exact measure of output, *calibrate* the sprayer. It's relatively easy to calibrate a home sprayer, and the calibration won't change unless the nozzle becomes dirty, there is a change in the nozzle, one's walking speed, or the sprayer pressure.

Keep in mind that the rate at which liquid is applied varies with pressure, walking speed, and nozzle size. High pressure and a large nozzle opening permit more liquid to be applied over a given area than do low pressure and/or a smaller nozzle.

To calibrate a sprayer and calculate how much pesticide to use, follow this procedure:

1. Fill the sprayer with plain water. Pump up the sprayer and spray water into a pint jar for 30 seconds. Measure how much water was sprayed and mark this delivery time and amount on the sprayer. This shows how much spray the sprayer delivers in 30 seconds.
2. Spray an area with water at normal walking speed for 30 seconds. Measure the area sprayed. This shows how much area can be sprayed in 30 seconds. For example, 30 seconds of spraying might deliver ½ cup (from step 1) and cover 100 square feet (from step 2).
3. Measure the area to be sprayed. Multiply length times width to determine the area of a rectangle. For triangles, multiply the base times the height and divide by two. Most areas can be calculated by combining rectangles and triangles or subtracting triangles from rectangles. If the area is large, divide it into sections. Let's say the area equals 2,000 square feet.
4. Calculate how much spray is needed to cover the area. Divide the total area (2,000 square feet) by the area sprayed in step three (100 square feet). Then multiply the answer times the amount of spray you measured in step one (½ cup):

   2,000 square feet ÷ 100 square feet = 20

   20 x ½ cup = 10 cups
5. Calculate how much product is needed for 10 cups of spray. For example, if the label calls for 3 tablespoons of pesticide for 1,000 square feet, divide the total area by 1,000. Then multiply the answer times 3 tablespoons:

   2,000 square feet ÷ 1,000 square feet = 2

   2 x 3 tablespoons = 6 tablespoons
6. Mix 6 tablespoons of pesticide with 10 cups of water and spray this amount over 2,000 square feet to achieve proper coverage.

Applying pesticides

Spray patterns

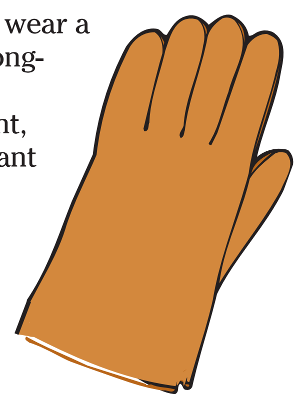
A good spray pattern gives uniform coverage with proper spray overlap. Too much overlap can cause some areas to end up with an extra dose of pesticide. However, the spray pattern should overlap slightly to ensure complete coverage. Sometimes complete overlap is beneficial. For example, if a sprayer's coverage is questionable (as is typical with hose-end sprayers), cut the application rate in half and apply the pesticide first in an east–west direction, then in a north–south direction. Always direct the spray pattern so as not to walk through it while spraying.

The spray pattern should be uninterrupted. If applying an herbicide, don't slow down or stop at each weed. If the herbicide has been mixed correctly and the sprayer properly calibrated, a continuous flow of chemical will be sufficient for good control.

When the recommended rate is in teaspoons or tablespoons per gallon, spray upright plants such as shade trees, fruit trees, shrubs, and vegetables until just before runoff. Every drop of pesticide solution that drips from the leaves represents lost product. Don't forget to spray the undersides of leaves.

Safety precautions

Before mixing or using a pesticide, read the label, even if the same product has been used before.



Even in summer, wear a long-sleeved shirt, long-legged trousers or a coverall-type garment, with chemical-resistant shoes, unlined neoprene or rubber gloves, and a wide-brimmed, plastic hard hat that covers the back of the neck. Wear goggles or a face shield to protect one's eyes if the label requires eye protection. Rubber or other chemical-resistant gloves and goggles are particularly important when mixing or pouring pesticides.

To prevent contamination and waste, always check application equipment for leaking hoses or connections and plugged, worn, or dripping nozzles *before* adding pesticide. Before spraying, clear all people, pets, and livestock from the area.

To minimize drift, apply pesticides only when there is a breeze of less than 5 miles per hour. If even moderate winds come up while spraying, stop immediately. Reduce drift by spraying at low pressure (do not pump the spray tank to maximum pressure) or by using a nozzle with a larger orifice. Generally, drift is least likely to occur in early morning or late evening.

Vaporization is the evaporation of an active ingredient during or after application. Pesticide vapors can injure nontarget plants. High temperatures increase vaporization of many chemicals. Choose pesticide formulations that do not evaporate easily and spray during the cool part of the day.

The common herbicide 2,4-D vaporizes easily, and its vapor can move long distances in hot or windy weather. Do not use it near highly sensitive plants such as grapes, tomatoes, and roses. Do not apply it in windy weather or when temperatures will exceed 85°F following application.

After using any pesticide, people should wash their hands and arms thoroughly with soap and water. Never eat, drink, or smoke without washing. Afterward, shower and put on clean clothes. Keep the clothing worn while spraying separate from the family wash. After washing pesticide-contaminated clothing, add detergent to the washer and run it again empty.

If sprayed by accident, change and shower immediately. Use first-aid procedures if necessary.

Cleaning equipment

Do not store mixed pesticides. Spray leftover mixed pesticide over an area that it will not harm. Check the pesticide label to determine safe areas.

Thoroughly clean all spray equipment inside and out with clean water immediately after use. Don't forget to flush the hose and nozzle by spraying clean water through them. Be careful not to let the cleaning water damage crops and do not dump it in one place where it will be concentrated and may become a pollutant. Spray the rinse water over a broad area so the pesticide will be diluted further. Never rinse pesticides down the drain.

To clean 2,4,-D-type herbicides from spray equipment, thoroughly rinse the equipment after spraying with a solution of ½ cup ammonia to 3 gallons of water. Spray part of this mixture to clean the pump, hose, and nozzles. Let the rest sit in the tank for 12 to 24 hours before spraying out and washing the tank.

Note: Some chemicals cannot be completely removed from a sprayer. Do not use a sprayer that has held weed killers to apply insecticides or fungicides to desirable plants.

Storage and disposal

Do not store pesticides in a house. Store all pesticides in their original containers in a locked cabinet.

Protect chemicals from temperature extremes; some can be damaged by freezing, direct sunlight, or heat.

After using the last of a liquid pesticide, rinse the bottle with water at least three times and pour the rinse water into the spray tank. Spray it out in a safe place. Drain the bottle well.

Dispose of containers as follows:

- *Glass*—If possible, break the container. Otherwise,

replace the lid, wrap the container in newspaper, and place it in a trash can for collection.
- *Rigid plastic*—Replace the lid, wrap the container in newspaper, and place it in a trash can for collection.
- *Cardboard, soft plastic, and bags*—Rinse if possible, then crush or puncture to prevent reuse. Wrap the container in newspaper and place it in a trash can for collection. Do not burn paper containers.

Never use empty pesticide containers for other uses and never allow children to play with empty containers.

Disposal of full or partially full containers can be a problem. Many communities have collection days for hazardous materials. If a particular community does not, contact a county Cooperative Extension Service office for advice.

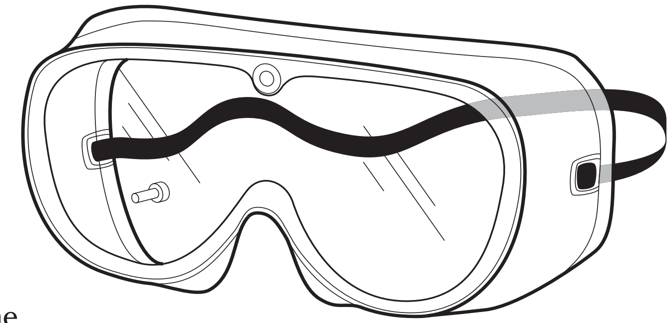
Pesticide toxicity

Most pesticides can cause severe illness or even death if misused, but every registered pesticide can be used safely. Accidental death can occur when pesticides are swallowed, usually by young children. Sometimes applicators die or are injured when they carelessly breathe vapors or allow highly toxic pesticides to remain on their skin.

Two types of pesticide toxicity (or damage) are often mentioned: acute and chronic. *Acute* effects are those resulting from a single exposure. They are usually noted within a few minutes to several days.

Chronic effects result from repeated low-level exposure and often do not manifest themselves for decades. Lung cancer is an example of a chronic effect of decades of smoking.

Always use safety precautions and treat all pesticides with respect. To prevent accidents, use and store pesticides away from children, keep pesticides in their original containers, and always follow label directions.



Symptoms of poisoning

Awareness of the early symptoms and signs of pesticide poisoning is important. Unfortunately, all pesticide poisoning symptoms are not the same. Each chemical family (organophosphates, carbamates, chlorinated hydrocarbons, etc.) affects the human body in a unique way.

Fumigants and solvents can make a person seem drunk. Symptoms include poor coordination, slurring of speech, confusion, and sleepiness.

Common pesticides such as organophosphates and carbamates injure the nervous system. Symptoms develop in stages, usually occurring in this order:

1. *Mild poisoning or early symptoms of severe poisoning*—Fatigue, headache, dizziness, blurred vision, excessive sweating and salivation, nausea and vomiting, stomach cramps, or diarrhea.
2. *Moderate poisoning or early symptoms of severe poisoning*—Inability to walk, weakness, chest discomfort, muscle twitches, constriction of pupils (only with organophosphates and carbamates); earlier symptoms become more severe.
3. *Severe poisoning*—Unconsciousness, severe constriction of pupils (only with organophosphates and carbamates), muscle twitches, convulsions, secretions from mouth and nose, breathing difficulty, death if not treated.

Illness may occur a few hours after exposure. If symptoms start more than 12 hours after exposure to a pesticide, some other illness is probably responsible. Check with a physician to be sure.

First-aid procedures

In case of poisoning, call a physician, Poison Control Center, or police emergency number (911). Have the pesticide package on hand and be able to identify what the victim took and how much was taken. Keep calm but don't delay unnecessarily.

Read the "Statement of Practical Treatment" on the label. These directions can save lives.

If a pesticide gets on the skin, wash it off as quickly as possible and remove all contaminated clothing. Prompt washing may prevent sickness even if the spill is large. Detergents work better than soap for removing pesticides. Don't forget to clean the hair and fingernails.

If a pesticide is inhaled, get the victim to fresh air right away. Loosen all tight-fitting clothing. If needed, give artificial respiration immediately. (Do not administer *direct* mouth-to-mouth resuscitation if the victim has swallowed a pesticide.) Do not stop until the victim is either breathing well or medical help arrives. Get the victim to a physician.

Unless trained in first aid, do not administer anything to a poison victim. Such an action may add to the harm already done.

Poison control center	
Wyoming	1-800-955-9119

Potential environmental hazards

There are several ways that pesticides can harm the environment or beneficial organisms, some of which are discussed in this section. To minimize the risk of damage, spray only when pest populations require it and use as little pesticide as possible. If more than one pesticide will control a pest, choose the one that is the least hazardous to the environment and most useful for the situation. Do not apply insecticides when temperatures are unusually low because many residues remain toxic much longer under these conditions.

Direct kill

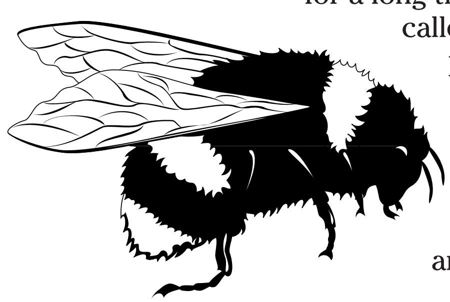
Fine mists of herbicides can drift to nearby crops or landscape plants and kill them. Bees and other pollinators can be killed if a crop is treated with a pesticide when they are in the field. The natural enemies of pest insects can also be killed by pesticides. Plants and animals in streams or ponds can be harmed by the accidental spraying of ditches and waterways, careless container disposal, and the leaching of harmful chemicals through the soil.

See Chapter 17, *Water Quality*.

Give special consideration to protecting insect pollinators such as honeybees and bumblebees. Apply insecticides that are highly toxic to bees only when bees are not active, i.e., in late evening and early morning. **Do not apply insecticides that affect bees when plants are blooming.**

Persistence and accumulation

Although most pesticides break down quickly into harmless products, some break down slowly and stay in the environment for a long time. These pesticides are called *persistent*. Some persistent pesticides can build up in the bodies of animals, including humans. These pesticides are called *accumulative*. Most persistent pesticides have very limited usage or are no longer available.



Compatibility and synergism

Compatibility occurs when two or more pesticides can be mixed together without reducing their effectiveness or harming the plant to which they are applied. For instance, carbaryl (Sevin) is often combined with a miticide such as Kelthane in order to kill both insects and mites at one time.

Synergism is the action of two materials that used together produce a greater effect than the sum of the materials used alone. Each of the materials used alone may have a limited effect, but the total effect is greatly increased when the two are used together. For example, chemical A kills 60 percent of a pest population and chemical B kills 20 percent, but chemicals A and B together kill 98 percent of the pests.

Synergism may increase control or allow the use of less chemical, but it also may make pesticides more harmful to nontarget organisms. A synergistic effect may also kill or damage the plant being protected.

Home garden versus commercial pesticides

Some pesticides are packaged specifically for home garden use. These products are packaged in small quantities, e.g., pints, quarts, ounces, or pounds. They are seldom highly toxic and are usually in low concentrations. The label rate is given on a per-gallon or per-square-foot basis.

Because of the limited label size on small containers, home garden products may not list all of the plants and/or pests for which a product is registered. For example, one manufacturer may sell a 25 percent emulsifiable concentrate insecticide as both a fruit and vegetable insect control and also a more generic insect spray. They are basically the same product, but plants and pests listed vary greatly. This situation causes confusion and stimulates the purchase of excessive amounts of pesticides.

Products packaged for commercial growers may seem less expensive, but do not be tempted to use them. They are generally more toxic than those for home use and require special protective clothing and equipment. These products are more concentrated and are sold in larger containers than homeowners can use or store safely. They are also much more difficult to calibrate and mix correctly since rates are usually based on a per-acre system.

A few products that are extremely toxic to humans or the environment are classified by the EPA as *restricted-use pesticides*. Labels on these products state "Restricted-use pesticide for retail sale to and application only by certified applicators or person under their direct supervision." A license from the Wyoming Department of Agriculture is required for purchase and use of restricted-use pesticides. This licensing is intended for commercial growers and applicators and does not automatically authorize them to use these products in home gardens, even their own.

Protect one's self, one's family, and the environment. Do not use pesticides from the commercial trade.

Integrated pest management

Although it is questionable whether all crops could be raised without the use of pesticides, it is certainly true that the amount of pesticides used can be reduced by applying them carefully and efficiently and by employing an *integrated pest management* (IPM) strategy.

IPM is probably the best answer to pest control. In this strategy, the wise use of pesticides is combined with appropriate cultural practices (e.g., planting pest-resistant crops, maintaining good plant health, and providing an excellent growth environment), alternative pest control methods, and the encouragement of each pest's natural enemies. Cultural, biological, mechanical, and chemical (organic or synthetic) methods of pest control are used.

Note that organic gardeners do use pesticides (for example, rotenone, sabadilla, *B.t.*, insecticidal soap, copper, and sulfur). Use the same care when using organic pesticides as when using synthetic chemicals.

Consider the following steps before automatically turning to a pesticide. See the box at the end of this chapter for a checklist.

First, make sure the pest has been identified correctly. Then determine whether control measures are needed. Is the problem severe enough to warrant treatment? If the expected loss from pest damage is acceptable or costs less than the control, treatment may not be desirable.

Do not use a pesticide unless there is a definite reason to do so. Sometimes a problem will be taken care of naturally by predatory insects or a change in weather. In other cases, nonchemical control measures may adequately solve the problem. For example, if the problem is only several caterpillars, one may be able to easily collect and kill them. Likewise, one may be able to dislodge a small population of aphids with a forceful spray of water from a garden hose. In such cases, it might not be necessary to use a pesticide.

Beneficial insects help keep pest populations down. Pesticides seldom discriminate; they kill good insects along with the bad.

Make sure the pest is present and in a vulnerable stage before treating a plant. For example, a caterpillar pest may have already pupated before its damage is noticed. In this case, treating for the caterpillar will have no effect.

Finally, make sure to choose the right pesticide. Make sure both the pest and plant are listed on the label. Choose the least toxic pesticide if possible.

Labels give a general idea of toxicity by the use of signal words. Pesticides labeled "Caution" are the least toxic, those labeled "Warning" are more so, and those labeled "Danger" are the most toxic. One can obtain a list of toxicity ratings from the Northwest Coalition for Alternatives to Pesticides. Other sources of information about pesticides include agricultural chemical references, IPM reference books, a county Cooperative Extension Service office, and the National Pesticide Telecommunications Network. (See "For more information.")

See Chapter 13, *Diagnosing Problems,* and Chapter 14, *IPM*.

Pesticides and the law

The registration and use of pesticides are governed by the EPA and state departments of agriculture. Under the amended Federal Insecticide, Fungicide, and Rodenticide Act (Federal Environmental Control Act of 1972), and other amendments, it is illegal to use a pesticide on a food crop unless the crop is listed on the label. The rate of application on the label may not be exceeded. Fines and other penalties vary.

Often, people ask whether it is safe to eat vegetables or fruits that have been sprayed with a product that is not recommended for that particular crop. The response should be, "I cannot recommend eating food from plants treated with an unregistered product."

Property owners are legally liable for the misuse of pesticides on their property. Recent court rulings extend that liability to include misuse by hired commercial applicators. Serious misuse by gardeners can result in treatment of a plant by the wrong pesticide or drift of a pesticide onto nontarget plants.

For more information

UW Cooperative Extension Service publications

Available online at www.uwyo.edu/ces/plantsci.htm. Pesticide use and safety publications MP-93.1 through MP-93.9 and MP-93.10 through MP-93.21

National Pesticide Telecommunications Network
Oregon State University
333 Weniger Hall
Corvallis, OR 97331-6502
Phone: 1-800-858-7378
Web: ace.orst.edu/info/nptn/

Before you spray—Checklist

Make sure to answer yes to these questions before applying any pesticide.

- ❒ Has the insect or disease causing the problem been identified?
- ❒ Is the level of damage substantial enough to warrant control?
- ❒ Is the problem unlikely to go away if action isn't taken?
- ❒ Have other cultural, biological, or mechanical control methods been tried?
- ❒ Is the pest present and in a vulnerable stage at the time the pesticide will be applied?
- ❒ Is the pesticide registered for use on the plant or site it will treat?
- ❒ Is the pest or disease listed on the pesticide label?
- ❒ Has the least toxic pesticide registered for use on the pest and crop been chosen?

Appendix—Conversion factors

Volume measurements

3 teaspoons	1 tablespoon
2 tablespoons	1 fluid ounce
16 tablespoons	1 cup
8 fluid ounces	1 cup
1/2 fluid ounce	1 tablespoon
1/2 pint	1 cup (8 fluid ounces or 16 tablespoons)
16 fluid ounces	1 pint (2 cups)
2 pints	1 quart (4 cups)
4 quarts	1 gallon (16 cups)
1 tablespoon	3 teaspoons (1/2 fluid ounce)
1 fluid ounce	2 tablespoons
1 cup	8 fluid ounces (16 tablespoons or 1/2 pint)
1 pint	16 fluid ounces (2 cups)
1 quart	2 pints (4 cups)
1 gallon	4 quarts (16 cups)

Area measurements

144 square inches	1 square foot
9 square feet	1 square yard
43,560 square feet	1 acre
4,840 square yards	1 acre
1 square foot	144 square inches
1 square yard	9 square feet
1 acre	43,560 square feet

Metric–U.S. conversions

1 liter	1.056 quart
1 gram	0.03527 ounce
1 kilogram	35.2740 ounces (2.2046 pounds)
1 meter	1.093 yards (3.281 feet)
1 kilometer	0.621 mile

U.S.–metric conversions

1 fluid ounce	29.5729 milliliters
1/2 pint	237 milliliters
1 quart	0.946 liter
1 gallon	3.785 liters
1 ounce	28.3495 grams
1 pound	453.59 grams (0.45359 kilograms)
1 yard	0.91 meter

Metric conversion factors

To change	***to***	***Multiply by***
Inches	Centimeters	2.540
Feet	Meters	0.305
Square yards	Square meters	0.836
Square meters	Square yards	1.196
Fluid ounces	Cubic centimeters	25.570
Quarts	Liters	0.946
Cubic centimeters	Fluid ounces	0.034
Liters	Quarts	1.057
Ounces	Grams	28.350
Kilograms	Pounds	2.205
Pounds	Kilograms	0.45359

Divider goes here

Plant Propagation

20

Plant propagation is the process of multiplying the numbers of a species, perpetuating a species, or maintaining the youthfulness of a plant. There are two types of propagation: sexual and asexual.

Sexual propagation is the union of pollen and egg, drawing from the genes of two parents to create a new individual. Sexual propagation involves the floral parts of one or more plants.

There are advantages to sexual propagation:

- It may be cheaper and quicker than other methods.
- It may be the only way to obtain new varieties.
- In certain species, it is the only viable method of propagation.
- It avoids transmission of certain diseases.

Asexual propagation involves regenerating a new plant from a vegetative part (root, stem, or leaf) of one parent. The new plant is genetically identical to the parent plant.

Asexual propagation also has advantages:

- In some species it may be easier and faster than sexual propagation.
- It may be the only way to perpetuate some cultivars.
- It bypasses the juvenile characteristics of certain species.

Topics in this chapter

Sexual propagation
- Seeds
- Spores (ferns)

Asexual propagation
- Cuttings
- Layering
- Offsets
- Separation
- Division
- Grafting
- Budding
- Plant tissue culture

Sexual propagation

Sexual propagation involves the union of pollen from a male flower part with the egg of a female ovary to produce a seed. The seed is made up of three parts: the outer *seed coat*, which protects the seed; the *endo-sperm*, 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 *germinates* (begins active growth).

See Chapter 1, *Botany*.

Adapted from *The Virginia Master Gardener Handbook*. Edited by Ray McNeilan, Extension agent emeritus, Multnomah County, Oregon State University. Adapted for Wyoming by Karen L. Panter, Cooperative Extension Service horticulture specilist, University of Wyoming.

Seeds

To obtain high-quality plants, start with high-quality seeds from a reliable dealer. Seed products should not contain any debris or other crop or weed seeds.

Select varieties to provide the size, color, and growth habit desired. Choose varieties that are adapted to a particular area and will reach maturity before an early frost.

Many vegetable and flower varieties are *hybrids* (a cross between two species), which cost a little more than open-pollinated types. However, hybrid plants usually have more vigor, more uniformity, and better production than nonhybrids. Sometimes they have specific disease resistance or other unique cultural characteristics.

Although some seeds keep for several years if stored properly, it is advisable to purchase only enough seed for the current year. If seeds are obtained well before their sowing date, keep them in a cool, dry place. Laminated foil packets help ensure dry storage. It's best to keep paper packets in tightly closed jars or containers at about 40°F and low humidity.

See Chapter 10, *Vegetable Gardening*.

Most seed companies take great care in handling seeds. Seed packets indicate the year for which the seeds were packaged, the expected germination percentage, the plant variety, and chemical seed treatment (e.g., with fungicides) if applicable.

Generally do not expect more than 65 to 80 percent of seeds to germinate. From these germinated seeds, expect about 60 to 75 percent to produce satisfactory vigorous, sturdy seedlings.

Some gardeners save seeds from their own gardens; however, such seeds are the result of random pollination by insects or other natural agents and may not produce plants like the parents. This is especially true of hybrid varieties.

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

Germination

Four environmental factors affect germination: water, oxygen, light, and temperature. Different seeds have different requirements, especially for temperature and light. Table 1 lists the specific requirements of several kinds of seeds. Seed catalogs and packets often list germination or cultural tips for individual varieties.

An adequate, continuous supply of water is important to ensure germination. Although seeds have a great ability to absorb (*imbibe*) water, the amount of water available in the growing medium affects imbibition. Once the germination process has begun, a dry period will kill the embryo.

Light can stimulate or inhibit the germination of some seeds. The light reaction involved is complex. Some crops require light for seed germination. Examples are ageratum, begonias, browallia, impatiens, lettuce, and petunias. Others such as calendula, centaurea, annual phlox, verbena, and vinca require darkness. For other plants, light doesn't matter at all.

When sowing seeds that require light, leave them on the soil surface or at most cover them lightly with fine peat moss or vermiculite. These materials, if not applied too heavily, permit some light to reach the seeds and do not limit germination. Supplemental light can be provided by suspending fluorescent lights 6 to 12 inches above the seeds for 16 hours a day.

In all viable seeds, *respiration* takes place. Respiration is the conversion of stored carbohydrates into energy, a process that requires oxygen. The respiration rate in nongerminating seeds is low, but some oxygen still is required. Because respiration increases during germination, the medium in which seeds are planted should be loose and well aerated. If the oxygen supply is limited, germination can be severely inhibited.

The temperature of the planting medium is another important factor in germination. Temperature not only affects the germination percentage but also the speed of germination. The importance of maintaining proper temperature cannot be overemphasized.

Some seeds germinate over a wide range of temperatures while others require a narrow range. Many seeds have minimum, maximum, and optimum temperatures for germination. For example, the minimum germination temperature for tomato seed is 50°F and the maximum is 95°F, but the optimum is about 80°F.

Table 1.—Seed germination requirements.

Plant	Approximate time to start seeds indoors before last spring frost (weeks)	Approximate germination time (days)	Optimum germination temperature (°F)	Germinates in light (L) or dark (D)
Ageratum	8	5–10	70	L
Alyssum	8	5–10	70	L, D
Aster	6	5–10	70	L, D
Balsam	6	5–10	70	L, D
Begonia	12 or more	10–15	70	L
Broccoli	8	5–10	70	L, D
Browallia	12	15–20	70	L
Cabbage	8	5–10	70	L, D
Cauliflower	8	5–10	70	L, D
Celosia	8	5–10	70	L, D
Centaurea	6	5–10	65	D
Coleus	8	5–10	65	L
Cosmos	4 or less	5–10	70	L, D
Cucumber	4 or less	5–10	85	L, D
Dahlia	8	5–10	70	L, D
Dianthus	10	5–10	70	L, D
Eggplant	8	5–10	70	L, D
Geranium	12 or more	10–20	70	L
Impatiens	10	15–20	70	L
Larkspur	12 or more	5–10	55	D
Lettuce, head	8	5–10	70	L
Marigold	6	5–10	70	L, D
Muskmelon	4 or less	5–10	85	L, D
Nicotiana	8	10–15	70	L
Pansy (Viola)	12 or more	5–10	65	D
Pepper	8	5–10	80	L, D
Petunia	10	5–10	70	L
Phlox	8	5–10	65	D
Portulaca	10	5–10	70	D
Snapdragon	10	5–10	65	L
Squash	4 or less	5–10	85	L, D
Stock	10	10–15	70	L, D
Tomato	6	5–10	80	L, D
Verbena	10	15–20	65	D
Vinca	12 or more	10–15	70	D
Watermelon	4 or less	5–10	85	L, D
Zinnia	6	5–10	70	L, D

See Chapter 1, *Botany*.

When the germination temperature is listed on a seed packet, it usually is the optimum temperature unless otherwise specified. Generally 65° to 75°F is best for most plants. One may need to place germination flats in special chambers or on radiators, heating cables, or heating mats to maintain the optimum temperature.

If environmental conditions are satisfactory, germination begins when certain internal requirements are met. A seed must have a mature embryo, a large enough endosperm to sustain the embryo during germination, and sufficient hormones to initiate the process.

Artificially breaking dormancy

One of the functions of dormancy is to prevent a seed from germinating until it is surrounded by a favorable environment. In some trees, shrubs, and other perennials, dormancy is difficult to break, even when the environment is ideal. Various treatments are performed on these seeds to break dormancy and stimulate germination.

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:

- To scarify seeds mechanically, file them with a metal file, rub them with sandpaper, or gently crack them with a hammer.
- To scarify seeds with acid, put them in a glass container and cover them with concentrated sulfuric (battery) acid at about twice the volume of seeds. Stir gently and allow the seeds to soak from 10 minutes to several hours, depending on the hardness of the seed coat. When the seed coat becomes thin, remove the seeds, wash them, and plant them.
- To scarify seeds with hot water, heat the water to 170° to 212°F and pour it over the seeds. As the water cools, allow the seeds to soak for 12 to 24 hours and then plant them.
- To use a warm-moist scarification method, store seeds for several months in nonsterile, warm, damp containers; the seed coat will be broken down by decay.

Seed stratification is a procedure that provides an artificial chilling period for seeds that require a cold, moist period before germinating.

To stratify seeds, fill a container with sand or vermiculite to about 1 inch from the top. Place the seeds on the surface of the medium and cover them with an additional ½ inch of medium. Water thoroughly and allow excess water to drain through the hole in the pot. Place the pot in a plastic bag and tie the bag with a twist tie or rubber band. Place the bag in a refrigerator. Periodically check to make sure the medium is moist but not wet. Additional water will probably not be necessary. After 10 to 12 weeks, remove the bag from the refrigerator. Take the pot out and set it in a warm place in the house. Water often enough to keep the medium moist. Soon the seedlings should emerge. When the young plants are about 3 inches tall, transplant them into pots to grow until planting time.

Another chilling procedure that is usually successful uses sphagnum peat moss. Seeds of most fruit trees can be germinated successfully by this procedure. Wet the moss thoroughly and then squeeze out the excess water. Mix the seeds with the moss and place the material in a plastic bag. Use a twist tie or rubber band to secure the top and then refrigerate the bag. Check it periodically. If there is condensation on the inside of the bag, the process will probably be successful. Temperatures in the range of 35° to 45°F are effective. Most refrigerators operate in this range. After 10 to 12 weeks, remove the bag from the refrigerator. Plant the seeds in pots. Handle the seeds carefully; often small roots and shoots are emerging by this time, so take care not to break them.

To stratify peach seeds, first remove them from their hard pit. Be careful when cracking the pits; any injury to the seeds can be an entry path for disease organisms.

Soil mixes for starting seeds

Many kinds of planting media can be used to start seeds, ranging from vermiculite alone or mixed with other artificial materials to various amended soil mixes. Regardless of the material, a germinating medium must be:

- Fine and uniform yet well aerated and loose
- Free of insects, disease organisms, and weed seeds
- Low in fertility and total soluble salts
- Capable of holding and moving moisture by capillary action

One mixture that meets these criteria is a combination of one-third vermiculite, one-third perlite, and one-third sphagnum peat moss. Do not use garden soil to start seedlings because it is not sterile, is too heavy, does not drain well, and will shrink from the sides of containers if allowed to dry out.

The importance of using a sterile medium and container cannot be overemphasized. A clean mix will prevent damping off and other plant diseases as well as eliminate potential plant pests (Figure 1).

Pots and other growing containers should also be thoroughly clean. First wash them to remove debris and then rinse them in a solution of 1 part chlorine bleach to 10 parts water. Avoid recontaminating the medium and tools.

An artificial, soilless mix does not need to be sterilized. The basic ingredients of such a mix are sphagnum peat moss, perlite, and vermiculite, all of which are generally free of diseases, weed seeds, and insects. These materials are readily available, easy to handle, lightweight, and able to produce uniform plant growth.

Ready-made soilless ("peat-lite") mixes or similar products are commercially available or can be made at home by thoroughly mixing the following ingredients:

- 4 quarts shredded sphagnum peat moss
- 4 quarts fine-grade vermiculite
- 1 tablespoon superphosphate
- 2 tablespoons ground limestone

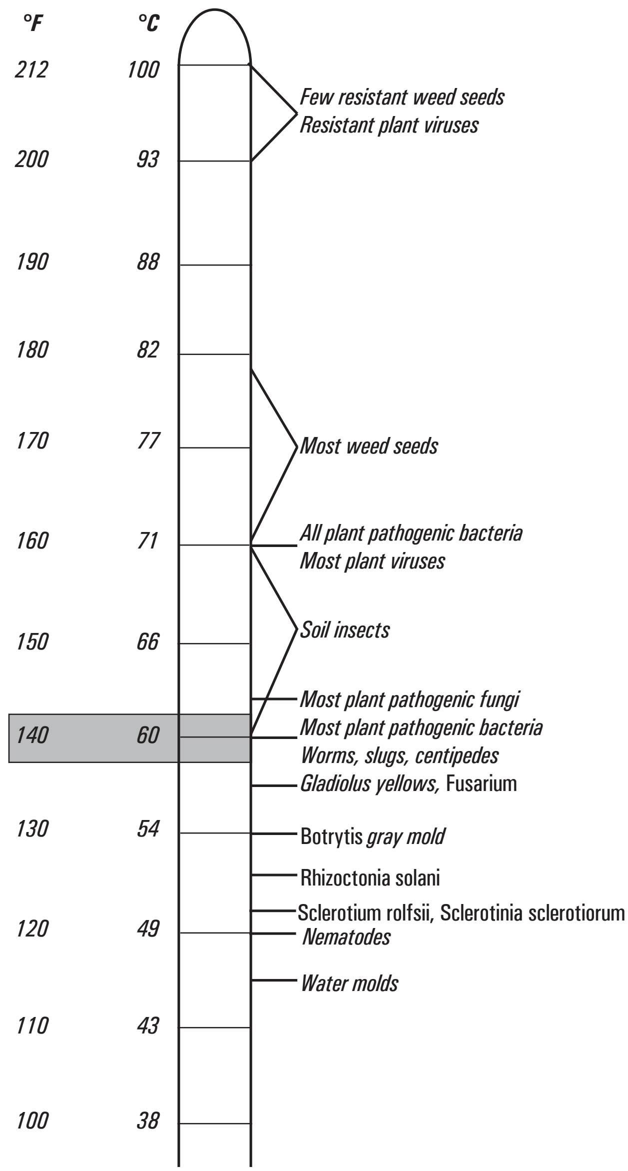


Figure 1.—Temperatures at which soil organisms are killed.

These mixes have little fertility so seedlings must be watered with a diluted fertilizer solution soon after they emerge.

Containers for starting seeds

Seedlings can be grown in a wide assortment of containers. One can buy wooden or plastic flats and trays or make them from scrap lumber. A convenient size is about 12 to 18 inches long, 12 inches wide, and 2 inches deep. Leave 1/8-inch cracks between the boards in the bottom or drill a series of holes to ensure drainage. Clay or plastic flowerpots can be used, too. Aluminum pie pans, cottage cheese containers, and the bottoms of milk cartons or bleach containers can be recycled for starting seeds, but good drainage must be provided.

Numerous types of pots and strips made of compressed peat, plant bands, and plastic cells are sold in garden stores and nurseries. Each cell or minipot holds a single plant, reducing the risk of root injury during transplanting. Peat pellets, peat or fiber-based blocks, and expanded plastic-foam cubes can also be used. With these products, the growing medium itself forms the container.

Starting seeds

The proper time for sowing seeds indoors for transplants depends on when plants may be safely moved outdoors. Sowing dates range from 4 to 12 weeks prior to the last spring frost depending on the cold hardiness of the plant, the speed of germination, the rate of growth, and conditions provided (Table 1). A common mistake is to sow seeds too early and then attempt to hold seedlings back under poor light or improper temperatures. The result is usually tall, weak, spindly plants that do not perform well in the garden.

Fill the selected container to within 3/4 inch from the top with moistened medium. For very small seeds, at least the top 1/4 inch should be a layer of fine, screened mix or vermiculite. Gently firm the medium at the corners and edges using one's fingers or a block of wood to provide a uniform, flat surface.

For medium to large seeds, make furrows with a narrow board or pot label about 1 to 2 inches apart and 1/8 to 1 1/4 inch deep across the surface of the growing medium (Figure 2). Sowing in rows encourages good light and air movement, so if damping-off fungus does appear it has

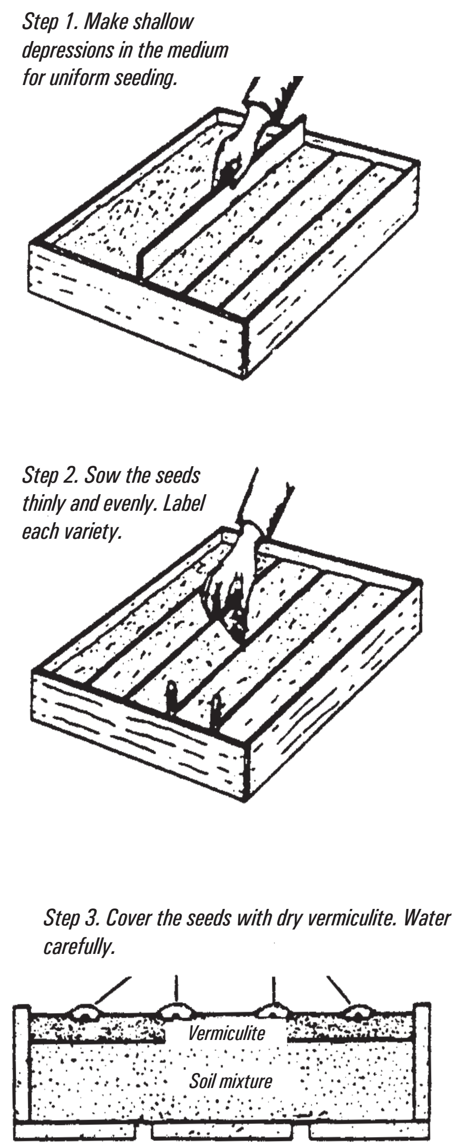


Figure 2.—Sowing seeds in a starter flat.

less chance of spreading. Seedlings in rows are also easier to label and to handle at transplanting time than those sown by broadcasting.

Sow the seeds thinly and uniformly in the rows by gently tapping the seed packet as it is moved along the row. Lightly cover the seeds with dry vermiculite or sifted medium if they require darkness for germination. Do not cover seeds too deeply. A suitable planting depth is usually about twice the diameter (not length) of the seed.

Do not cover extremely fine seeds such as those of petunias, begonias, and snapdragons; instead, lightly press them into the medium or water them in with a fine-mist spray. If broadcasting these seeds, strive for a uniform stand by sowing half the seeds in one direction then sowing the other way with the remaining seeds.

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

Pregermination is another method of starting seeds. This method involves sprouting the seeds before planting them in pots or in the garden. It reduces the time to germination because temperature and moisture are easy to control, and it guarantees a high germination percentage because no seeds are lost to environmental factors.

To pregerminate seeds, lay them between folds of cotton cloth or paper towels placed on top of a layer of vermiculite or similar material in a pan. Water gently and put them in a warm place. Keep the seeds moist. When roots begin to show, plant the seeds in containers or directly in the garden. Be careful not to break tender roots.

When planting pregerminated seeds in a container that will later be set in a garden, place one seed in each 2 to 3-inch-deep container. Plant the seeds only one-half the recommended depth. Gently press a little growing medium over the sprouted seeds and add about $^1/_4$ inch of milled sphagnum peat moss. This will keep the surface uniformly moist and make it easy for shoots to push through. Keep pots in a warm place and care for them like any other newly transplanted seedlings. Continued attention to watering is critical.

A convenient way to plant small, delicate, pregerminated seeds is to suspend them in a gel. Make a gel by blending cornstarch with boiling water until the consistency is thick enough to keep the seeds suspended. Be sure to cool it thoroughly before use. Place the gel and seedlings in a plastic bag with a hole in it. Squeeze the gel through the hole along a premarked garden row. Spacing of seeds is determined by the number of seeds in the gel. If the spacing is too dense, add more gel; if it is too wide, add more seeds. The gel will keep the germinating seeds moist until they establish themselves in the soil.

The proper amount of moisture is crucial to seedling survival. After sowing seeds, moisten the planting mix thoroughly. Use a fine-mist spray or place the containers in a pan or tray with about 1 inch of warm water in the bottom. Avoid splashing or excessive flooding that might displace small seeds. When the planting mix is saturated, set the container aside to drain.

While seeds are germinating, keep the planting medium moist but not wet. Ideally, seed flats should remain sufficiently moist without additional water. One way to maintain moisture is to slip the whole flat or pot into a clear plastic bag after the initial watering. Many home gardeners cover flats with panes of glass instead of plastic bags. The plastic or glass should be at least 1 to $1^1/_2$ inches above the soil. Keep the container out of direct sunlight to prevent the temperature inside from rising too high and harming the seeds.

Be sure to remove the plastic bag or glass cover as soon as the first seedlings appear. Then, as the growing medium surface dries, water carefully to avoid washing the seedlings out of the medium.

Care of indoor seedlings

Proper watering is crucial to good seedling growth. Lack of uniformity, over watering, or drying out are problems related to hand watering. A low-pressure misting system can give excellent moisture uniformity. During the daytime give 4 seconds of mist every 6 minutes or 10 seconds every 15 minutes. Bottom heat is helpful with a mist system.

Subirrigation (watering from below) may also work well to keep the flats moist. However, because flats or pots may sit in water constantly, the medium may absorb too much water, and seeds may rot from lack of oxygen.

After seedlings are established, move the flats to a light, airy, cool location where nighttime temperatures are 55° to 60°F, and daytime temperatures are 65° to 70°F. These conditions prevent soft, leggy growth and minimize disease troubles. Some crops, of course, may germinate or grow best at a different temperature. Keep them in a separate location in proper conditions.

Seedlings must receive bright light after germination. If possible, place them in a south-facing window. 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 the plants 6 inches from the tubes and keep the lights on about 16 hours each day. As the seedlings grow, raise the lights.

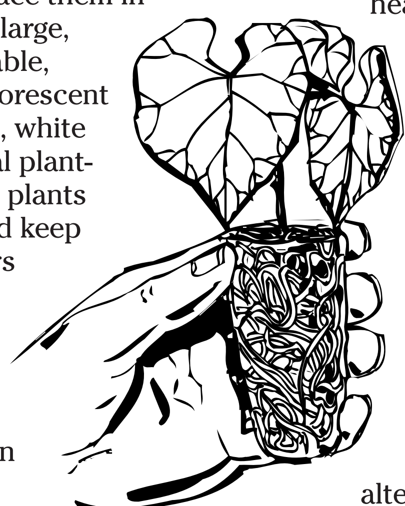
Transplanting seedlings to larger pots

If seeds are not planted in individual containers, they will need to be transplanted to give them proper growing space. One of the most common mistakes is leaving seedlings in a seed flat too long. The ideal time to transplant seedlings is when they are small and there is little danger from setback—usually about the time the first true leaves appear above or between the cotyledons (the "seed" leaves).

One can buy or make growing mixes and containers for seedlings. A growing medium should contain more plant nutrients than a germination mix. Some commercial soilless mixes contain fertilizer. Add fertilizer to those that do not.

To transplant seedlings, carefully dig up the small plants with a knife or wooden plant label. Let the group of seedlings fall apart or gently ease them apart into small groups. Then pick out individual plants. Avoid tearing roots in the process. Handle small seedlings by their leaves, not their delicate stems.

Punch a hole in the planting medium. Make it deep enough to put the seedling at the same depth it was growing in the seed flat. Place small plants or slow growers 1 inch apart and rapid-growing, large seedlings about 2 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.



Continue watering as before. About every 2 weeks after the seedlings are established, use a soluble houseplant fertilizer at the dilution recommended by the manufacturer. Remember that young seedlings are easily damaged by too much fertilizer, especially if they are under any moisture stress.

Hardening indoor-grown seedlings

Hardening is the process of altering plant growth to withstand the change in environment that occurs when plants are transferred from a greenhouse or home to a garden. A severe setback in growth may occur if indoor-grown plants are planted outdoors without a transition period. Hardening is more critical for early crops which are more likely to face adverse climatic conditions than it is for crops planted later in the season.

Harden plants by gradually reducing the temperature, relative humidity, and water. As a result, plants will accumulate carbohydrates, and cell walls will thicken, thus changing soft, succulent growth to firmer, harder tissue.

Start this process at least two weeks before planting seedlings outside. If possible, move plants to a location indoors with a temperature of 45° to 50°F or outdoors in the shade. A cold frame is excellent for this purpose. Shade plants at first and then gradually move them into sunlight. Each day increase the length of exposure slightly. Reduce the frequency of watering 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.

The hardening process is intended to slow plant growth. If carried to the extreme of actually stopping growth, however, some crops suffer significant damage. For example, cauliflower may make thumb-size heads and fail to develop further if hardened too severely. Cucumbers and melons also stop growth if hardened too much.

Transplanting seedlings to a garden

If transplanting seedlings from individual plastic pots or cell packs, remove each plant and its soil/root ball from its pot before planting. Seedlings growing in individual peat pots or compressed peat pellets can be planted directly in the garden, pot and all. Be careful to cover the pot completely. If the top edge of the pot extends above the soil level, it may act as a wick and draw water away from soil in the pot. To avoid this problem, tear off the top lip of the pot and then plant the pot flush with the soil level.

If seedlings have been grown in community packs, one will need to break or cut apart the roots of individual plants to separate them. Water thoroughly before cutting the growing medium.

Spores (ferns)

Although ferns are more easily propagated by other methods, some gardeners like the challenge of raising ferns from spores. One tested method for propagating small quantities is described here.

First, sterilize a solid brick by baking it at 250°F for 30 minutes. Place it in a pan and cover it with water. When the brick is wet throughout, squeeze a thin layer of moist soil and peat (equal parts) onto the top of the brick. Pack a second layer (about 1 inch) on top of that. Sprinkle fern spores on top. Cover the brick with plastic (not touching the spores) and put it in a warm place in indirect light. It may take up to a month or more for spores to germinate. Keep them moist at all times.

Each spore will develop a *prothallus* (first generation of a fern), forming a light green mat. Mist lightly once a week to maintain high surface moisture; the male *gametes* must be able to swim to the *archegonia* (female parts).

After about three weeks, fertilization should have occurred. Use tweezers to pull apart the mat into 1/4-inch squares. Space them 1/2 inch apart in a flat containing 2 inches of sand, 1/4 inch of charcoal, and about 2 inches of soil/peat mix. Cover the flat with plastic and keep it moist. When fern fronds appear and become crowded, transplant them to small pots. Gradually reduce the humidity until they can survive in the open. Exposure to light can be increased at this time.

Asexual propagation

Asexual propagation is the best way to maintain an individual plant that best represents a species. *Clones* are identical to their one parent and can be propagated only asexually. Bartlett pears (developed in 1770) and Delicious apples (1870) are two examples of clones that have been propagated asexually for many years.

The major methods of asexual propagation are as follows:

- Cutting (rooting a severed piece of the parent plant)
- Layering (rooting a part of the parent and then severing it)
- Offsetting (removing new shoots that form at a plant's base)
- Separating (dividing bulbs or corms)
- Dividing (dividing rooted crowns)
- Grafting (joining a piece of shoot and dormant buds from one plant to a different rootstock)
- Budding (joining a bud from one plant to a different rootstock)

Cuttings

Many types of plants both woody and herbaceous are propagated by cuttings. A cutting is a vegetative plant part severed from the parent plant that will ultimately form a whole new plant.

Take cuttings with a sharp knife or razor blade to reduce injury to the parent plant. Dip the cutting tool in rubbing alcohol or a mixture of 1 part bleach and 9 parts water to prevent transmitting diseases from infected plant parts to healthy ones. Remove flowers and flower buds from the cuttings to allow them to use their energy and stored carbohydrates for root and shoot formation rather than fruit and seed production.

To hasten rooting, to increase the number of roots, or to obtain uniform rooting (except on soft, fleshy stems), dip cut tip in a rooting hormone, preferably one containing a fungicide. Prevent possible contamination of the entire supply of rooting hormones by putting some in a separate container for dipping cuttings.

It is important to choose the correct rooting medium to get optimum rooting in the shortest time. In general, a rooting medium should be sterile, low in fertility, well drained, and able to retain enough moisture to prevent water stress. Use coarse sand, vermiculite, or a mixture of peat and perlite. Moisten the medium before inserting the cuttings and keep it evenly moist while cuttings are rooting and forming new shoots.

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

Stem cuttings

Many plant species are propagated by stem cuttings. For some plants, one can take cuttings at any time of the year. However, to root successfully stem cuttings of many woody plants must be taken in the fall or in the dormant season.

There are three types of stem cuttings, depending on the location of the cut. They are discussed below.

Tip—Detach a 2 to 6-inch piece of stem that includes the terminal bud (Figure 3a). Make the cut just below a node. Remove lower leaves that would touch or be below the growing medium. Dip the cut end of the stem in rooting hormone if desired and gently tap the end of the cutting to remove excess hormones. Insert the cutting deeply enough into the medium to support itself. At least one node must be below the surface.

Medial—Make two cuts on the stem (Figure 3b). The first cut should be just above a node and the second cut just above another node 2 to 6 inches down the stem. Prepare and insert the cutting as for a tip cutting. Be sure to position it right side up. (Look for axial buds; they are always above the leaves.)

Cane—Cut cane-like stems into sections containing one or two "eyes" (nodes) (Figure 4). Dust the ends with fungicide or

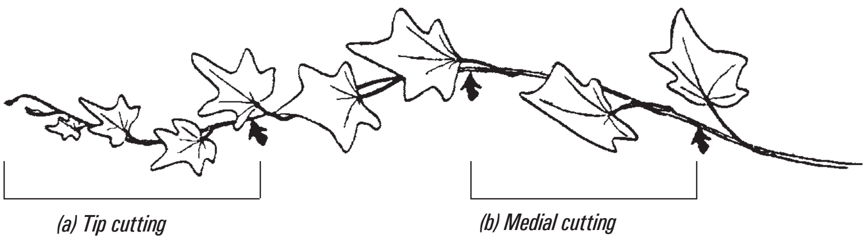


Figure 3.—Tip cutting (a) and medial cutting (b).

activated charcoal. Allow them to dry for several hours. Lay each cutting horizontally with about half of the cutting below the medium surface and the eye facing upward (Figure 4a). Cane cuttings are usually potted when roots and new shoots appear, but new shoots from dracaena and croton are often cut off and rerooted in sand.

Use *single-eye* cane cuttings for plants with alternate leaves when space or stock material is limited (Figure 4b). Cut a stem about $^1/_2$ inch above and $^1/_2$ inch below a node. Place the cutting horizontally or vertically in the medium.

Use *double-eye* cuttings for plants with opposite leaves when space or stock material is limited (Figure 4c). Cut a stem about $^1/_2$ inch above and $^1/_2$ inch below the same node. Insert each cutting vertically in the medium with the node just touching the surface.

A *heel* cutting efficiently uses stock material from woody stems (Figure 4d). Make a shield-shaped cut about halfway through the wood around a leaf and axial bud. Remove the shield containing the leaf and bud and insert it horizontally into the medium.

Leaf cuttings

Leaf cuttings are used almost exclusively for a few indoor plants. The leaves of most plants either produce a few roots but no plant or just decay. The four types of leaf cuttings are described below (Figure 5).

Whole leaf with petiole (Figure 5a)—Detach a leaf and $^1/_2$ to $1^1/_2$ inches of petiole. (The petiole is the part that attaches a leaf to a stem.) Insert the lower end of the petiole into the medium. One or more new plants will form at the base of the petiole. Once the new plants have their own roots, one can sever the leaf and reuse the petiole for additional cuttings.

Whole leaf without petiole (Figure 5b)—This method is used for plants with petioleless leaves. Insert a leaf vertically into the medium. A new plant will form from the axillary bud. One can remove the leaf when the new plant has its own roots.

Split vein (Figure 5c)—Detach a leaf from a stock plant. Slit its veins on the lower leaf

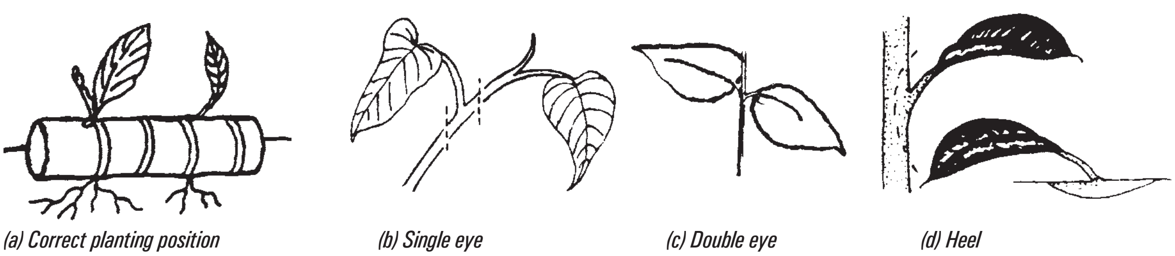
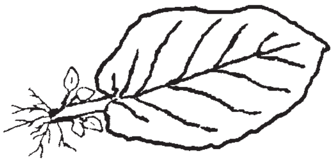
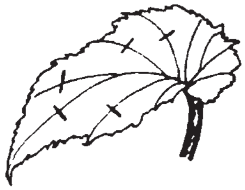


Figure 4.—Cane cuttings.


(a) Whole leaf with petiole


(b) Whole leaf without petiole


(c) Split vein

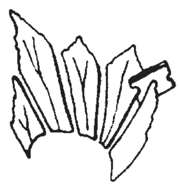

(d) Leaf section

Figure 5.—Types of leaf cuttings.

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

Leaf section (Figure 5d)—This method is frequently used with snake plants and fibrous-rooted begonias. Cut begonia leaves into wedges, each with at least one vein. Lay the wedges flat on the medium. A new plant will arise at the vein. Cut snake plant leaves into 2-inch sections. Consistently make the lower cut slanted and the upper cut straight to be able to tell which is the top. Insert the cuttings vertically. Roots will form fairly quickly, and eventually a new plant will appear at the base of the cutting. These and other succulent cuttings rot if kept too moist.

Root cuttings

Root cuttings are usually taken from 2 to 3-year-old plants during their dormant season when they have a large carbohydrate supply. Root cuttings of some species produce new shoots, which then form their own root systems. Other plants develop root systems from the cuttings before producing new shoots.

Plants with large roots—This method is often used outdoors on woody and perennial species. Make a straight top cut first. Then make a slanted cut 2 to 6 inches below the first cut. Store about three weeks in moist sawdust, sphagnum 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 (Figure 6a).

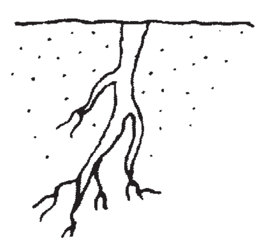
Plants with small roots—This method is usually done indoors or in a hotbed. Take 1 to 2-inch sections of roots. Insert cuttings horizontally about $^1/_2$ inch below the medium surface (Figure 6b).

Layering

Stems still attached to their parent plant may form roots where they touch a rooting medium (Figure 7). When severed from the parent plant, the rooted stem becomes a new plant. This method of vegetative propagation, called *layering*, is highly successful because it helps the cutting avoid shortages of water and carbon dioxide that often affect cuttings from other methods of propagation. The rooting medium should provide aeration and a constant supply of moisture.

Some plants layer themselves naturally, but one can assist the process. Some ways to encourage layering include:

- Girdling the stem where it is bent
- Wounding one side of the stem
- Bending the stem very sharply


(a) Plants with large roots

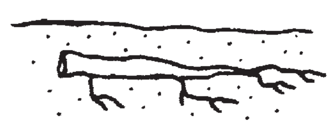

(b) Plants with small roots

Figure 6.—Root cuttings.

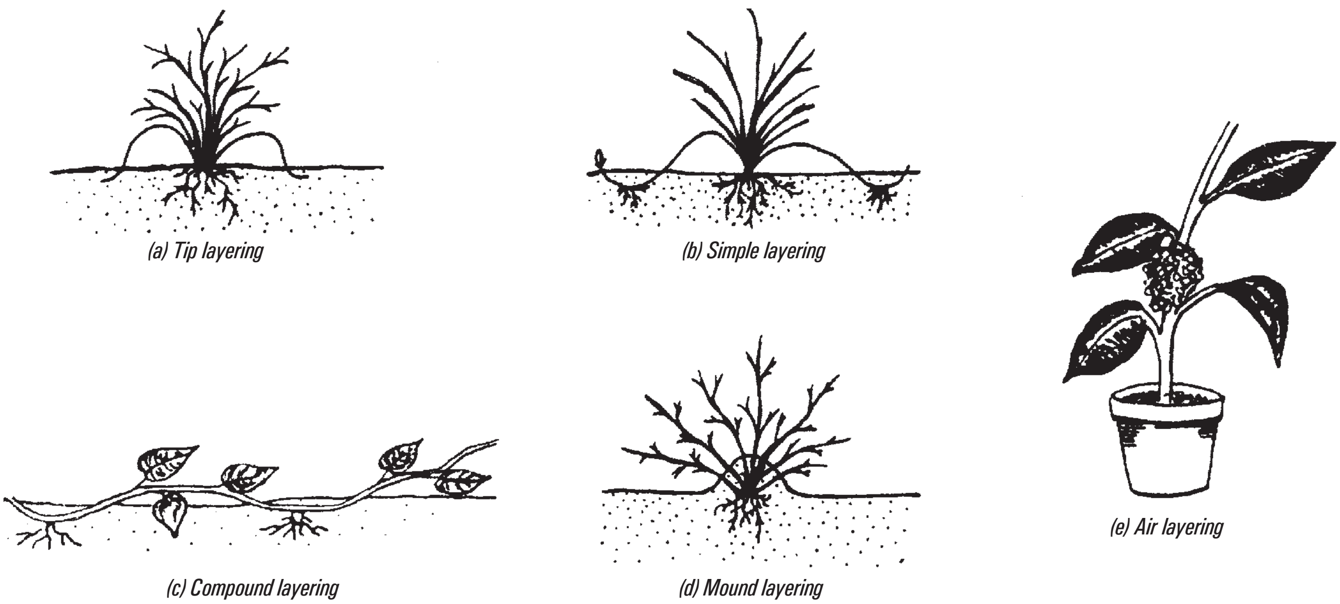


Figure 7.—Types of layering.

Tip layering

Dig a hole 3 to 4 inches deep. Insert the shoot tip and cover it with soil (Figure 7a). The tip will grow downward first and then bend sharply and grow upward. Roots form at the bend, and the recurved tip becomes a new plant. Remove the new plant and plant it in early spring or late fall. An example of a plant that can be propagated this way is raspberries.

Simple layering

Bend the stem to the ground. Cover part of it with soil, leaving the last 6 to 12 inches exposed (Figure 7b). Bend the tip into a vertical position and stake it in place. The sharp bend often induces rooting, but wounding the lower side of the branch or twisting the stem to loosen the bark may help. Examples of plants suitable for simple layering are honeysuckles and forsythias.

Compound layering

This method works for plants with flexible stems. Bend the stem to the rooting medium as for simple layering but alternately cover and expose stem sections (Figure 7c). Wound the lower side of the stem sections to be covered. Heart-leaf philodendrons and pothos respond well to this method of layering.

Mound (stool) layering

Cut the plant back to 1 inch above the ground in the dormant season. Mound soil over emerging shoots in spring to enhance rooting (Figure 7d). Apple rootstocks are propagated this way.

Air layering

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 open the slit with a toothpick. Surround the wound with wet, unmilled sphagnum peat moss. Wrap plastic or foil around the moss and tie it in place (Figure 7e). When roots pervade the moss, cut the plant off below the newly formed root ball. Air layering is commonly used with dumb cane and rubber trees.

Plants with stolons or runners

Plants that produce stolons or runners also reproduce by layering because new plants grow along stems of the original one (Figure 8). A *stolon* roots wherever it touches the growing medium and then produces new shoots. A *runner* originates in a leaf axil and grows along the ground or downward from a hanging basket, producing a new plant at its tip.

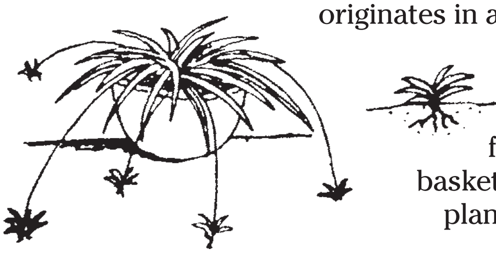


Figure 8.—Propagation using stolons.

Plants that produce stolons or runners are propagated by severing the new plants from their parent stems. One can root plantlets at the tips of runners while they still are attached to the parent or detach them and place them in a rooting medium. Strawberries and spider plants are often propagated this way.

Offsets

Plants with a rosetted stem often reproduce by forming new shoots or *offsets* at their base or in leaf axils (Figure 9). To propagate them, sever the new shoots from the parent plant after they develop their own root system. For some species, one can remove unrooted offsets and place them in a rooting medium. In some cases, the offsets must be cut from the parent while others may simply be lifted off. Examples of plants with offsets are date palms, haworthia, bromeliads, and many cacti.

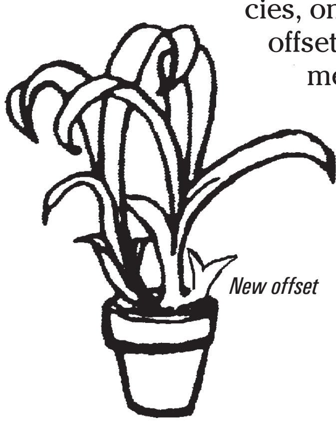


Figure 9.—A plant with offsets.

Separation

Separation is a form of propagation used with plants that produce bulbs or corms.

Bulbs

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

Corms

A large new corm forms on top of an old corm, and tiny cormels form around the large corm (Figure 10). After the leaves wither, dig up the corms and allow them to dry in indirect light for two to three weeks. Remove the cormels, then gently separate the new corm from the old corm. Discard the old corm. Store the new corm in a cool place until planting time. Crocus and gladiolus reproduce via corms.

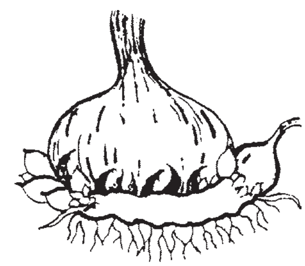


Figure 10.—Separating corms.

Division

One can divide plants with more than one rooted crown and plant the crowns separately (Figure 11). If the stems are not joined, gently pull the plants apart. If crowns are united by horizontal stems, cut the stems and roots with a sharp knife to minimize injury. Division is commonly used on snake plants, irises, prayer plants, and daylilies.

Grafting

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

The portion of a cultivar that is to be propagated is called a *scion*. It consists of a piece of shoot with dormant buds that will produce a stem and branches. A *rootstock* or stock provides the new plant's root system and sometimes the lower part of the stem.

When the scion is grafted onto the rootstock, the cambium of the two must touch. The cambium is a layer of cells located between a stem's xylem and phloem. New xylem and phloem cells originate from cambial tissue.

Four conditions must be met for grafting to be successful:

- The scion and rootstock must be compatible.
- Each must be at the proper stage of development.
- The cambial layers of the scion and stock must meet.
- The graft union must be kept moist until the wound heals.

Cleft grafting

Cleft grafting is often used to change the cultivar or top growth of a shoot or young tree, usually a seedling (Figure 12). It is especially successful if done in early spring.

Collect scion wood 3/8 to 5/8 inch in diameter. Cut a limb or small trunk of the stock perpendicular to its length. Make a 2-inch vertical cut through the center of the first cut. Be careful not to tear the bark. Use a wedge to keep the cut open.

Prepare two scion pieces 3 to 4 inches long. Cut the lower end of each scion piece into a wedge. Insert the scions at the outer edges of the cut in the stock. Tilt the tops of the scions slightly outward and the bottoms slightly inward to be sure the cambial layers of the scions and stock touch. Remove the wedge propping the slit open and cover all cut surfaces with grafting wax.

At the time of grafting, cut back limbs of the old variety (the rootstock). Gradually reduce the total leaf surface of the old variety as the new one increases until at the end of one or two years the new variety completely takes over. Completely removing all of the limbs of the old variety at the time of grafting increases the shock to the tree and causes excessive suckering. Also, the scions may grow too fast, making them susceptible to wind damage.

See Chapter 1, *Botany*.

(a) Daylily *(b) Iris* *(c) Dahlia*

Figure 11.—Dividing daylilies (a), irises (b), and dahlias (c).

Bark grafting

Unlike most grafting methods, bark grafting can be used on large limbs (Figure 13). Collect scion wood $^3/_8$ to ½ inch in diameter when the plant is dormant. Wrap the wood in moist paper, place it in a plastic bag, and store it in a refrigerator. Saw off a limb or the trunk of the rootstock at a right angle to itself.

In spring when bark is easy to separate from wood, make a ½-inch diagonal cut on one side of the scion and a 1 to 1½-inch diagonal cut on the other side. Leave two buds above the longer cut. Cut through the bark of the stock a little wider than the scion. Remove the top third of the bark from this cut. Insert the scion with the longer cut against the wood. Nail the graft in place with flat-headed wire nails. Cover all wounds with grafting wax. Cut back selected limbs of the old variety as described earlier for cleft grafting.

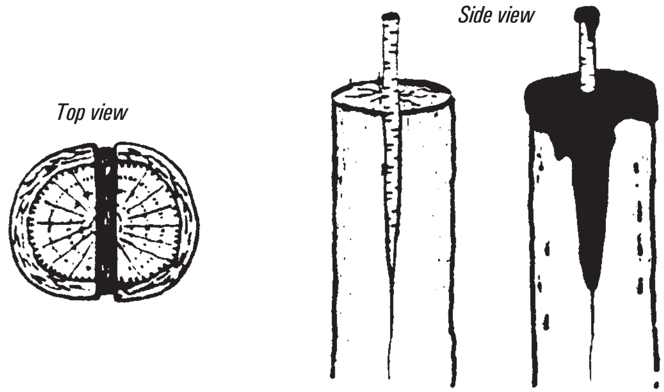


Figure 12.—Cleft grafting.

Whip and tongue grafting

This method is often used for material ¼ to ½ inch in diameter (Figure 14). The scion and rootstock are usually the same diameter, but the scion may be narrower. This type of graft is strong, heals quickly, and provides excellent cambial contact. Make one sloping cut 2½ inches long 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 and then tie and wax the union.

Care of grafts

It is an excellent idea to inspect grafts after two to three weeks to see whether the wax has cracked. If necessary rewax the exposed areas. After this time the union will probably be strong enough that no more waxing is necessary.

For successful grafting be sure to maintain proper care for the following year or two. If using a binding material such as strong cord or nursery tape on the graft, cut it shortly after growth starts to prevent girdling and later the death of the graft. 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.

Budding

Budding or bud grafting is the union of a rootstock with a scion containing one bud and a small piece of bark. It is especially useful

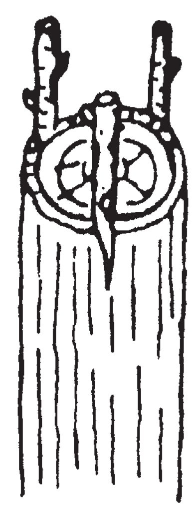


Figure 13.—Bark graft.

Figure 14.—Whip and tongue graft.

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 while the plants are actively growing so their bark slips easily. Remove a rectangular piece of bark from the rootstock. Cover this wound with a bud and matching piece of bark from the scion (Figure 15). If the rootstock bark is thicker than that of the scion, pare it down to meet the thinner bark so the patch is held firmly in place when the union is wrapped.

Chip budding

This budding method can be used when bark is not slipping. Slice downward into the rootstock at a 45° angle through one-fourth of the wood. Make a second cut about 1 inch above the first cut. From the scion, remove a bud with a chip of bark and wood that will fit the rootstock wound. Fit this chip to the stock and wrap the union (Figure 16).

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 rootstock's bark, avoiding any buds. 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 one bud, bark, and a thin section of wood. Push the shield under the loosened stock bark. Wrap the union, leaving the bud exposed (Figure 17).

Care of buds

Place the bud into the rootstock in August. Force the bud to develop the following spring by cutting the stock off 3 to 4 inches above it. Tie the new shoot to the resulting stub to prevent wind damage. After the shoot makes a strong union with the stock, cut off the stub close to the budded area.

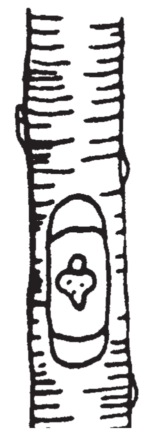


Figure 15.—Patch budding.

Plant tissue culture

Although technical procedures for aseptic culture of plant cells, tissues, and organs vary widely, one can use a simplified procedure at home with only a few supplies from a grocery store. Follow the procedures below to propagate various species of plants. Some are easy (e.g., African violets, coleus, and chrysanthemums) while others are difficult (e.g., orchids, ferns, and weeping figs).

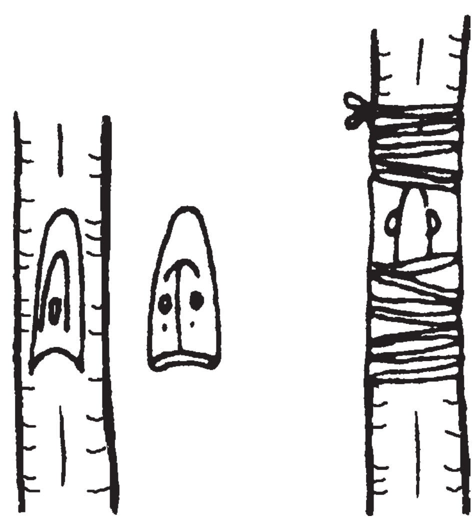


Figure 16.—Chip budding.

Medium preparation

For 1 quart of medium, use the following ingredients:

- 1/8 cup of sugar
- 1 teaspoon all-purpose, soluble fertilizer. Check the label to make sure it has all of the major and minor elements, especially ammonium nitrate. If the latter is lacking, add 1/3 teaspoon of a 35-0-0 soluble fertilizer.
- 1 tablet (100 mg) of inositol (myo-inositol), available at most health food stores
- 1/4 of a pulverized vitamin tablet containing 1 to 2 milligrams of thiamine
- 4 tablespoons of coconut milk (a cytokinin source) drained from a fresh coconut. Freeze the remainder for later use.
- 3 to 4 grains of a commercial rooting compound with 0.1 percent active ingredient IBA

Mix all of the ingredients in a 1-quart home-canning jar. Fill the jar with distilled or deionized water. If purified water is not available, boil the water for several minutes before adding it. Shake the mixture and make sure all materials have dissolved.

Any heat-resistant glass receptacle with a lid can be used as a culture jar. Baby food jars work well.

Half fill each culture bottle with cotton or paper to support the plant material. Pour the medium into each culture bottle so that the support material is just above the solution. Loosely screw on the lids.

Now sterilize the bottles in a pressure cooker under 10 pounds of pressure for 30 minutes or in an oven at 320°F for four hours. Remove them from the sterilizer, place them in a clean area, and allow the medium to cool.

If the bottles won't be used for several days, wrap groups of bottles in foil before sterilizing and then sterilize the whole package. Then remove the bottles and cool them without removing the foil cover. Tweezers and razor blades can be sterilized in the same manner. Additional sterilized water will also be needed.

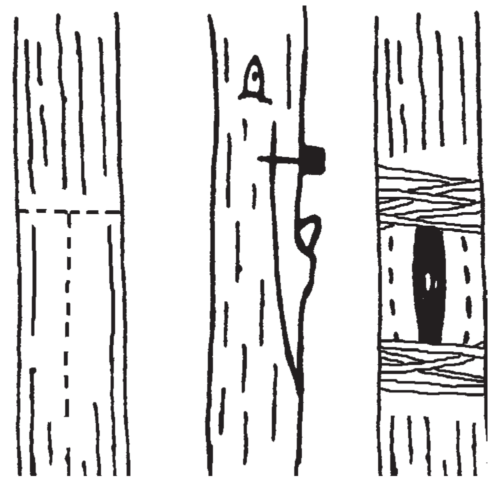


Figure 17.—T budding.

Plant disinfestation and culture

Once the growing medium is sterilized and cooled, prepare plant material for culturing. Because plants usually harbor bacterial and fungal spores, they must be cleaned (disinfected) before placing them on the sterile medium. Otherwise bacteria and fungi may grow faster than the plants and dominate the culture.

Scrub one's hands and countertops with soap and water just before disinfesting plant material. Use rubbing alcohol or a dilute bleach solution to wipe down the working surface.

Various plant parts can be cultured, but small, actively growing portions usually result in the most vigorous plantlets. For example, ferns are most readily propagated by using only 1/2 inch of the tip of a rhizome. For other species 1/2 to 1 inch of the shoot tip is sufficient.

Remove leaves attached to the tip and discard them. Completely submerge the plant part in a solution of 1 part commercial bleach to 9 parts water for 8 to 10 minutes. Then rinse off excess bleach by dropping the plant part into sterile water.

Remember, once the plant material has been in the bleach, it has been disinfested and should be touched only with sterile tweezers.

After rinsing the plant material, remove any bleach-damaged tissue with a sterile razor blade. Then remove the cap of a culture bottle containing sterile medium and place the plant part onto the support material in the bottle. Make sure the plant part is not completely submerged in the medium and recap the bottle quickly.

After culturing all of the plants, place them in a warm, well-lighted (no direct sunlight) environment to encourage growth. If the medium is contaminated, it will be obvious within three to four days. Remove and wash contaminated culture bottles as quickly as possible to prevent the spread of bacteria or fungi to uncontaminated cultures.

When plantlets have grown to sufficient size, transplant them into soil. Handle them as gently as possible because they are leaving a warm, humid environment for a cool, dry one. After transplanting, water the plants thoroughly and place them in a clear plastic bag for several days. Gradually remove the bag to acclimate the plants to their new environment; start with one hour per day and gradually increase time out of the bag over a two-week period until the plants are strong enough to no longer need the bag.

For more information

Washington State University Cooperative Extension publications

Grafting and Budding Plants to Propagate, Topwork, Repair (PNW0496)

Layering to Renew or Multiply Plants (PNW0165)

Propagating Deciduous and Evergreen Shrubs, Trees, and Vines with Stem Cuttings (PNW0152)

Propagating from Bulbs, Corms, Rhizomes, and Tuberous Roots and Stems (PNW0164)

Propagating Herbaceous Plants from Cuttings (PNW0151)

Propagating Plants from Seed (PNW0170)

Other publications

Hartmann, H.T., D.E. Kester, F.T. Davies, Jr., and R.L. Geneve, *Plant Propagation: Principles and Practices* (Prentice Hall, Inc., Upper Saddle River, New Jersey, 2002) 880 pp. including CD.

Sunset Western Garden Book (Sunset Publishing Corporation, Menlo Park, California) 768 pp.

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Arachnids

21

A client lurches in with three small, wide-eyed children trailing behind and a look of horror and disgust on her face. The individual holds a jar at arms length and blurts out, “What kind of spider is it and is it poisonous?” This is a common occurrence and can be a golden opportunity to educate people. The general public can easily be alarmed when encountering “big bugs,” and often these “big bugs” aren’t even insects. These creatures belong to Class Arachnida and are commonly called arachnids. Arachnids, together with Class Insecta, account for a large proportion of the animal life on earth.

In Wyoming, large spiders, windscorpions, and sometimes even scorpions can appear in homes, gardens and recreation areas. Some of the smallest arachnids such as ticks and mites can cause much greater problems for people than big hairy spiders. Most arachnids are relatively harmless to humans but because of their appearance and reputation for venomous attacks, the general public often feels that all arachnids are enemies, things to be feared and eradicated. The reality is that a spider in one’s garden is an ally and helps control insect pest populations. The relatively few species of arachnids that cause problems in gardens or homes can usually be dealt with effectively and often without the use of synthetic pesticides.

Classification of arachnids

Arachnids are in the Kingdom Animalia, Phylum Arthropoda, and are closely related to other Classes like Insecta that have an exoskeleton (hard outer shell) instead of an internal bone structure like amphibians, reptiles, birds, and mammals. There are several major groups of arachnids that are called orders in common classification schemes. The most common orders of

Topics in this chapter

By Jody Logue, Cooperative Extension master gardener in Natrona County, Alexandre Latchininsky, Extension entomology specialist, Scott Schell, Extension entomology assistant, and Karen L. Panter, Extension horticulture specialist, University of Wyoming.

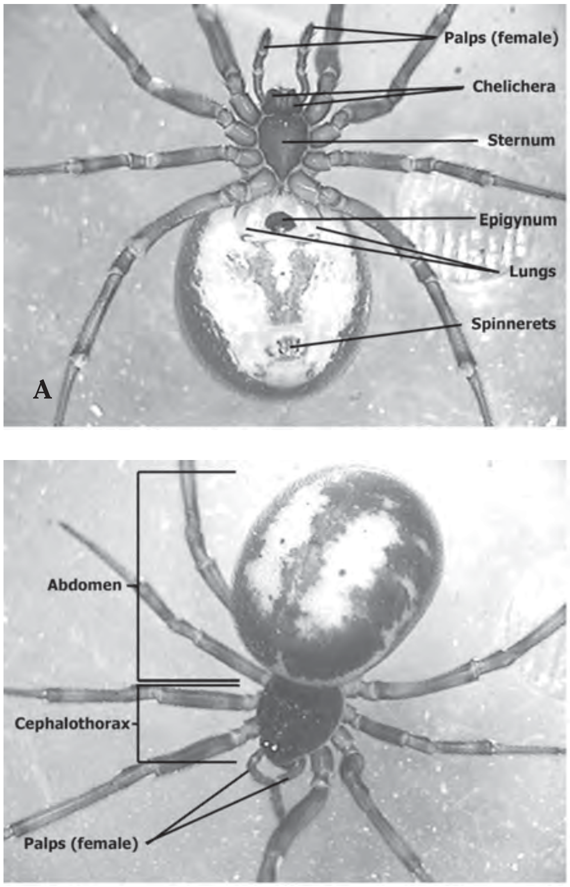

Figure 1. Illustration of the typical characteristics of the Class Arachnida: (a) bottom view and (b) top view. (Judy Logue photo)

*Figure 2. The Northern Scorpion (*Paruroctonus boreus*) shown here feeding on a cricket is the onlyl species that has been reported in Wyoming. (Dan Johnson, Lethbridge, Alberta photo)*

arachnids found in Wyoming are Scorpiones (scorpions), Araneae (spiders), Opiliones (harvestmen), Acari (mites and ticks), Solifugae (windscorpions), and Pseudoscorpiones (pseudoscorpions).

The characteristics that separate arachnids from other arthropods are their lack of antennae and their six pairs of appendages as adults (Figure 1). The first paired appendages are *chelicerae*, which can be jaw like or fanged. The second paired appendages are called *pedipalps* and can be used as feelers, claws, or for locomotion. The remaining four pairs of appendages are *legs* although some mites have just four legs and larval stages of ticks can have just six legs. Unlike insects which have three body parts (head, thorax, and abdomen), bodies of arachnids have two distinct regions: a combined head and thorax called a *cephalothorax* and an *abdomen*. If eyes are present they are always simple in structure, not compound as in insects, and they vary greatly in size, number, and arrangement.

Scorpions

In Wyoming the appearance of only one small species, *Parurotonus boreus*, has been recorded (Figure 2). As in all scorpions, the second pair of appendages, the pedipalps, are long and end in large pincers that are used for grasping and subduing their prey (insects or other arachnids). The last five segments of the abdomen form a long tail that terminates in a stinger that is used for defense or subduing large prey. Only one species, *Centruroides sculpturatus,* found in the southwestern United States, is considered to be dangerously venomous to humans (See *An Introduction to the Study of Insects* for more information). All other species in the U.S. can produce a painful sting. Scorpions hunt primarily at night, and they sometimes take shelter under rocks in landscaping or in dark sheds and garages. Scorpions are not aggressive to humans, and their role as predators of insects is beneficial to humans.

*Figure 3. This is an example of a male spider. Specifically, it is an adult male black widow spider (*Latrodectus mactans*). Spencer Schell Photo.*

Spiders

Spiders are the most commonly encountered arachnids in Wyoming, and because there are more than 3,600 North American species, they can be found in almost every habitat, home, and garden in the state. To distinguish them from other arachnids, look for a distinct cephalothorax joined to an unsegmented abdomen (Figure 3). Spiders have usually four pairs but sometimes three pairs of simple eyes. The arrangement and number of the eyes on the cephalothorax can be used to help distinguish the various spider families (Figure 4). The chelicerae are fanged and connected to venom glands. The pedipalps can be long and leg like or in adult males can have a clubbed end with structures that are used in sexual reproduction (Figure 5).

Four pairs of legs terminate in either two or three small claws which can vary in shape and length depending on the hunting style of the spider. At the end of the abdomen are six (a few families have two or four) spinnerets that can produce silk. Silk is probably the reason spiders have such successful lives. Spiders can use the silk for capturing prey, protecting their eggs, making their homes, and even dispersing themselves throughout the environment. All spiders are predaceous and feed mainly on insects, which makes them a gardener's friend since they help keep pest populations in check.

*Figure 4. The distinctive eye pattern of a male brown recluse spider (*Loxosceles reclusa*) shows how the six eyes are arranged in three pairs on the cephalothorax. Most spiders have eight eyes. (Spencer Schell Photo)*

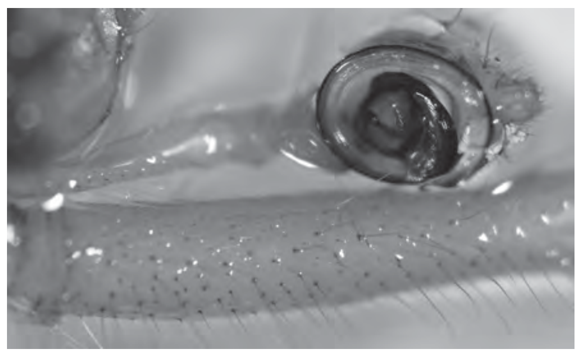

*Figure 5. This close up of the ventral side of the left pedipalp of a male hobo spider (*Tegenaria agrestis*) shows the complex and diagnostic structure it uses in sexual reproduction. (Spencer Schell Photo)*

The only species of spider that is native to Wyoming and dangerous to humans is the black widow, *Latrodectus mactans* (Figure 6). The male is not considered dangerous, and the female is only aggressive in defense of her eggs. In the summer, black widows often build their sparse, shiny webs across the entrance of abandoned gopher and prairie dog burrows. They can sometimes be found in and around homes in dark sheltered areas. They should be removed from situations where people, especially children or the elderly, could encounter them. Anyone bitten by a black widow should seek immediate medical help. Physicians can adminis-

*Figure 6. The ventral view of an adult female black widow spider (*Latrodectus mactans*) shows the typical red-colored "hour-glass" shape on the smooth, black, abdomen with a penny in the background to provide scale. (Spencer Schell Photo)*

*Figure 7. An overhead view of a male hobo spider (*Tegenaria agrestis*) shows its body length. Native to Europe and originally introduced into the Pacific Northwest, these spiders are now widely distributed in Wyoming. (Spencer Schell Photo)*

ter treatment to counteract the neurotoxic venom's effect.

Other primarily outdoor spiders that may sometimes show up in houses are yellow sac spiders *(Chiracanthium* species), wolf spiders, grass spiders, and jumping spiders. Of these, the yellow sac spider is the only one likely to bite humans. The effects of the bite can range from barely noticeable to a reddened area with a pus-filled lesion that can take a week to heal (See *Field Guide for the Management of Urban Spiders* for more information). Wolf spiders and jumping spiders can be captured and released outside to continue their beneficial hunting.

Two spiders of the funnel web-building family (Ageleidae) introduced from Europe have adapted to the indoor habitat and established themselves in Wyoming. The domestic house spider (*Tegenaria domestica*) is now commonly found in houses all over the U.S. *Tegenaria agrestis*, also known as the hobo or aggressive house spider and originally introduced into the Pacific Northwest, is now widely distributed in Wyoming (Figure 7). The presence of these spiders in homes is often indicated by their distinctive funnel-shaped webs along the baseboards and under household appliances. Sometimes these webs are abundant in crawl spaces and/or basements and provide a source for dispersing immature spiders. Adult males searching for mates may appear frequently in the living areas of homes.

A spider species that is notorious but rarely encountered in Wyoming is the brown recluse *(Loxosceles reclusa*) (Figure 4). Originally found only in the south central U.S., it can be introduced into Wyoming homes as people move from areas where the spiders are common. The brown recluse possesses venom that can cause necrotic skin lesions. Thankfully non-aggressive by nature, the brown recluse will only bite if trapped against a person's skin (See *Field Guide for the Management of Urban Spiders* for more information). The spiders can gather in very large numbers in houses in areas of their native range with the human occupants completely unaware of their presence.

To lower the odds of being bitten by any arachnid, there are important steps people can take.

One of the best ways to prevent arachnids from entering a house is to keep material like fire wood, empty boxes, tall plants, and other debris away from the perimeter of houses and patios. By eliminating places for spiders to build their webs and provide shelter for their insect prey, one

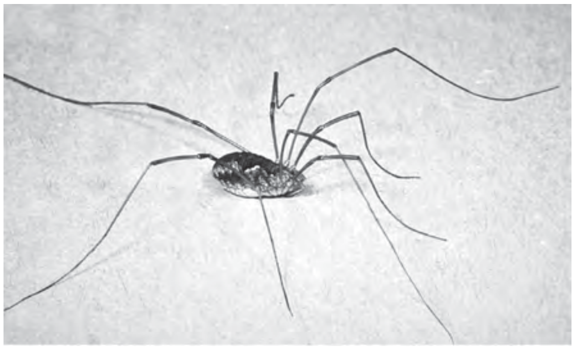

Figure 8. This is a typical example of the Order Opiliones found in Wyoming. Commonly called harvestmen or daddy longlegs, they are easily distinguished from spiders by their sac-like body with the cephalothorax broadly joined to a segmented abdomen. (Great Plains Diagnostic Network Photo)

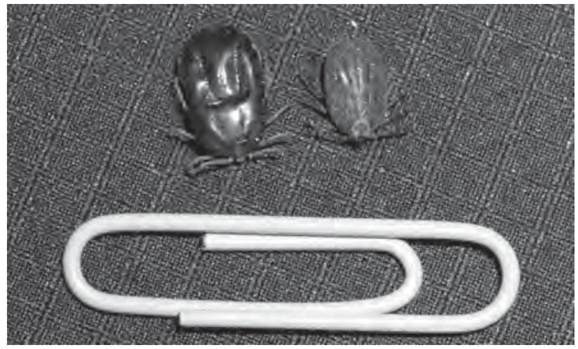

Figure 9. Ticks of the two families found in North America are shown engorged with blood. The larger tick is an example of the Argasidae Family of soft ticks. The smaller tick is an example of Family Ixodidae or hard ticks. (Scott Schell Photo)

can reduce the number of potential unwanted arachnid visitors. Using well-maintained window screens and sealing gaps around doors, sills, and foundations will also help keep spiders outside. Cleaning up spider webs and eliminating any insects infesting a home will make it difficult for spiders to live and reproduce inside. Avoid leaving clothing on the floor, check shoes and slippers before wearing them, and keep bedding from touching the floor to prevent spiders from getting up onto a bed. All these techniques can help prevent arachnid bites. It is always best to seek medical help in the event of any suspected or confirmed spider bite.

Harvestmen

Harvestmen or daddy longlegs, belong to the Order Opiliones. The cephalothorax of these insects is broadly joined to the segmented abdomen, giving them the appearance of a sac-like body. The chelicerae are small and clawlike. The pedipalps are short and slender. In the most commonly encountered representatives of the Order in Wyoming (Suborder Palpatores), the rearmost four pairs of appendages are long skinny legs (Figure 8). There are usually just two simple eyes present on the cephalothorax. Daddy longlegs have scent glands and can secrete a distinct odor when disturbed, probably as a natural defense or alarm pheromone (See *An Introduction to the Study of Insects* for more information). Most harvestmen are predators of insects and other arachnids. They can sometimes cluster in large groups under eaves, in basements, and in crawl spaces. They are beneficial in gardens and harmless to humans.

Ticks and mites

Acari is a very large order with more than 30,000 species described and an estimated half a million more undescribed (See *An Introduction to the Study of Insects* for more information). They inhabit just about every habitat type on earth and can be predators, parasites, scavengers, or herbivores. The majority of them are tiny and free living in soils and forest leaf litter. The largest members of Acari common to Wyoming are the adult hard and soft ticks which can be more than 10 millimeters in length when fully engorged with blood meals from their hosts (Figure 9).

All members of the Order Acari have a generally oval body shape with little differentiation between the cephalothorax and abdomen (Figure 10). Adults of most species have eight legs although some of the

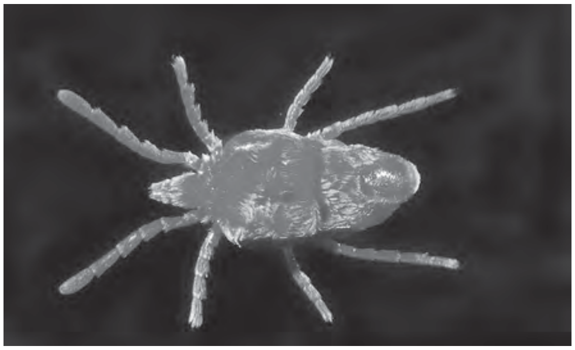

Figure 10. A red velvet mite shows the typical body structure of adult free-living mites. (Great Plains Diagnostic Network Photo)

*Figure 11. This is an adult female Rocky Mountain wood tick (*Dermancentor andersoni*) with a pale-colored dorsal plate called a scutum that is characteristic of all hard ticks. The insect is shown in an unfed condition. (Spencer Schell Photo)*

plant-feeding mites and parasitic mites only have four legs. Newly-hatched ticks and mite larval stages will often have just six legs. Many mites completely lack eyes and, if they are present, they are small and simple in structure. The members of the Order Acari are often organized into three major groups: Parasitiformes, Acariformes, and Pilioacariformes, with the latter not represented in Wyoming.

The Parasitiformes group includes parasitic ticks that attach themselves to humans and other animals. In addition to losing blood when they feed, ticks can also vector infectious diseases. Because it takes awhile for a tick to find a feeding site on a potential host, checking people and pets frequently for ticks after outdoor activities is a good preventative measure. Wearing light-colored clothing also makes it easier to see ticks and remove them before they get on skin. Insect repellents that contain at least 20 percent DEET as the active ingredient also act to fight ticks. Commercially available sprays that contain permethrin applied to outer clothing will rapidly kill ticks. Follow label directions for the use of all repellent products.

The tick most frequently encountered in Wyoming is the Rocky Mountain wood tick, *Dermancentor andersoni* (Figure 11). The new adults of this species that have successfully overwintered emerge in the spring looking for a large animal host to feed on. The larval stages specialize in feeding on small mammals, but humans are also suitable hosts for the adult ticks. In most years the adult ticks aren't commonly encountered after July 1 in low-elevation areas (See *Medical Entomology* for more information). Big game winter ranges are nearly ideal habitats for these ticks. These areas often have the low brushy vegetation preferred by this tick species and a large rodent population available for the tick nymphs. The Rocky Mountain wood tick is rarely found in dense timber or pure grasslands (See *Medical Entomology* for more information). In areas with suitable habitat, large numbers of adult ticks can be found questing for a host on the vegetation next to and hanging over game trails. This wood tick is the major carrier of Rocky Mountain spotted fever, can also vector tularemia (Colorado tick fever), and is responsible for most cases of tick paralysis in the U.S. (See *Ticks and What You Can Do About Them* for more information).

Most hard ticks, like *D. andersoni,* attach to their host with barbed-mouth parts, secrete a cement-like substance around the wound, and stay attached anywhere from

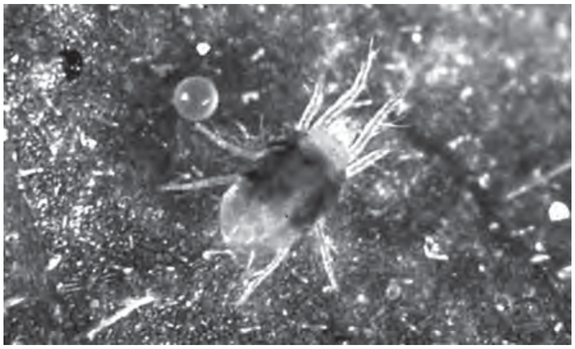

*Figure 12. A tiny two-spotted spider mite (*Tetranchhus urticae*) stands next to its even smaller, spherical egg. (University of Wyoming Cooperative Extension Service entomology photo)*

three days to several weeks. They cannot easily disengage from the host if they are embedded. The "folk remedies" for removing attached ticks such as "smothering" the tick in oil, nail polish, or rubbing alcohol or burning the tick with a match or a cigarette (which risks creating an open-wound entry point for any disease organism carried by the tick or a secondary infection) failed to make the ticks detach in a scientifically controlled test (See *Ticks and What You Can Do About Them* for more information).

The following methods from Roger Drummond's book *Ticks and What You Can Do About Them* are recognized as the best way to remove ticks from humans and pets:

1. If possible, use blunt, curved forceps, tweezers, or an appropriate tick removal device. If using fingers, cover them with rubber gloves, waxed paper, plastic, or paper toweling.
2. Place the tips of the tweezers or edges of the device around the tick's mouthparts where they enter the skin. If using fingers, gently but firmly grasp the tick.
3. Using fingers, forceps, or tweezers, remove the tick with a steady pull away from the skin. Do not jerk or twist the tick.
4. Take great care not to crush or puncture the body of the tick or to touch any fluids from the tick.
5. After removing the tick, disinfect the skin where the tick was attached with alcohol or povidone iodine and wash with soap and water.

Early removal of a tick is best as this reduces the probability of disease transmission. A detached tick should be retained for medical diagnosis in a sealed vial in a refrigerator or cooler. The site where the tick was attached should be monitored for signs of infection, and the overall health of the bite victim should be watched for symptoms of tick-borne diseases. Medical attention should be sought immediately if the bite victim begins to feel ill.

Among the Acariformes (mites) group are arachnids most likely to cause problems for a Wyoming gardener. The spider mites (Family Tetranychidae) and the gall and rust mites (Family Eriophyidae) attack a wide variety of plants and can cause serious losses to orchards, field crops, gardens, ornamentals, and greenhouse crops.

Spider mites, such as the two-spotted spider mite (*Tetranychus urticae*), cause feeding injury to the surface of plant leaves (Figure 12). They and other species of spider mites are most dangerous when host plants are drought stressed. The leaves of the plants become discolored, typically bronzed, and fine, silken webbing produced by the mites (hence the name spider mite) is very noticeable wherever populations are high. The vigor of a plant can be greatly reduced. Spider mites are prolific and develop from egg to adult in 10 days in favorable conditions. Spider mites are resistant to many common insecticides that will kill their natural predators, allowing the unchecked mite population to increase.

Perhaps the best and least expensive way to combat them is to keep susceptible plants from getting drought stressed. Direct spray with water on the infested foliage will

Figure 13. Mites of the Family Eriophyidea caused the blister galls on the leaves of this ash tree. These mites are so small that if it weren't for the plant tissue damage and discoloration they cause, they would go mostly unnoticed. (UW Cooperative Extension Service entomology photo)

also reduce their populations. Higher humidity favors the predatory mites, and leaves that are not drought-stressed produce less concentrated, nutritious food for the spider mites. Applications of labeled miticides can be effective if they are applied properly to non-resistant strains of mites. Horticultural oils can sometimes be successfully used to reduce overwintering populations of spider mites (See *Insects and Diseases of Woody Plants of the Central Rockies* for more information).

Gall, rust, and blister mites are tiny and require at least 15X hand lenses to be even vaguely observed. These tiny mites belong to the Family Eriophyidae and are unique arachnids in that they only have four legs. Sometimes their damage is mistakenly blamed on plant pathogens that cause galling and leaf discolorations (Figure 13). As the common name suggests, gall mites can cause distorted growths of plant tissue generically referred to as galls. The mites are sheltered by the galls they cause and can be difficult to control chemically. These galls are often diagnostic in their form and in the specific plant tissue attacked. Most of the time gall mites are not a serious threat to plant health but may detract from the aesthetics of an affected plant.

Rust mites, on the other hand, do not cause galls but are detected by rust-colored spotting on the leaf surface. Blister mites feed on the underside of leaves close to the leaf midrib which produces brown "blisters" to appear on the upper leaf surface. Many species of fruit and ornamental trees can be attacked. The detection of rust mites can be difficult without a microscope. Although they are susceptible to insecticides like carbaryl, care must be taken when treating for rust mites so as not to cause an outbreak of spider mites resistant to carbaryl (See *Insects and Diseases of Woody Plants of the Central Rockies* for more information). Dormant oils applied at the correct times and miticides, applied according to the product label, can be effective for controlling Eriophyid mites. Keeping trees unstressed, well watered, and pruned can also help prevent damaging infestations of these tiny arachnids.

Windscorpions

Called windscorpions due to their ability to move quickly over the ground while in search of their arthropod prey, these distinctive, fierce-looking predators belong to the Order Solifugae (Figure 14). There are approximately 120 species in North America, chiefly distributed in arid regions. Wyoming has several species present within its borders. They all range in body length from 20 to 30 millimeters, from the head to the end of the abdomen and are pale tan to light brown in color. Being arachnids, they have six pairs of appendages. The front pair represents powerfully constructed two-part chelicerae that are used to crush their prey into a pulp from which the fluids are sucked and the hard parts discarded. They lack venom glands but can inflict a painful pinch if carelessly handled (See *An Introduction to the Study of Insects* for more information).

Figure 14. This windscorpion (Order Solifugae) has six pairs of appendages: first the jaw-like chelicerae, then, in this specimen, long leg-like pedipalps, and then four pairs of legs.

Figure 15. This is an illustration of a typical pseudoscorpion. They are typically less than 5 millimeters in length with scorpion-like pedipalps that end in pincers. (Scanned from: Animals, 1419 copyright-free illustrations selected by Jim Hartner)

The long pedipalps are the next set of appendages and are used as feelers that help locate prey for these primarily nocturnal hunters. They give the windscorpions the appearance of having 10 legs. The first true set of legs is thinner and shorter than the pedipalps and is also used primarily as feelers. The last three pairs of legs are used for locomotion. A pair of simple eyes on the cephalothorax just behind the chelicerae is present. The abdomen is segmented and narrows at its attachment to the cephalothorax. Sometimes Solifugids will take shelter in basements, sheds, and garages during the day. Gardeners will sometimes encounter them under landscaping rocks. Windscorpions should be considered allies in keeping a garden healthy because they help keep nocturnal garden pests like cutworms and earwigs under control.

Pseudoscorpions

Pseudoscorpions, as the name suggests, look like tiny (less than 5mm in length), tailless scorpions (Figure 15). The chelicerae have dual functions: they are used for feeding, and they also have silk-producing glands that they use to make a cocoon in which to overwinter. The pedipalps are large in relation to the body and end in claws. They are used to grasp the prey. Most of the 200 species described in the U.S. have venom glands that open on the end of the pedipalps (See *An Introduction to the Study of Insects* for more information). They have four pairs of legs behind the pedipalps that are unique among arachnids in lacking a patellar leg segment. Depending on species, pseudoscorpions may or may not have simple eyes. The cephalothorax and abdomen are flattened top to bottom. The abdomen is broadly attached to the cephalothorax, is segmented, and has a rounded end. These creatures are predators of smaller arthropods and help keep nature in balance. These tiny arachnids can be found in leaf litter, under stones and bark, and are abundant under the right conditions. They are harmless to humans and gardens. Pseudoscorpions are an interesting but seldom-noticed part of nature.

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Landscaping

22

Landscaping is more than merely planting trees and shrubs. This chapter is meant to offer a realistic approach to landscape planning. An end design should meet one's needs and incorporate principles of sustainability into an evolving landscape. Designing a landscape provides an opportunity to create habitats for people, plants, and wildlife; conserve water; and have an aesthetically pleasing, low-maintenance environment. A sustainable landscape requires minimal inputs of labor, water, fertilizer, and pesticides.

A landscape master plan or design is essential to ensure that the elements and principles of design flow throughout an environment and create a sense of rhythm, balance, and harmony.

General considerations

There are several easy steps to follow. The first and most important step is to do a landscape site analysis of one's current property. The purpose of a landscape site analysis is to determine the existing land use and condition before any design programs can be initiated or problems can be solved. A site analysis will give an inventory of the good as well as the troublesome spots on a particular piece of property. This will also help develop a good landscape design whether it's for a new property or for an existing landscape being renovated.

The first step in doing a site analysis is to have a map of the property. This map should be to scale and have a north arrow pointing to the top of the page. The measurements of any buildings along with pertinent information about underground utilities, above-ground utilities, and any easements are needed. Following is a series of questions to consider when completing a landscape site analysis.

Topics in this chapter

By Catherine Wissner, Laramie County Cooperative Extension Service horticulturist, University of Wyoming, and Chip Bubl, extension agent, Columbia County, Oregon State University.

See Chapter 17, *Water Quality.*

What is the water situation?

A number of factors need to be determined. Has the water been tested for pH and salts, and what is the quality? What is the water supply? Determine the location, size, and capacity of the source of water. What are the costs of obtaining the water on the site, is there a tap fee, and what are the costs of the water line? Identify the locations of all sources of existing water such as lakes, ponds, and seasonal streams that need to be taken into consideration for any water runoff from the property.

Where are the utility easements?

Trees below power lines or plants and structures in utility easements may be prohibited; therefore, check city or county regulations before digging or planting. Keep in mind that any trees planted under power lines may be trimmed by a power company in the future. Offset any trees to be planted under these lines. *Call before digging.*

What direction is the wind?

What are the prevailing winds in the area, and what are the seasonal variations? Buildings, windbreaks, and/or geography formations can affect the direction of the wind and the velocity; do take these into consideration. Weather systems will affect the direction of the wind.

What is the topography (landform)?

The "lay of the land" plays a very important role in plant and structure placement. Whether a home is on top of a hill, into a hill, or down in a valley will play a very important role in planting decisions.

- 0-3 percent grade, flat to gently sloping, possible surface drainage problems, soil depth is greater here
- 3-8 percent grade, gently sloping to rolling terrain, soil concentration in low areas
- 8-15 percent grade, hilly often rocky terrain. Soil planting depths are too limited for extensive introduction of ornamental plants and most trees. Modifications of the terrain are very costly.

What are the micro and macroclimates on the site?

Climate is the set of meteorological conditions that characteristically prevail over a period of time in a particular region. The conditions experienced in a small area are expressed as a microclimate. Each site will be unique with different zones throughout it. Each side of a structure will be different, and windbreaks will affect all of the above. Determine how the wind and snow affect the microclimate zones around any buildings.

What are the sun angles?

Consider the sun and how it moves around a landscape. Are there places in the landscape that should be shaded in the summer but open to sunlight in the winter? Winter sun angles are lower than those in the summer.

How do the sun angles affect the site?

Plants can be the first lines of defense to absorb, reflect, or filter extreme temperature elements, allowing buildings to benefit.

- Where are the shady areas?
- What time of day does shade appear?
- Where are the sunny spots?
- Where are the hot spots?
- Where are the cold areas?

What are the soils?

A good soil can be defined as a mixture that has good structure and texture, is loose and pliable, is high in organic mater and nutrient content, retains water but is also well drained and consequently high in oxygen content, and has a proper pH to allow plant growth.

See Chapter 2, *Soils and Fertilizers*.

- Have a soil test completed to learn the specifics on pH, salt content, organic matter, and fertility needs. Has the soil been disturbed and compacted by construction?
- If this is an existing landscape, has the soil been amended or is it compacted?

What is the neighborhood like?

Are there great views that need to be preserved or views that need to be screened or modified? Planting in "view corridors" may be restricted. A city or homeowner's association may have an official concept of development regulating trees along streets and lawns between the curb and the sidewalk.

- Is the site in the open prairie on acreage, in a subdivision with large lots, or in town on a typical city lot?
- Is there a homeowner's association with rules and regulations on landscaping?
- Some subdivisions limit the amount of lawn, and the type of grass allowed may be designated. The mowing height of grass and the use of chemicals might also be controlled. Sometimes the amount of irrigated area will be controlled, and specific soil preparation may be required. Check with city and county agencies or homeowner's associations before planting.

Is more time spent outside or inside the home?

How much time will be spent in the garden? The amount of yard maintenance required for a property is a huge consideration in final landscape design.

Site analysis is a tool to help in the first step of the design process; it should be used to help determine what plants are appropriate for the different microclimates on the property.

Basic principles

A landscape should be a sustainable one that supports environmental quality and the conservation of natural resources. Once established, it should grow and mature virtually on its own — as if nature had planted it.

The focus of a good landscape design is to enhance or modify the existing microclimate and to increase plant and wildlife diversity.

Most importantly, a landscape should reduce water use and reduce maintenance.

Start with the basics:

1. A site analysis
2. A planning theme
3. A list of functions for the landscape
4. A general outline.

Step one: Site analysis

Answer the questions listed above with regard to soils, sun, wind, etc.

Step two: Theme development

Get a basic idea of what is wanted by developing a theme (i.e., a butterfly or hummingbird garden, a rose garden, an herb garden, or a specific color garden). Start to put ideas on paper. At first, leave out specific types of plants and select plants based on height and color for the design. Try to limit plant color to three or four major colors at the most. This will keep the design from looking too busy.

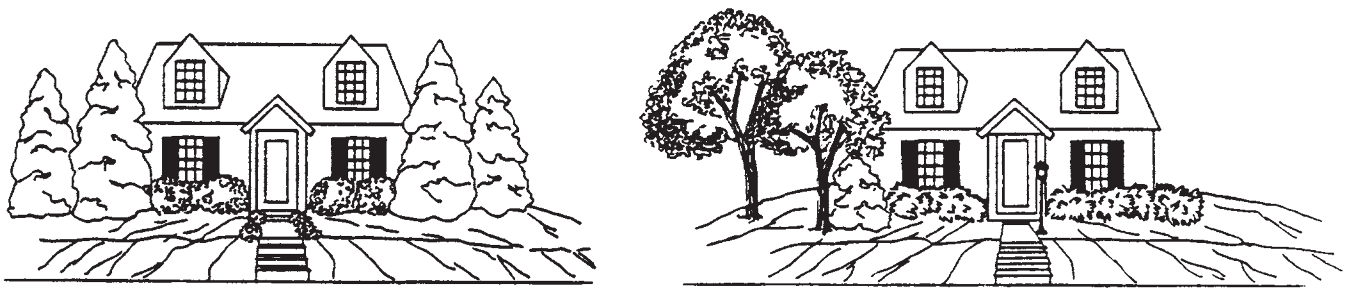

Figure 1. (a) Symmetrical balance *(b) Asymmetrical balance*

Design principles to follow:

Unity is obtained by consistent style. A design should flow visually from one area to the next. Unity means that all parts of a composition or landscape go together—they fit. A natural feeling evolves when each activity area belongs to and blends with the entire landscape. Everything selected for a landscape must complement the central scheme. An example would be planning a brick walkway, a brick retaining wall, or a brick planter using the same color of brick.

Texture describes the surface quality of an object than can be seen or felt. Surfaces in a landscape include buildings, walks, patios, groundcovers, and plants. The texture of plants differs as the relationships between the leaves, twigs, and branches differ. Coarse, medium, or fine could be used to describe texture and so could smooth, rough, glossy, or dull.

Balance in design refers to the equilibrium of a design (Figure 1). Symmetrical design occurs when balance is achieved; one side of a design is a mirror image of the other side. There is a distinct dividing line between the two sides—equal lines, forms, textures, or colors are on each side of a symmetrical design. Asymmetrical balance uses different forms, colors, and textures to obtain a balance of visual attraction. These opposing compositions on either side of a central axis create equal attraction.

Transition can be obtained by the arrangement of objects with varying textures, forms, or sizes in a logical sequential order. Examples include coarse to medium to fine textures, round to oval to linear structural forms, or cylindrical to globular to prostrate plant material or hardscaping material. Transition refers to the three-dimensional perspective of composition such as planting a 12-inch-high plant in front of a 2½-foot-high perennial or a 5-foot-high shrub in front of a 10-foot-high shrub to create transition, depth, and texture.

Proportion or scale refers to the size of parts in a design in relation to each other and to the design as a whole. A three-foot pool would be lost in a large open lawn but would fit beautifully into a small private area. A colossal fountain would dominate a private garden but could enhance a large city plaza.

Rhythm is achieved when the elements of a design create a feeling of motion, leading a viewer's eye through or even beyond the planned area (Figure 2). Tools like color schemes, line, and form can be repeated to attain rhythm in landscape design. Rhythm reduces confusion.

Focalization occurs when a viewer's eye is quickly forced along straight lines to a particular point. Generally, weaker or flowing lines of focalization are desirable in a residential landscape. The transition of plants or other objects along these lines can strengthen or weaken a focalization. Curved lines are stronger when curved toward each other than when curved outward. Lines curved in the same direction create indirect focalization. Planting materials along the lines to create stronger

Figure 2. Rhythm and line. The eye is directed toward the house by the plantings.

or weaker focalization can alter the scene. Since focalization can be used to direct attention to a point, traffic in an area is usually directed to that point. Guiding the view toward specific features may attract the eye of the unaware.

The *repetition* of plants and building materials with a specific theme creates harmony. Repetition refers to the repeated use of features like plants with identical shape, line, form, texture, and/or color. Too much repetition creates monotony but when used effectively can lead to rhythm, focalization, or emphasis. Too much variety in a design creates a cluttered or busy appearance.

Simplicity goes hand in hand with repetition and can be achieved by the elimination of unnecessary detail. Too much variety or detail creates a confusion of perception. Simplicity is the reduction of a design to its simplest, functional form, avoiding unnecessary cost and maintenance.

Step three: Determining landscape functions

One needs to have a general idea of what is wanted from a landscape and how to get there. What is the theme or goal of the design? Different areas around a particular property have different functions. Play areas, barbecue areas, private secluded areas, and storage areas for tools, ponds, or greenhouses might be desired. Use the Landscape Design Questionnaire to determine how a landscape might be used.

Landscape Design Questionnaire

1. Who will be using the yard now?__________ Who will be using it in the short-term future?__________________
2. What style of landscaping is desired? formal_____ natural______ informal_________
3. What will be the theme? Victorian flower garden____________ butterfly and bird garden____ Oriental____ native plants____ other_______________
4. Where is hardscaping needed? paths_____ walls____ patio____ raised gardens____ fencing____ pool____ dry creeks_____ streams_____ other____________________.
5. What structures are planned? gazebo____ deck_____ barbecue area_____ child's play set_________ other__________.
6. Will there be outdoor lighting? yes______ no______
7. Will there be an in-ground sprinkler system? yes______ no______

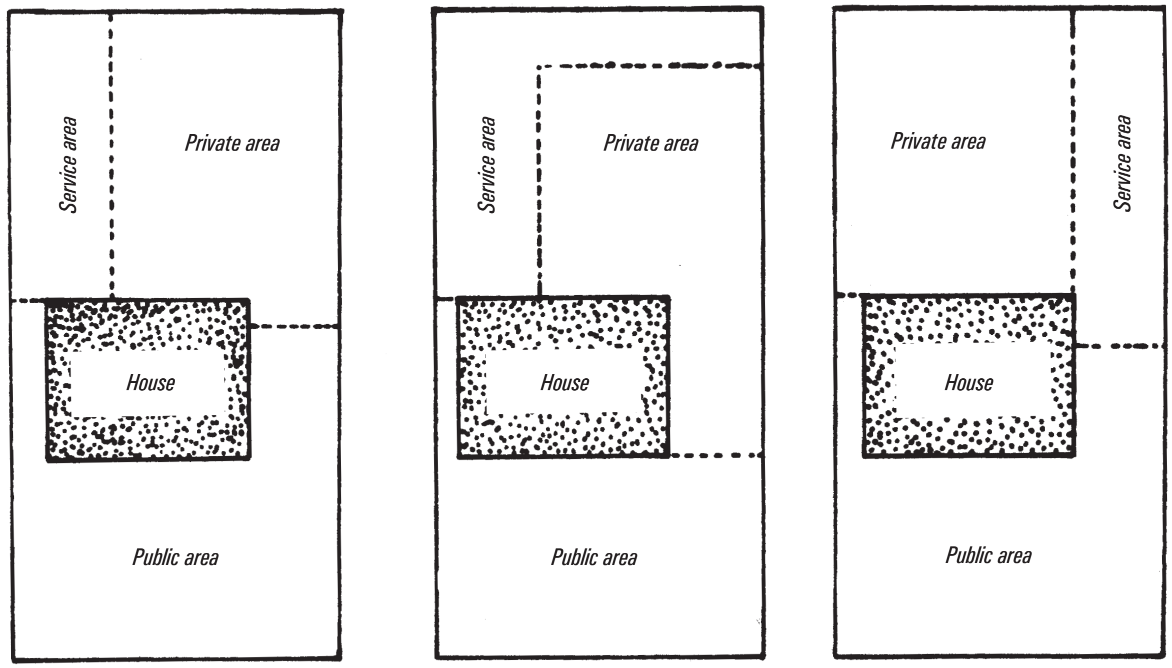

Figure 3. Use areas in a landscape.

Step four: Putting a plan on paper

Set the scale of a design on paper:

Example: 1 inch equals 20 feet or 1 inch equals 40 feet.

- Lay out the property to scale on paper, measuring everything that is permanent on the site.
- Include existing plants and structures.
- Add a north arrow pointing to the top of the paper/map/plan. The north arrow should be located in the bottom righthand corner along with the scale of the project.

Family activities, growth, and change:

Don't plan a static landscape. As a family's needs change, so may a landscape. Analyze family activities and design a landscape that will mature with the family.

- Barbecue and picnic areas should be easily accessible from the house.
- Play areas for children should be easily viewed from the house.

Private areas within a landscape:

A landscape is made up of several parts. One of these will be a private area, a place where family members and guests can gather to enjoy the outdoors without the openness of streets or neighbors. Properly grouped shrubs, perennial flowerbeds, and trees work well for developing a sense of privacy without compromising safety and home security (Figure 3).

Service and work areas in a landscape design:

Keep areas leading to utility meters open for easy access by utility workers. Lawn maintenance equipment should be easy to get to and close to the lawn area. If applicable, design areas for firewood storage, compost piles, kennels, or clotheslines.

Public areas:

This is the street-side view the public has of a landscape (Figure 3). There are several ways to arrange this area. There can be an open view of the house or a sheltered view with more privacy. To develop privacy, colorful plants, trees, and shrubs need to be planted closer to the curb. The more color next to the house, the less privacy there will be. Color will draw the eye of a viewer to a focal point.

Design hardscape:

What is the natural flow of movement through the site? The natural flow of people through the site will determine where the paths and lawn areas go in a design plan.

- Paths: Concrete, brick, or exposed aggregate paths can be used to pull people in, slow them down, or speed them up.
- Walls: Rocks, concrete, wood, and concrete block materials should complement paths, fences, or garden structures.
- Fences: Metal, wood, rock, and concrete can be used.
- Garden structures: These include decks, gazebos, swings, benches, and barbecue stands.
- Ponds or pools: Formal or natural areas can be planned with the landscape design theme in mind.

Lawn areas:

These provide an opportunity to control two major components in a landscape: water usage and time spent lawn mowing. By properly designing the shape and size of a lawn, one can conserve water. Simple wide curves or straight lines can help keep mowing easy and fast. Tight waves and narrow angles will increase mowing time and increase the difficulty of maintenance.

See Chapter 8, *Lawns*

Use edging around a lawn area to help keep the grass where it belongs and out of flower and shrub beds. Consider installing an underground irrigation system to help conserve water, avoid brown or dead spots in the lawn, save time, and increase the value of the property.

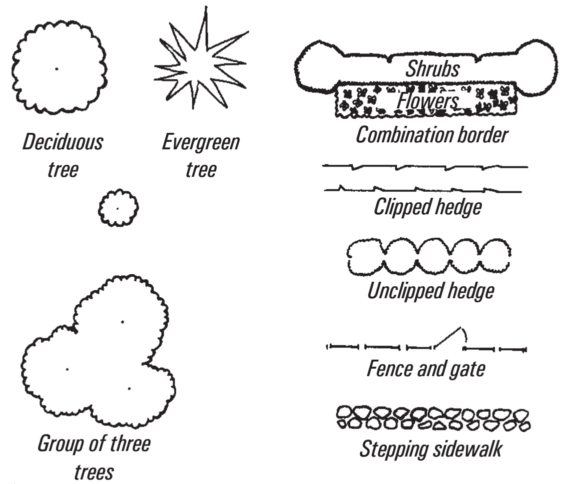

Figure 4. Landscape symbols.

Landscape plants:

The first consideration when choosing plants for a landscape is the mature size of the plants. A “cute” 2-foot-tall blue spruce in a nursery will grow 50 feet tall with a 20 to 25-foot spread. Below are several points to take into consideration when picking plants:

See Chapter 6, *Herbaceous Ornamentals;* Chapter 7*, Woody Plants*

- What is the purpose of a tree, shrub, or flower? Is it for shade, screening, seasonal color, or to create privacy within a landscape?
- The mature form of a plant must be considered along with how its size will fit into a landscape. Is the plant hardy to the location in the landscape? Check the site analysis to be sure.
- Plan ahead for the mature size of a plant. Draw the mature plant on paper (i.e. an 18-inch-diameter Shasta daisy at maturity or the 40-foot spread of an American linden tree at maturity). This step is critical in the long-term planning of a landscape and the health of the plants.
- Assign perennials, shrubs, and trees specific symbols (Figure 4). This helps keep track of what each group of plants is and where it is to be located.

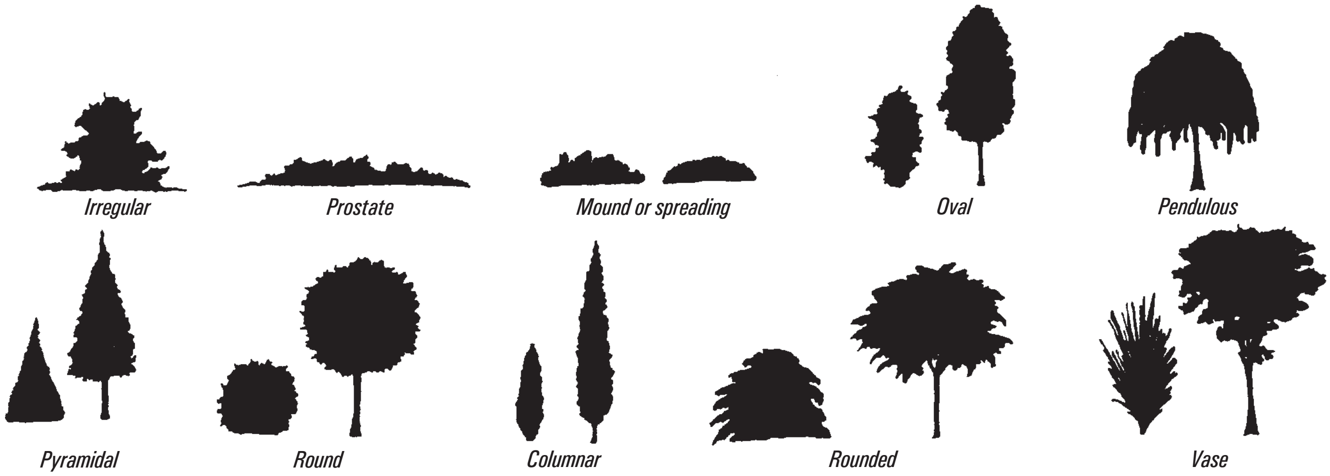

Figure 5. Plant forms.

- Design plant materials that have similar leaf color and texture patterns. Daylilies, red-hot pokers, and ornamental grasses all look good together. Hyssop, agastache, coreopsis, and penstemon also fit well together. Before and after plants flower, they need to complement one another.

Start to think about what plants are desired. What plants need to go where? Which ones grow best according to the site analysis? The size, height, shape, and color of plants are very important (Figure 5) when adding plant material into the design. Use the Landscape Plant Questionnaire as a guide.

One can manipulate the visual size of a landscape by using different colors of plant leaf and texture. For example, dark leaves make a space look smaller or closer while light, small-colored leaves make a space seem bigger or deeper.

Limit the color range in a landscape design to keep it simple. Try to keep the same colors and species of plants grouped together rather than staggering them. Too much color jumping from different plantings will make a landscape busy and cluttered, causing difficulty focusing on any one area. The line of vision should flow from one location to the next.

Only after a hardscape and general design is on paper can one consider specific plant materials. Only at this point should one start to label in favorite plants.

Landscape Plant Questionnaire

1. What are your favorite colors? ______________________________

2. Do you want flowers that are fragrant? yes______ no______

3. Are there special gardens in your design? rose garden_____ shade area____ herb garden____ cut flower garden_____ flowers for drying______ alpine garden _____ vegetable garden________ other_________________

4. What wildlife types are in the area?____________________________________

5. Is wildlife a problem? yes______ no______

6. Are fruit trees and shrubs desired? yes______ no______ What types? ____.

7. What type of trees are desired? Evergreen_______ Deciduous________

8. Is a windbreak needed? yes______ no______

9. How much lawn is needed? _______________________________

10. How will mulches, wood chips, rocks, and other weed barriers be used?____

For more information

UW Cooperative Extension Service publications

Low-Maintenance Grasses for Revegetating Disturbed Areas and Lawns (B-1070)
Landscaping: Recommended Trees for Wyoming (B-1090)
Landscaping: Recommended Shrubs for Wyoming (B-1108)
Gardening: Vegetables in Wyoming (B-1115)
Landscaping: Turf in Wyoming (B-1129)
Landscaping: Water-Wise Wyoming Gardens (B-1143)
Gardening: Growing Herbs in Wyoming (B-1144)
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23

Vertebrate Pest Management

Vertebrate pests, while not as numerous or pervasive as disease or invertebrate problems, can occasionally be a real concern. A pest can be defined as an organism that causes, is perceived to cause, or is likely to cause economic or aesthetic damage to humans or their property.

Before attempting to manage a vertebrate pest, there are many things to consider. First, is control really necessary? Several variables should affect a decision:

- What kind of animal is it? Positive identification is essential for effective management. Identification must often be done by studying signs left by the animal since most vertebrates are nocturnal or difficult to observe.
- How much damage might occur without any control?
- What are the benefits of control versus the cost of damage? In other words, what are the economic or aesthetic thresholds at which the extent of potential damage warrants control?
- Does the species have any aesthetic or recreational value or is it legally protected? If so, options may be limited.
- Finally, what effect will a control program have on nontarget animals and the environment?

If a control program is called for, there are usually several options, depending on the pest. Ideally, the goal is to eliminate or repel the pest or change its bad habits in a way that will not endanger humans, nontarget animals, or the environment. Before beginning any direct control action, such as the use of traps or poison baits, think about whether there are alternative ways to manage the animals and if those ways are legal. Regulations related to non-game mammals can be found in *Wyoming Game and Fish Department Regulations,* Chapter 52 (see "For More Information" at the end of this chapter).

Topics in this chapter

- Population dynamics and pest management
- Managing common vertebrate pests
  - Rats and mice
  - Bats
  - Pocket gophers
  - Voles
  - Ground squirrels
  - Deer and elk
  - Tree squirrels
  - Rabbits
  - Raccoons
  - Birds

By Dave Pehling, Extension analyst, Snohomish County, Washington State University. Adapted for Wyoming by Chris Saunders, former Casper regional public information specialist, and Michelle Zitek, Laramie region information and education specialist, Wyoming Game and Fish Department.

Population dynamics and pest management

Some pests can be managed indirectly—without resorting to chemicals or traps—by manipulating their habitat. To manage habitat effectively, one needs a working knowledge of *population dynamics*—or how populations change in relation to the environment.

Each living area has a limited *carrying capacity* for a given species; it will support only a limited number of that species. Excess population either dies or migrates.

Carrying capacity is determined in part by three limiting factors: food, water, and shelter. If one can control these factors—especially food and shelter—he or she can manipulate the population density.

Managing common vertebrate pests

Rats and mice

Worldwide, rats and mice are the most notorious vertebrate pests that plague humankind. Of these, the Norway rat (*Rattus norvegicus*) and the house mouse (*Mus musculus*) are the most common. Adult Norway rats are robust, weighing 10 to 17 ounces, and are 13 to 18 inches in total length. The tail is usually shorter than the head and body. Color ranges from gray to brown to almost black.

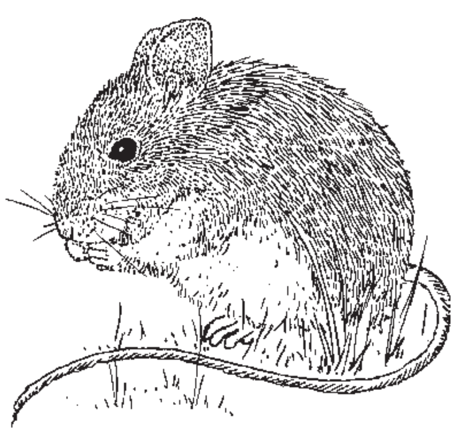


Figure 1.—Deer mouse.

The common house mouse is second only to rats as a destructive pest. House mice can be distinguished from young rats by their proportionally smaller heads and feet. These three rodents are not native to North America but stowed away in the ships of early European arrivals.

Outlying areas are likely to have native deer mice (*Peromyscus maniculatus*, Figure 1) rather than imported house mice. Deer mice have white underparts on their body and tail.

Rats and mice are mostly nocturnal, so an infestation often goes undetected until the rodents become numerous. By knowing what signs to look for, one usually can catch a rodent problem before it gets out of hand.

Rats and mice tend to move over regular routes and usually produce defined runways. The runways show up particularly well in dusty areas, especially if flour or other tracking powder is sprinkled around likely spots. Outdoors, rats leave trails through vegetation and dig or gnaw 2 to 3-inch holes around buildings and foundations. Another telltale sign is the grease smudges that rats leave when traveling close to a wall, around a beam, or through a hole. Finally, fresh rat and mouse droppings, which are moist and soft, are a reliable sign of infestation.

There are four important steps to effective rat and mouse control:

- Eliminating harborage (shelter)
- Rodent proofing structures
- Eliminating food and water
- Killing the rodents

Eliminating harborage

The elimination of harborage often is overlooked in a rodent control program but is an easy way to discourage rodents. Rats in particular like to inhabit woodpiles and stacks of stored material. Place stacks or piles on pallets at least 8 inches off the ground; 18 inches is even better. If possible, the stacks should be 18 inches from walls and no more than 6 feet wide with at least a 12-inch aisle between stacks.

Reduce dense vegetation and rubbish piles around structures as much as possible. Prune ornamental shrubs away from the ground. Also, avoid planting groundcovers such as ivy that offer harborage to rats. Finally, block spaces under buildings and fill in old burrows.

Rodent proofing structures

Complete rodent proofing is usually not possible, especially in barns and older buildings. If approached properly, however, rodent proofing goes a long way toward reducing an infestation.

To keep rats out of buildings, close any opening they can get their teeth into (that is, more than $^1/_2$ inch in diameter). Mice can often squeeze through openings as small as $^3/_8$ inch. Be sure to seal openings around pipes and floor drains and keep drains tightly covered. Cover edges subject to gnawing such as door bottoms with heavy sheet metal or wire mesh. Place metal rat guards on pipes, wires, and other places rats climb. Cover other openings with 19-gauge or heavier hardware cloth with $^1/_4$-inch or less mesh. In severe cases, one can keep rats from burrowing under foundations by building an offset curtain wall of concrete, hardware cloth, or sheet metal.

Eliminating food and water

The elimination of food and water is the third step in effective rat and mouse control. Strict control of food materials is essential in any rodent control program.

The following steps can be helpful:

- Be sure all human and animal foods are stored in rodent-proof buildings, rooms, or containers.
- Dispose of garbage and other waste in tightly covered metal cans.
- Never feed outside pets more than they can eat at one sitting.
- Be sure to clean up pet droppings. Rats can do very well on a straight diet of feces.
- Clean up windfall fruits, nuts, and ornamental seedpods.
- Don’t scatter food for birds and squirrels. Be aware that birds often throw seed onto the ground, so a rodent-proof feeding station is no guarantee against pest problems.

See Chapter 5, *Weeds*.

Killing existing rodents

Along with general cleanup and controlling food sources, one can directly reduce infestations by careful use of rodenticides and traps.

Rodenticides

Poisons are one option for killing rats and mice. There are several effective rodenticides on the market. They are available as concentrates, mixed baits, weatherproof blocks, and premeasured packets. All are effective and safe to use as long as one follows the label directions. **Always read the label before using any pesticide.**

See Chapter 19, *Pesticides*.

The most widely available rodent poisons are *anticoagulants*, which usually contain warfarin, brodifacoum, diphaci-none, or bomadialone as the active ingredient. There are many brands available.

Anticoagulant rodenticides reduce the blood’s clotting properties until an animal bleeds to death internally, usually after several feedings. Most other types of rodent poisons are either not readily available or contain chemicals highly toxic to humans and animals.

Baits containing warfarin were the most popular for many years and are still usually effective if used correctly. These materials are of relatively low toxicity to humans, pets, and livestock. An animal poisoned by anticoagulants may bleed at the nose and mouth, have bloody stools, exhibit labored breathing, or have all three symptoms. Vitamin K_1, administered for an extended length of time, is the antidote.

The problem with warfarin-based rodenticides and other first-generation anticoagulants such as diphacinone is that rodents must feed almost exclusively on the bait for several days. A few populations of rats have developed resistance.

Modern, second-generation anticoagulants such as brodifacoum, bromadialone, and difethialone are often effective with a single dose. They may be a bit more hazardous than milder poisons if the label is not followed exactly, but they are probably more effective where other food sources cannot be eliminated. In addition, no U.S. rodent populations have developed resistance to these materials. There is a slight hazard of secondary poisoning of wildlife and pets if they feed on a lot of dead rodents.

There are only a few *nonanticoagulant* rodenticides available to the public. They contain the ingredients cholecalciferol, bromethalin, or zinc phosphide.

Cholecalciferol (Vitamin D_3) is a calcium-mobilizing chemical that upsets a rodent's blood-calcium level so that the animal dies of hypercalcemia. Most other mammals are not as sensitive to changes in blood-calcium levels, so the poison has relatively low to moderate toxicity to most nontarget animals.

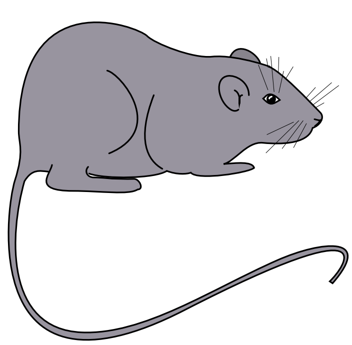
Bromethalin is another recent addition to the rodenticide shelf. This material is a potent nerve poison that paralyzes and kills rodents within two to four days.

Zinc phosphide is the oldest of the available nonanticoagulant rodenticides. This chemical, available under several brand names, is a quick- acting stomach poison that sometimes kills a rodent within 17 minutes after feeding.

Zinc phosphide is quite toxic to all warm-blooded animals and must be used with caution. Do not handle it with bare hands because it can be absorbed through the skin. Be careful not to breathe the dust or vapors. Also, it decomposes quickly, especially in damp situations, and has a short shelf life. (If there's no smell, it's too old.) Fortunately, zinc phosphide repels most animals due to its strong odor and taste, which rodents seem to like. There may be a problem with secondary poisoning since some sources claim that zinc phosphide remains active in an animal's gut for a couple of days after death.

One of the main disadvantages of acute or quick-kill rodenticides is that the target animal often samples just a small dose of the bait to begin with. Sublethal doses of these quick-acting poisons make an animal very sick. After recovering, the animal becomes bait shy and difficult to poison. To overcome this problem, it's best to first bait the area with grain until all of the rodents are feeding well. Then replace the nontoxic baits with a quick-kill rodenticide that contains a similar grain base. Since the rodents are used to feeding at these stations, they will gorge on the poison and die. This technique results in quick control and is often the most economical method when dealing with large numbers of rodents.

Once control is achieved with any rodenticide, it's a good idea to continue with a preventive baiting program using an anticoagulant. This step is especially important on farms and in other areas where there is a good chance of reinfestation. A tracking patch of flour or dust placed along walls is an excellent way to check for rats and mice. Permanent, tamper-proof bait stations placed around buildings will take care of incoming rodents before they become a problem. Place bait stations at least every 15 to 20 feet where rodents have been active.



Remember, if there is a lot of other food available, if there are too few bait stations or not enough bait, or if baiting is stopped too soon, there will not be good control.

To be most effective, bait stations must be placed where rodents can easily get to them. At the same time, they must be protected from dampness, pets, stock, and children. One effective method is to place pans of bait in runways and cover them with a board or a box with a hole in each end. For prolonged baiting and outdoor situations, one can make or purchase a tamper-proof bait box to safely present a continuous supply of fresh bait.

With baiting, rodents sometimes die between walls and begin to smell in a couple of days. If the odor source can be located, drill a small hole in the wall 6 inches above the floor and spray in a pint of deodorant or disinfectant. Repeat between the two adjacent studs. Commercial deodorants are the most effective and may be available through hospital supply houses or drugstores.

Hard-to-locate odors can sometimes be pinpointed by releasing a few blowflies in the room. The flies will congregate on the wall at the source of the problem, which can then be treated. If the odor cannot be located precisely, apply deodorant in the general area. If left untreated, the odor usually disappears in about a month but may last longer.

Trapping

Traps are especially useful if one doesn't want to use poisons or for catching bait-shy rodents that survive a baiting program. One of the big advantages of trapping is that pests don’t die in an inaccessible place where they may cause odors.

When trapping rats, it is most effective to set one or two traps at least every 15 to 20 feet wherever there are signs of activity. For mice, place traps every 5 to 10 feet. Place traps facing the wall along baseboards and near possible entry holes or other covers. When possible, wire traps to a secure anchor to prevent dying rodents from dragging them off.

One may have to try several baits to find what works best in a particular situation. Nutmeats, gumdrops, or raw bacon usually work well. Whichever bait is chosen, be sure it is fixed securely to the trap so it cannot be licked off. Being cautious by nature, rats sometimes avoid a trap or strange bait for as long as 14 days. Mice, on the other hand, are generally unwary and easily caught.

Glue-board traps are quite effective when set in runways. Large ones can be used for either rats or mice, but rats can sometimes escape with these traps so fasten them down if possible. In addition, remember that glue boards do not work well in cold, wet, or dusty areas and that captured rodents are often alive and struggling when found.

Remember to check traps daily to remove dead rodents and reset sprung traps. Wear gloves when emptying traps to avoid being bitten by fleas or lice. Drop dead rodents into sealable plastic bags for disposal.

Electronic sonic repellers

These units, made by several companies, emit sonic waves which are said to disrupt rodents’ activities and eventually drive them away. When tested under laboratory conditions, none of the devices has proven effective for any pest.

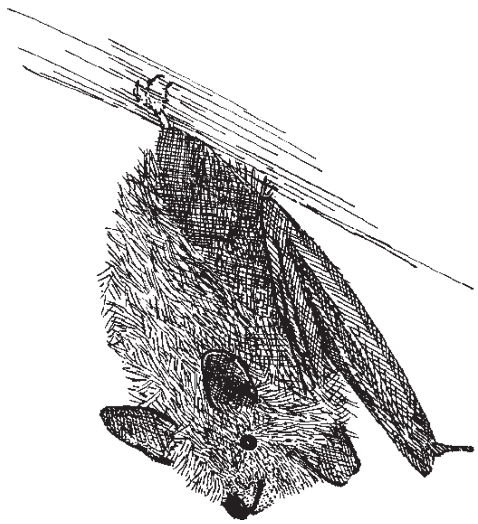


Figure 2.—Brown bat.

Bats

Bats are the only true flying mammals. They sometimes invade attics and wall voids. Although they usually don't cause any structural damage and in fact eat insect pests, many homeowners dislike the noises they sometimes make. In addition, large colonies leave a lot of smelly guano and may carry parasites. Furthermore, about ½ of one percent contract rabies. Infected bats can transmit rabies to unvaccinated pets and humans. Even though skunks, foxes, and raccoons are more likely to contract and spread rabies, live bats should never be handled with bare hands, especially if they are acting abnormally by doing such things as fluttering on the ground. If bitten or scratched, capture the animal with the brain intact for examination by health authorities. Be sure pets are vaccinated and don't allow them to lick the skin if they might have access to bats.

There are many species of bats in Wyoming, but the one that causes most problems in buildings is the little brown bat (*Myotis lucifugus*, Figure 2). These little animals are highly colonial during summer and winter. Their summer and winter roosts are usually separate. Young are born in June or July, one per female.

The surest way to eliminate or prevent a bat problem is to close possible entry points. Depending on the species, bats can enter cracks as narrow as ³⁄₈ inch wide. Older structures may be very difficult to bat proof.

Before bat proofing a building, first evict any bats present. To do so, hang ¼-inch mesh bird netting loosely over the entrances. Secure it on the top and sides with duct tape and leave the bottom free-hanging a foot or so below the opening. Bats will be able to leave but not return. Depending on the building, two or more nets may be needed. Do bat-proofing early in the summer or in the fall to prevent young, flightless bats from dying inside. It's a good idea to erect a bat house nearby to give the animals a place to go. Doing so may prevent them from looking for other ways into the building.

After evicting the bats, which may take three or four days, close large openings in the building with sheet metal, wood, or ¼-inch or smaller screen. Caulk small holes, cracks, and gaps in shakes and tiles or fill them with foam insulation. Any lingering odors can be masked with deodorants or disinfectants.

Pocket gophers

Pocket gophers (*Thomomys* spp., Figure 3) are burrowing rodents that can cause a great deal of damage to vegetation, buried cables, dikes, and irrigation pipe. Pocket gophers feed almost exclusively on plant

Figure 3.—Pocket gopher.

material below and occasionally above ground.

There are four species of pocket gophers in the Wyoming. Most are 5 to $6^1/_2$ inches long with a 2 to 3-inch tail (Figure 3). Fur is usually brown or grayish, and the typical rodent's buck teeth are easily visible. The name pocket gopher comes from the external, fur-lined cheek pouches on each side of the mouth that are used for transporting food to storage areas.

Females produce from one to three broods per year depending on the availability of high-quality forage. An average litter size is five to six (sometimes as many as 13). The young stay in the nest for several weeks, eventually wandering off to claim their own territories.

Controls

Pocket gophers may be controlled any time of the year, but control is most successful when new mounds are appearing, usually in the spring and fall. Both traps and toxic baits are effective, but Wyoming and Idaho pocket gophers cannot intentionally be taken without a permit. Although these two species are not common, nonlethal take is recommended unless the species are correctly identified.

Several styles of pocket gopher traps are widely available and easy to use. One can set them in the lateral tunnel leading to a mound, but they are more effective when set in the main run. Locate the main run by probing a foot or so away from a mound. Place two traps back to back in the deep run and stake them down. Relocate the traps if a catch is not made within two or three days.

Baiting is another option. Place toxic baits in main tunnels according to label directions. Locate the tunnels with a probe and place the bait down the probe hole. An alternative method is to excavate the tunnel with a trowel and place the bait directly in the run. Bait each burrow system in two or three places for best results. Check the area periodically for two weeks after treatment and dispose of any carcasses.

Fumigants, although available, are seldom effective unless the soil is saturated with water or consists of dense clay.

Voles

There are several species of voles (*Microtus* spp.) or "meadow mice," in Wyoming (Figure 4). All of them are plant feeders, and many are proficient burrowers. These small, short-eared, short-tailed rodents can cause damage by feeding on tree roots and girdling trunks. They also tunnel through vegetable and flower gardens, feeding on juicy roots, tubers, and bulbs.

Voles are active day and night in all seasons. They are seldom seen because they spend most of their time underground or in dense grass. They can have as many as five litters per year with as many as 11 young per litter. They are the main food source for many predators.

How can one tell whether he or she has a vole problem? Obvious signs include gnawed roots and root crops. (Note the small grooves left by the two large front teeth.) In badly infested areas, wiggle trees during the dormant period to locate dead ones. If they move very much, the entire root system probably is gone. During the growing season, damaged trees are leggy and thinly leafed with a reddish tinge to the foliage. If one pulls up a vole-damaged tree,

Figure 4.—Vole.

the underground part often looks as if it has been run through a pencil sharpener.

The girdling of tree trunks just above the soil line and extensive, well-used tunnels through soil, grass, or thatch are other signs of infestation. Finally, voles often leave open, 1-inch holes in areas of heavy activity.

Vole damage is sometimes confused with that caused by rabbits or mountain beavers, but there are differences. Rabbits usually damage trunks and twigs higher up and leave larger tooth marks at 45° angles.

Management

Vegetation management is the key to keeping vole populations low. For example:

- Mow the grass between trees and keep it short.
- Prevent or eliminate thatch that voles can hide under.
- Be very careful if using mulches around trees and shrubs. Voles are often encouraged by a nice, loose mulch.
- Be sure to pick up fallen fruits and vegetables so voles cannot feed on them.
- In gardens, try to keep surrounding areas free of tall grass and thatch and don't leave root vegetables in the ground over winter.
- Be aware that fallen seed from bird feeders is very attractive to rodents of all kinds.

Controls

Biological

Almost all small meat eaters love to feed on voles. Hawks, owls, coyotes, foxes, weasels, and shrews can help keep vole populations from exploding.

Mechanical

Place hardware cloth cylinders (1/4-inch mesh) around the lower trunks of shrubs and young trees to exclude voles. Be sure to bury the lower edges 6 inches deep.

Tree guards that control rabbit damage do not discourage voles since the animals feed mostly underground. In fact, voles have been known to nest under loose-fitting guards.

For very small populations, trapping may provide sufficient control. Use ordinary mousetraps baited with peanut butter or apples. Dig into underground tunnels to place the traps and then cover them with boards. Check the traps daily and reset them as needed. This method is very time-consuming but useful in lieu of poisoned baits.

Chemical

Check with a Cooperative Extension Service office about chemical control. Mole and gopher baits registered for home use kill voles when applied according to label directions, but they are not registered for use on voles.

Several rodenticides are registered for professional use on voles. Some are more water resistant and attractive to voles than others. Registered chemicals include zinc phosphide (very toxic, decomposes quickly in damp situations), chlorophacinone, and diphacinone (both anticoagulants). **Always read the label before using any pesticide.**

Bait pellets must get into voles' burrows to be most effective. One can save time and effort by baiting only where there is feeding activity. Since vole populations fluctuate wildly, it's a good idea to first place apple or carrot pieces in various likely places such as damaged areas, tunnels, and runways to locate areas of active feeding. Cover the food with a shingle or 12 by 12-inch piece of cardboard. Weigh down the cover to keep it from blowing away. Keep the bait as dry as possible to encourage feeding. If there is no feeding on these materials within 24 to 48 hours, there are probably no voles within the immediate few square yards.

About a week after placing the poison bait, put out more apple or carrot pieces. If there is no feeding within a couple of days, the baiting program was successful.

Ground squirrels

Several species of ground squirrels (*Spermophilus* spp., Figure 5) live in Wyoming. They are abundant, feed mostly on vegetation, and can be very damaging to gardens. They are also vigorous burrowers, leaving many open holes throughout their home ranges, and have been implicated in the transmission of plague and other diseases.

Ground squirrels are generally dormant during the hottest part of summer and during the winter. Breeding takes place soon after emergence in spring, and a single litter of two to 10 young are born four to five weeks later. Some species can reach population densities of more than 100 per acre.

Management and controls

Ground squirrels can be excluded from buildings with standard rodent-proofing techniques. Metal rodent guards usually protect fruit trees. Fencing is usually not effective in barring these rodents from an area, nor do scare devices work.

Ground squirrels are not legally protected, but check local laws before using lethal methods.

Trapping can be effective with small infestations. Cage-type traps may be used but check with a local extension office or state game and fish department before releasing these rodents back into the environment. Relocation may not be legal. If a trapped animal must be destroyed, drop the entire trap into a large garbage can full of water.

Lethal traps such as the Better Squirrel and Rat Trap (a choker-type trap) or the Conibear 110 body-catch trap may also be used. For small ground squirrels regular rat traps might work. One trap for every 10 to 15 squirrels present should quickly control the population. Be sure to keep traps inaccessible to nontarget wildlife and pets.

Fumigants are available and can be quite effective if used when rodents are active. They work best when the soil is moist and dense, which helps keep the gas in the burrows.

Rodenticides are usually not registered for home use on ground squirrels. Check with an extension office to see whether any are legal.

Deer, antelope, moose, and elk

Deer and elk (*cervus elaphus*) are highly valued as game animals and watchable wildlife (Figures 6 and 7). However, they can cause extensive and continuing damage to crops and ornamentals.

Mule deer (*Odocoileus hemionus*) and pronghorn antelope (*Antilocapra americana*) are the most common cloven-hoofed pests in Wyoming. Whitetail deer (*Odocoileus virginianus*) also live in many parts of Wyoming, mainly near riparian

Figure 5.—Ground squirrel.

areas. They are easily identified by their bushy tail, which is used as a flag to signal alarm. Mule deer have smaller tails with black markings.

Deer, antelope, moose (*Alces alces*), and elk feed on a wide variety of plants, both woody and herbaceous. Most damage is caused by their browsing on woody ornamentals, fruit trees, and other crops. Browsing damage is easily identified by the ragged tips where twigs have been broken. Rodents and rabbits, in contrast, leave a clean cut when they browse.

See Chapter 5, *Weeds*.

Management

The only consistently effective tool for reducing deer, antelope, moose, and elk damage is fencing. Fences range from simple, baited electric fences to expensive, 7-foot, high-tension fences or woven-wire fences. Simple fences are quite effective in areas where deer are just beginning to cause damage. In areas where deer and elk have been feeding for some time, more impenetrable fences are necessary. It is important that fences be visible so that animals don't accidentally stampede through them.

If the animals are browsing on just a few plants, place cylinders of welded wire mesh around each plant. New seedlings can be protected with plastic mesh tubes or netting.

In some cases, registered repellents can reduce damage sufficiently. However, they must be reapplied periodically, especially after heavy rain. If animals are used to feeding in an area, repellents are less effective.

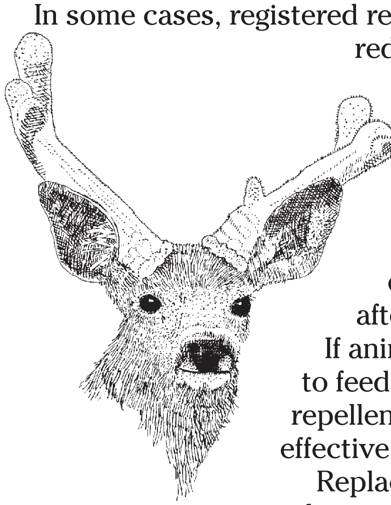


Figure 6.—Mule deer.

Replacing heavily damaged plants with

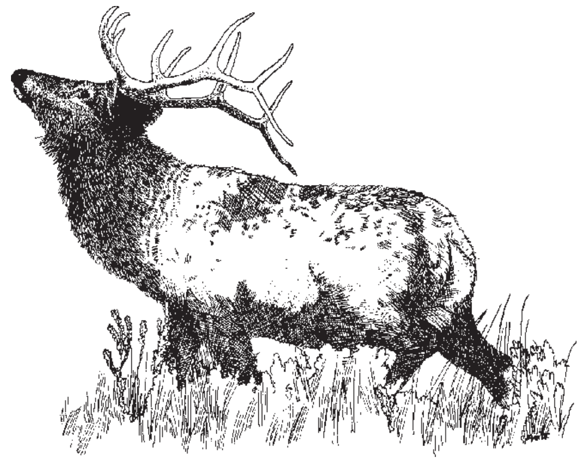


Figure 7.—Elk.

more resistant varieties is another option. There are many kinds of ornamental plants that deer and elk don't like. However, even some of these plants are browsed when animals are really hungry.

In areas where hunting is allowed, opening the land to responsible hunters can reduce browsing damage.

Other remedies range from hanging bars of deodorant soap to scattering lion dung about the garden. Sometimes these methods work, but many times they do not.

For more information specific to a particular location, contact the state game and fish department.

Tree squirrels

Two species of tree squirrels are common in Wyoming—the red squirrel (*Tamiasciurus hudsonicus*) and the fox squirrel (*Sciurus niger*) (Figure 8).

Squirrels become troublesome when they attack fruit, vegetable, and ornamental crops. They are also incessant raiders of bird feeders and bird nests and can damage ornamental trees by clipping twigs and stripping bark. In areas where nesting places are scarce, they gnaw into attics and wall voids, causing serious damage.

Management

Methods for controlling squirrels vary. Usually a combination of nonlethal methods can be used including exclusion, repellents, and cage trapping. Check with the state game and fish department for current regulations.

Try these nonlethal methods of control:

- In areas where squirrels are a potential problem, eliminate food sources to keep the carrying capacity low. Lots of food means lots of squirrels. Clean up fallen fruits, ornamental berries, and seeds as much as possible. If feeding birds, be sure to use squirrel-proof feeders.
- Cover attic vents with heavy wire mesh and seal other openings.
- Protect plants somewhat with registered repellents or wire cages.
- If squirrels are digging up bulbs, lay chicken wire over the bulbs, stake it securely, and cover it lightly with mulch.
- Protect fruit trees by placing rodent guards on the trunks 6 feet off the ground. This method will *not* work if there are tall trees, fences, or buildings nearby from which squirrels can leap to trees.

Figure 8.—Tree squirrel.

Rabbits

In Wyoming, there are seven species of rabbits and hares. A few of them sometimes become garden pests.

Whitetail and blacktail “jackrabbits” (*Lepus townsendii* and *L. californicus*) are actually hares. The only other hare is the snowshoe hare (*L. americanus*), which lives in mountains except in the very driest areas.

The true rabbits (Figure 9) include the mountain cottontail, *(Sylvilagus nuttalli)*, desert cottontail (*S. audubonii*), and pygmy rabbit (*S. idahoensis*). The eastern cottontail (*S. floridanus*) is rare in Wyoming but has been documented here.

Rabbits and hares are very prolific, having as many as six (sometimes even more) litters per year with several in each litter.

Hares and rabbits eat a wide variety of herbaceous and woody plants. They often feed on bark and stems during winter and can cause a lot of damage to gardens and landscaping in yards, especially during peak population years. In spring and summer they develop an appetite for flowers (especially tulips) and vegetables.

Rabbit-damaged trees and shrubs are easily identified by characteristic tooth marks. Twigs are usually clipped cleanly at a 45° angle, and bark on lower stems and branches is gnawed away, leaving parallel grooves in the wood.

Management and controls

One of the most effective methods of reducing rabbit damage is to fence the animals out. A 2-foot-high chicken wire fence is usually sufficient to protect a garden. Mesh size should be no more than 1 inch, and the bottom of the fence must be tight against the ground or buried a few inches. If feral domestic rabbits or hares are the problem, the fence should be 30 to 36 inches high with the bottom 6 inches bent outward and buried 6 inches.

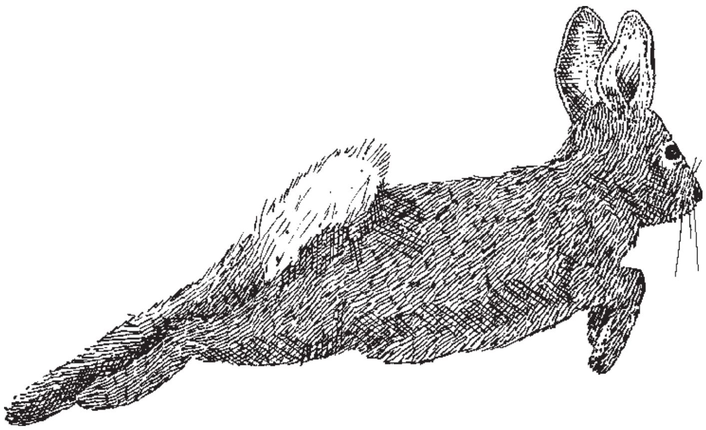


Figure 9.—Cottontail rabbit.

Protect individual plants with cylinders of 1/4-inch mesh hardware cloth about 18 to 20 inches high. Commercial tree wraps can also be effective.

Habitat manipulation can also help reduce rabbit/hare damage. Removing briar patches, brush piles, and other hiding places will reduce the overall number of animals in an area.

Several repellents are registered for rabbit and hare management. Most are somewhat effective if feeding pressure is not too great. Many are labeled for use only on ornamentals.

Since rabbits and hares are usually classified as game animals, contact the state game and fish department for regulations about trapping or shooting. Pygmy rabbits are protected.

Raccoons

Raccoons (*Procyon lotor*) are native animals that live throughout most of the United States (Figure 10). These animals, which can weigh as much as 50 pounds, readily adapt to suburban environments. With few predators and plenty of human-supplied food, populations often grow out of control.

Raccoons are generally nocturnal and *omnivorous* (i.e., they eat both meat and plants). They often stage midnight raids on gardens. They can easily climb fruit trees and tip over garbage cans and will even roll up newly laid turf to get at worms and grubs underneath. In addition, they invade crawl spaces and can destroy the insulation under houses, leaving large quantities of odorous feces. In some areas, they are important vectors of rabies and raccoon roundworm.

Management and controls

Exclusion is usually the most effective way to manage raccoon damage. Gardens can be protected with a two-strand electric fence. The first wire should be about 6 inches from the ground and the second wire 6 inches higher. Chain link and chicken-wire fences also work if a single strand of electrified wire is stretched along the top.

Other suggestions include:

- Sheet-metal rodent guards, as suggested for squirrels, can protect large fruit trees.
- In some situations, a radio left playing in the garden repels the pests until harvest, but this is usually only a temporary measure.
- A noisy dog patrolling the yard is usually an effective deterrent against raccoons and other vertebrate pests.
- For animals nesting under houses, find out where they are getting in and securely block the entrance when they

Figure 10.—Raccoon.

leave at night to forage. Be sure any young have left, too. A tracking patch at the entrance can indicate when the animals have emerged.
- To use a cage trap, check with the state game and fish department or animal control department for instructions and information about laws.

Raccoons are not protected.

Birds

Birds can cause problems in gardens by their roosting, nesting, and feeding habits, depending on the species. The most common culprits are crows, starlings, woodpeckers, pigeons, house ("English") sparrows, robins, and geese. Other species may be occasional pests (Figure 11).

Bird management can present special problems since most species are protected by law. However, there are many tools available for reducing damage.

Roosting and nesting damage

Where birds roost or nest there will be droppings. Bird droppings can damage machinery and stored feed and present possible disease hazards.

Roosting can be prevented by making the area uncomfortable for birds through the use of barriers. Solid, angled barriers or wire obstructions ("porcupine" wires and stretched wire) can prevent birds from using ledges as roosts. Wire obstructions also work well on building peaks.

"Bird glues" can also reduce roosting. Birds don't like getting these sticky materials on their feathers, so they usually avoid them. Glues must be reapplied occasionally and don't work well in dusty or wet conditions.

House sparrows, starlings, and swallows often try to nest in or on buildings. Bird netting, screens, and wire barriers can prevent these invasions. Try to close up any unnecessary openings.

Woodpeckers (Figure 11) can present special problems when they use a structure as a drumming station during courtship. Cedar siding is especially attractive and prone to damage. An infestation of carpenter ants or solitary bees can also lure woodpeckers to peck holes in wood siding. If carpenter ants are present, eliminate them.

Scare devices are sometimes useful in driving these birds away. Another method is to hang bird netting from the eaves so it dangles a few inches from the side of the structure.

Crop damage

Birds can cause extensive damage to all kinds of crops. Those most prone to damage include strawberries, cherries, apples, and grapes. The following methods can reduce damage:
- Bird netting is useful for protecting low-growing plants. Be sure the netting reaches the ground or is gathered around the trunk of the plant or birds will fly up underneath to attack.
- Various scare devices such as scarecrows, hanging flashers, flags, and balloons can reduce damage if they are moved about so birds do not become accustomed to them.

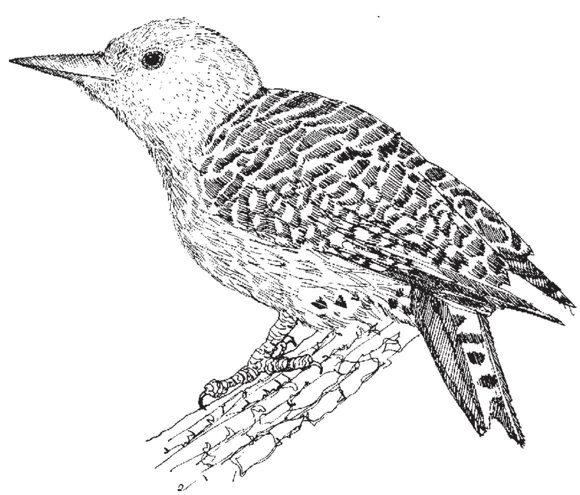


Figure 11.—Woodpecker.

- Sonic devices that broadcast alarm calls are useful for the particular species making the call but may not be appropriate if there are nearby neighbors. Ultrasonic and subsonic devices have not been proven effective on any pest species.
- The repellent methyl anthranilate was recently registered for home use on a variety of crops. This material is derived from grape skins and has reduced bird damage in test plots. Effectiveness in field situations varies.
- Trapping can be used only against nonprotected birds (house sparrows, domestic pigeons, and starlings) but can help reduce local populations of these species. Specific kinds of cage traps must be used to avoid harming protected species.

For more information

Prevention and Control of Wildlife Damage, volumes 1 and 2 (University of Nebraska Cooperative Extension, Great Plains Agricultural Council Wildlife Committee, USDA/APHIS/Animal Damage Control).

Vertebrate Pest Control, Leaflet 2976 (University of California Cooperative Extension). 15 pp.

Wyoming Game and Fish Department Regulations, http://gf.state.wy.us

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Glossary

Abscission (àb-sìzh´-en)—The dropping of leaves, flowers, or fruit by a plant. Can result from natural growth processes (e.g., fruit ripening) or from external factors such as temperature or chemicals.

Abscission layer—Specialized cells, usually at the base of a leaf stalk or fruit stem, that trigger both the separation of the leaf or fruit and the development of scar tissue to protect the plant.

Absorption—The intake of water and other materials through root or leaf cells.

Accumulated heat units—Number of hours in a growing season. Usually calculated at temperatures above 50°F, but can be calculated at other temperatures, depending on the crop. A day's heat units are calculated as:

$$\frac{\text{Max temp (°F)} + \text{Min temp (°F)}}{2} - 50\text{°F}$$

Daily values are totaled for the season. Values less than zero are ignored (but not deducted from the total).

Acid soil—Soil with pH below 7 on a pH scale of 1 to 14. The lower the pH, the more acid the soil. (See also pH.)

Active ingredient—The chemical in a pesticide formulation that actually kills the target pest.

Additive—A substance that, when added to a pesticide, reduces the surface tension between two unlike materials (e.g., spray droplets and a plant surface), thus improving adherence. Also called an adjuvant or surfactant.

Adjuvant (àj´-e-vent)—See Additive.

Adventitious (àd´-vèn-tìsh´-es)—Growth not ordinarily expected, usually the result of stress or injury. A plant's normal growth comes from meristematic tissue, but adventitious growth comes from nonmeristematic tissue.

Pronunciation guide

â	b**a**se	o	n**o**te
à	c**a**t	ò	p**o**nd
ä	p**a**pa	ô	**o**rgan
ê	m**e**	oo	t**oo**t
è	**e**nd	ù	b**u**lb
î	m**i**te	û	t**u**rn
ì	f**i**sh	e	muc**ou**s

Compiled by Mike Hammitt, master gardener, Cowlitz County, Washington State University; and Teresa Welch, publications editor, Oregon State University. Adapted for Wyoming by Karen L. Panter, Cooperative Extension Service horticulture specialist.

Adventitious bud—A bud in an unusual place on a plant, often on an internode. May be the result of injury. Suckers and water sprouts usually grow from adventitious buds.

Adventitious root—A root in an unusual place, often where a branch contacts soil or damp material. A plant cannot be reproduced from cuttings or layering unless adventitious roots develop.

Aeration—Mechanically loosening or puncturing soil to increase permeability to water and air.

Aerobic—Active in the presence of free oxygen.

After-ripening—The seed maturation process that must be completed before germination can occur.

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

Alkaline soil—Soil with pH above 7 on a pH scale of 1 to 14. The higher the reading, the more alkaline the soil. (See also pH.)

Allelopathy (à-lê-lòp´-e-thê)—The excretion by some plants of compounds from their leaves and/or roots that inhibit the growth of other plants.

Ammonium (NH_4^+)—A plant-available form of nitrogen contained in many fertilizers and generated in the soil by the breakdown of organic matter. (See also Nitrogen cycle.)

Anaerobic—Active in the absence of free oxygen.

Anion (àn´-î-en)—A negatively charged ion. Plant nutrient examples include nitrate (NO_3^-), phosphate ($H_2PO_4^-$), and sulfate (SO_4^{2-}). (See also Cation.)

Annual—A plant that completes its life cycle in one growing season.

Anther—The pollen-bearing part of a flower's male sexual organ. The filament supports the anther; together they are referred to as the stamen.

Anvil pruner—A pruning tool that cuts a branch between one sharpened blade and a flat, anvil-shaped piece of metal. Has a tendency to crush rather than make a smooth cut.

Apex—The tip of a stem or root.

Apical dominance (â´-pì-kel)—The inhibition of lateral bud growth by the presence of the hormone auxin in a plant's terminal bud. Removing the growing tip removes auxin and promotes lateral bud break and subsequent branching, usually directly below the cut.

Arboretum—An area devoted to specimen plantings of trees and shrubs.

Asexual propagation—See Vegetative propagation.

Aspect—Direction of exposure to sunlight.

Assimilation—Building of cell matter from inorganic and organic materials (carbohydrates and sugars).

Attractant—A material that lures pests.

Auxin (ôk´-sìn)—One of the best known and most important plant hormones. Most abundantly produced in a plant's actively growing tips. Generally stimulates growth by cell division in the tip region and by cell elongation lower down the shoot. Growth of lateral buds is strongly inhibited by the normal concentration of auxin in the growing tip.

Available water supply—Soil water that is available for plant uptake. Excludes water bound tightly to soil particles.

Axil (àk´-sìl)—The upper angle formed by a leaf's stalk (petiole) and the internodes above it on a stem.

Axillary bud—A bud that forms in an axil.

***Bacillus thuringiensis* (*Bt*)** (be-sìl´-es thûr-èn´-jê-èn´-sìs)—A bacterium used as a biological control agent for many insect pests.

Bacterium—A single-celled, microscopic organism having a cell wall but no chlorophyll. Reproduces by cell division.

Balled and burlapped (B&B)—A plant dug with soil. The root ball is enclosed with burlap or a synthetic material.

Band—To apply a pesticide or fertilizer in a strip over or along each crop row.

Bare-root (BR)—A plant with little or no soil around its roots; a common method of selling deciduous plants and small evergreens.

Basal (bâ´-sel, -zel)—(1) At or near the base of a branch or trunk. (2) At or near a plant's crown.

Basal break—New growth that develops at the base of a branch or near a plant's crown.

Beneficial insect—An insect that helps gardening efforts. May pollinate flowers, eat harmful insects or parasitize them, or break down plant material in the soil, thereby releasing its nutrients. Some insects are both harmful and beneficial. For example, butterflies can be pollinators in their adult form but destructive in their larval (caterpillar) form.

Berry—The fleshy fruit of cane fruits, bush fruits, and strawberries.

Biennial—A plant that germinates and produces foliage and roots during its first growing season, then produces flowers and seeds and usually dies during its second growing season.

Biennial bearing—Producing fruit in alternate years.

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

Blanch—To exclude light from plants or parts of plants to render them white or tender. Often done to cauliflower, endive, celery, and leeks.

Blight—Rapid, extensive discoloration, wilting, and death of plant tissue.

Blotch—A blot or spot (usually superficial and irregular in shape) on leaves, shoots, or fruit.

Bole—See Trunk.

Bolting—Producing seed or flowering prematurely, usually due to heat. For example, cool-weather crops such as lettuce bolt during summer. Leaf crops are discouraged from bolting by removal of flower heads. (See also Deadhead.)

Bonsai (bòn-sî´)—One of the fine arts of gardening; growing carefully trained, dwarfed plants in containers selected to harmonize with the plants. Branches are pruned and roots trimmed to create the desired effect.

Botanical insecticide—An insecticide, such as rotenone or pyrethrum, derived from a plant. Most botanicals biodegrade quickly. Most, but not all, have low toxicity to mammals.

Botrytis (bo-trî´-tìs)—A fungal disease promoted by cool, moist weather. Also known as gray mold or fruit rot.

Bract—A modified leaf, usually small, but sometimes large and brightly colored, growing at the base of a flower or on its stalk. Clearly seen on dogwoods and poinsettias.

Bramble—A spiny cane bush with berry fruits (e.g., raspberries and blackberries).

Branch—A subsidiary stem arising from a plant's main stem or from another branch.

Break—(1) Any new growth coming from a bud. (2) See Bud break.

Broadcast—(1) To sow seed by scattering it over the soil surface. (2) To apply a pesticide or fertilizer uniformly to an entire, specific area by scattering or spraying it.

Broadleaf evergreen—A non-needled evergreen.

BTU (British thermal unit)—Amount of heat required to raise the temperature of 1 pound of water 1°F.

Bud—A small protuberance on a stem or branch, sometimes enclosed in protective scales, containing an undeveloped shoot, leaf, or flower.

Bud break—The resumption of growth by resting buds.

Bud head—A swollen or enlarged area where a bud was grafted to a stock.

Bud scale—A modified leaf that forms a protective covering for a bud.

Bud sport—See Mutation.

Bud union—The suture line where a bud or scion was grafted to a stock. Sometimes called a graft union.

Budding—The grafting of a bud onto stock of a different plant. The bud is the scion.

Budstick—A shoot or twig used as a source of buds for budding.

Bulb—An underground storage organ consisting of a thin, flattened stem surrounded by layers of fleshy, dried leaf bases. Roots are attached to the bottom. (See also Corm, Tuber, Rhizome.)

Bulbil (bùl´-bel, -bìl´)**—**A small bulb-like organ that sometimes forms in place of flowers.

Bulblet—(1) An underground bulbil. (2) A tiny bulb produced at the base of a mother bulb.

Calcium carbonate ($CaCO_3$)—A compound found in limestone, ashes, bones, and shells; the primary component of lime.

Callus—Tissue that develops when cambium or other meristematic tissue is wounded.

Calorie—Amount of heat required to raise the temperature of 1 cubic centimeter of water 1°C.

Calyx (kā´-lìks, kàl´-ìks)**—**The collective term for the sepals (the cup, usually green, between a flower and its stem).

Cambium (kàm´-bē-em)**—**The living, growing layer of cells between the xylem and phloem. In woody plants, it is located just beneath the bark.

Candelabrum (kàn´dl-ä´-brem)**—**A strong, dominant rose cane with accelerated growth that originates from a bud union and explodes with many blooms.

Candle—On a pine tree, new terminal growth from which needles emerge.

Cane—The externally woody, internally pithy stem of a bramble or vine.

Canker—A localized lesion on a limb or trunk, usually due to disease or injury. Part of the bark or wood appears to be eaten away or is sunken.

Canopy—(1) The top branches and foliage of a plant. (2) The shape-producing structure of a tree or shrub.

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.

Capitulum (ke-pìch´-e-lem)**—**(1) A dense, short, compact cluster of sessile flowers, as in composite plants or clover. (2) A very dense grouping of flower buds, as in broccoli.

Caterpillar—See Larva.

Catfacing—Disfigurement or malformation of a fruit. Fruits typically affected include tomatoes and strawberries. Although not fully understood, catfacing is thought to be caused by insects or adverse weather during fruit development.

Cation (kàt´-ī-en)**—**A positively charged ion. Plant nutrient examples include calcium (Ca^{++}) and potassium (K^+). (See also Anion.)

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

Cell—The smallest structure in a plant.

Central leader—(1) A trunk or stem extending up through the axis of a tree or shrub and clearly emerging at the top. (2) A system of pruning that uses the central leader as a basic component. (See also Leader.)

Cercus (pl., cerci) (ser´-kes)—A threadlike or sometimes forceps-like tail near the tip of an insect's abdomen (usually a pair).

Chelate (kê´-lât)—A complex organic substance that holds micronutrients, usually iron, in a form available for absorption by plants.

Chlorophyll—The green pigment in plants. Responsible for trapping light energy for photosynthesis.

Chloroplast—A specialized component of certain cells. Contains chlorophyll and is responsible for photosynthesis.

Chlorosis (kle-ro´-sìs)—Yellowing of a leaf.

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

Climber—A plant that climbs on its own by twining or using gripping pads, tendrils, or some other method to attach itself to a structure or another plant. Plants that must be trained to a support are properly called trailing plants, not climbers.

Cloche—A plastic, glass, or plexiglass plant cover used to warm the growing environment and protect plants from frost.

Clone—A plant group whose members have all been derived from a single individual through constant propagation by vegetative (asexual) means, e.g., by buds, bulbs, grafts, cuttings, or laboratory tissue culture.

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

Cold composting—A slow composting process that involves 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.

Cold frame—A plastic-, glass-, or plexiglass-covered frame that relies on sunlight as a source of heat to warm the growing environment for tender plants.

Cole crops—A group of vegetables belonging to the cabbage family; plants of the genus *Brassica*, including cauliflower, broccoli, cabbage, turnips, and brussels sprouts.

Coleoptera (ko´lê-òp´-ter-e)—An insect family made up of species having horny front wings that fit over their hindwings. Includes beetles and weevils.

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. (See also Shoulder ring.)

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

Companion planting—The practice of growing two or more types of plants together in the hope that the combination will discourage disease and insect pests.

Compatible—Different varieties or species that set fruit when cross-pollinated or make a successful graft union when intergrafted. (See also Pollenizer.)

Complete metamorphosis—A type of insect development in which the insect passes through the stages of egg, larva, pupa, and adult. The larva usually is different in form from the adult. (See also Simple metamorphosis.)

Compost—The product created by the breakdown of organic waste under conditions manipulated by humans. Used to improve both the texture and fertility of garden soil. (See also Humus.)

Compound bud—More than one bud on the same side of a node. Usually, unless growth is extremely vigorous, only one of the buds develops, and its branch may have a very sharp angle of attachment. If it is removed, a wider angled shoot usually is formed from the second (accessory) bud. Ashes and walnuts are examples of plants that typically have compound buds.

Conifer—A cone-bearing tree or shrub, usually evergreen. Pine, spruce, fir, cedar, yew, and juniper are examples.

Conk—A fungal fruiting structure (e.g., shelf or bracket fungi) formed on rotting woody plants.

Contact pesticide—A pesticide that kills on contact.

Cordon (kôr´-den)—(1) A method of espaliering fruit trees, vines, etc. to horizontal, vertical, or angled wire or wooden supports so maximum branch surface is exposed to the sun, resulting in maximum fruit production. (2) A branch attached to such a support.

Corm—An underground storage organ consisting of the swollen base of a stem with roots attached to the underside. Crocus and gladiolus are examples of plants that form corms. (See also Bulb, Tuber, Rhizome.)

Cormel (kôr´-mel)—A small, underdeveloped corm, usually attached to a larger corm. (See also Bulbil, Bulblet.)

Cornicle—A short, blunt horn or tube (sometimes button-like) on the top and near the end of an aphid's abdomen. Emits a waxy liquid that helps protect against enemies.

Corolla (ke-ròl´-e)—Collectively, all of a flower's petals.

Cortex—Cells that make up the primary tissue of roots or stems.

Corymb (kôr´-ìmb)—A usually flat-topped flower cluster in which the individual flower stalks grow upward from various points on the main stem to approximately the same level.

Cotyledon (kòt´l-êd´-n)—A seed leaf; the first leaf from a sprouting seed. Monocots have one cotyledon; dicots have two.

Cover crop—A crop dug into the soil to return valuable organic matter and nitrogen to the soil. Legumes such as clover, cowpeas, and vetch are common cover crops. Also called green manure.

Cross-pollination—The fertilization of an ovary on one plant with pollen from another plant, producing an offspring with a genetic makeup distinct from that of either parent. (See also Pollenizer.)

Crotch angle—The angle formed between a trunk and a main scaffold limb. The strongest angle is 45° to 60°.

Crown—(1) Collectively, the branches and foliage of a tree or shrub. (2) The thickened base of a plant's stem or trunk to which the roots are attached.

Cultivar—A specially cultivated variety of a plant that most often is reproduced vegetatively. For example, 'Transparent' is a cultivar of apple. (See also Variety.)

Cuticle—(1) A relatively impermeable surface layer on the epidermis of leaves and fruits. (2) The outer layer of an insect's body.

Cutin (kyoot´-en)—(1) A waxy substance on plant surfaces that tends to make the surface waterproof and can protect leaves from dehydration and disease. (2) A waxy substance on an insect's cuticle that protects the insect from dehydration.

Cutting—A piece of leaf, stem, or root removed from a plant and prompted to develop into a new plant that is genetically identical to the parent plant.

Cyme (sîm)—A flower stalk on which the florets start blooming from the top of the stem and progress toward the bottom.

Cyst—The swollen, egg-containing female body of certain nematodes. Can be seen on the outside of infected roots.

Damping-off—A disease caused by many different organisms. In the most conspicuous cases, a seedling's stem collapses at or near the soil surface, and the seedling topples. Another type rots seedlings before they emerge from the soil or causes seeds to decay before germinating.

Day-neutral plant—A species capable of flowering without regard to day length. (See also Short-day plant, Long-day plant.)

Deadhead—To remove individual, spent flowers from a plant for the purpose of preventing senescence and prolonging blooming. For effective results, the ovary behind the flower must be removed as well.

Deciduous (dì-sìj´-oo-es)—A plant that sheds all of its leaves annually.

Decomposition—The breakdown of organic materials by microorganisms.

Defoliation (dê-fo´-lê-â-shen)—The unnatural loss of a plant's leaves, generally to the detriment of its health. Can be caused by high wind, excess heat, drought, frost, chemicals, insects, or disease.

Dehorning—A drastic method of pruning a neglected tree or shrub. Entails the removal of large branches, especially high in the crown, a few at a time over several seasons.

Dermaptera (der-màp´-ter-e)—An insect family made up of species having chewing mouthparts and a pair of large, forceps-like appendages near the tail. Wingless or with one or two pairs of inconspicuous wings. Earwigs are an example.

Desiccation—Drying out of tissue.

Determinate—A plant growth habit in which stems stop growing at a certain height and produce a flower cluster at the tip. Determinate tomatoes, for example, are short, early-fruiting, have concentrated fruit set, and do not require staking. (See also Indeterminate.)

Dethatch—To remove thatch (a tightly intermingled layer of stems, leaves, and roots, living and dead, that forms between the soil surface and green vegetation of grass).

Diatomaceous earth (dî-et-e-mâ´-shes)—The fossilized remains of diatoms (a type of tiny algae) used to kill insect pests, snails, and slugs.

Dicotyledon, dicot (dî´kòt´l-êd´-n)—A plant having two cotyledons (seed leaves).

Dieback—Progressive death of shoots, branches, or roots, generally starting at the tips.

Differentiation—A change in composition, structure, and function of cells and tissues during growth.

Dioecious (dî-ê´-shes)—A plant species having male and female flowers on separate plants. An example is holly. For female holly to produce berries, a male holly must be in the vicinity to provide pollen. (See also Monoecious.)

Disbud—The selective removal of some flower buds so remaining buds receive more of the plant's energy and produce larger, showier flowers. Roses, chrysanthemums, and camellias often are disbudded.

Division—The breaking or cutting apart of a plant's crown for the purpose of producing additional plants, all genetically identical to the parent plant.

Dormancy—The annual period when a plant's growth processes greatly slow down.

Dormant—Resting or not growing. A deciduous tree is dormant in the winter.

Dormant bud—A bud formed during a growing season that remains at rest during the following winter or dry season. If it does not expand during the following growing season, it is termed latent.

Dormant oil—A horticultural oil applied during the dormant season to control insect pests and diseases.

Double, semidouble—A flower with more than the normal number of petals, sepals, bracts, or florets. May be designated botanically by the terms flore pleno, plena, or pleniflora.

Double worked—Grafted twice, i.e., grafted to an intermediate stock.

Drainage—The ability of soil to transmit water through the surface and subsoil.

Dripline—An imaginary line on the ground directly beneath the outermost tips of a plant's foliage. Rain tends to drip from leaves onto this line.

Drip zone—The area from the trunk of a tree or shrub to the edge of its canopy. Most, but not all, of a plant's feeder roots are located within this area.

Drupe fruit—See Stone fruit.

Dwarfed—Restricted plant size without loss of health and vigor.

Ecology—The science of relationships between organisms and their environment.

Economic threshold—The level at which pest damage justifies the cost of control. In home gardening, the threshold may be aesthetic rather than economic.

Emasculate (ĭ-màs´-kye-lât)**—**To remove a flower's anthers.

Embryo—The dormant, immature plant within a seed; the "germ" referred to in wheat germ.

Embryo culture—See Tissue culture.

Enation (en-â´-shen)**—**Epidermal outgrowths on leaves or stems.

Endosperm (èn´-de-spûrm´)**—**The nutritive tissue within the seed of a flowering plant. Surrounds and is absorbed by the embryo.

Enzyme—A biological catalyst that aids in conversion of food from one form to another.

Epidermis (èp-ì-dûr´-mìs)**—**The outermost layer of cells covering a plant's leaves, roots, and young parts.

Epinasty (èp´-ì-nàs-tê)**—**An abnormal downward-curving growth or movement of a leaf, leaf part, or stem.

Espalier (ĭ-spàl´-yer)**—**The training of a tree or shrub to grow flat on a trellis or wall. Espalier patterns may be very precise and formal or more natural and informal.

Etiolation (êt´-ê-e-lâ´-shen)**—**Development of yellow, long, spindly growth on a plant as a result of insufficient light.

Evergreen—A plant that never loses all of its foliage at the same time.

Excise—To remove or extract, as an embryo from a seed or ovule.

Excurrent—A tree form in which the main trunk remains dominant with small, more or less horizontal branches. Fir and sweetgum are examples.

Exfoliating—Peeling off in shreds or thin layers, as in bark from a tree.

Exoskeleton—The outer support structure of an insect.

Exotic—Non-native.

Fallow—To keep part of a garden unplanted or in a cover crop during the growing season.

Family—A broad group of plants with common characteristics.

Fasciation (fàs´-ê-â´-shen)—Distortion of a plant that results in thin, flattened, and sometimes curved shoots.

Feeder roots—Fine roots and root branches with a large absorbing area (root hairs). Responsible for taking up the majority of a plant's water and nutrients from the soil.

Fertility (soil)—The presence of minerals necessary for plant life.

Fertilization—(1) The fusion of male and female germ cells following pollination. (2) The addition of plant nutrients to the environment around a plant.

Fertilizer—A natural or synthetic product added to the soil or sprayed on plants 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.

Fibrous root—A root system that branches in all directions, often directly from the plant's crown, rather than branching in a hierarchical fashion from a central root. (See also Taproot.)

Filament—The stalk supporting a flower's anthers.

Flagging—Loss of turgor and drooping of plant parts, usually as a result of water stress.

Floricane—Second-year growth of caneberries. Produces fruit on laterals.

Foliar fertilization, foliar feeding—Fertilization of a plant by applying diluted soluble fertilizer, such as fish emulsion or kelp, directly to the leaves.

Force—To bring a plant into early growth, generally by raising the temperature or transplanting it to a warmer situation. Tulips and paperwhites are examples of plants that often are forced.

Form—(1) A naturally occurring characteristic different from other plants in the same population. (2) The growth habit (shape) of a plant.

Formal—(1) A garden that is laid out in precise symmetrical patterns. (2) A flower, such as some camellias, that consists of layers of regularly overlapping petals.

Frond—Specifically, the foliage of ferns, but often applied to any foliage that looks fern-like, such as palm leaves.

Fruit—The edible portion of a plant that is closely associated with a flower. Botanically, a fruit is a ripened, mature ovary.

Fruiting habit—The location and manner in which fruit is borne on woody plants.

Fungicide—Any material capable of killing fungi. Sulfur and copper sulfate are two common mineral fungicides.

Fungus—A plant organism that lacks chlorophyll, reproduces via spores, and usually has filamentous growth. Examples are molds, yeasts, and mushrooms.

Gall—A growth on plant stems or leaves caused by abnormal cell growth stimulated by the sucking of some insects (e.g., aphids) or by viral, fungal, or bacterial infection.

Genus—A group of related species, each of which is distinct and unlikely to cross with any other. A group of genera forms a family, and a group of families forms an order. (See also Species.)

Geotropism (jê-ò´-tre-pìz´-em)—The turning or curving of a plant's parts in response to gravity. A root growing downward is an example. Geotropism is controlled largely by the hormone auxin.

Germination—The initial sprouting stage of a seed.

Girdling—The cutting, removing, or clamping of bark all the way around a trunk or branch. Sometimes, girdling is done deliberately to kill an unwanted tree, but often it results from feeding by insects or rodents. Wires and ties used to support a tree can cause girdling, as can string trimmers.

Glabrous (glâ´-bres)—Hairless, but not necessarily smooth.

Glaucous (glô´-kes)—Covered with a grayish, bluish, or whitish waxy coating that is easily rubbed off. Blue spruce needles are an example of glaucous leaves.

Gradual metamorphosis—See Simple metamorphosis.

Graft union—See Bud union.

Grafting—The act of inserting a shoot or bud of one plant into the trunk, branch, or roots of another, where it grows and becomes a permanent part of the plant.

Gravitational water—Water in excess of a soil's capacity. Drains downward to groundwater.

Green cone—An enclosed composting unit often used for composting food waste.

Green manure—See Cover crop.

Groundcover—Plants used in lieu of grass for holding soil and providing leaf texture.

Growing season—The period between the beginning of growth in the spring and the cessation of growth in the fall.

Growth regulator—A compound applied to a plant to alter its growth in a specific way. May be a natural or synthetic substance. (See also Hormone.)

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

Haltere (hòl´-tìr)—A small, knob-like organ (sometimes shaped like a baseball bat or bowling pin) located on the thorax of insects of the order Diptera. Takes the place of hindwings and helps balance the insect in flight.

Hardening off—The process of gradually exposing seedlings started indoors to outdoor conditions before transplanting.

Hardpan—An impervious layer of soil or rock that prevents root growth and downward drainage of water.

Hardy—Frost- or freeze-tolerant. In horticulture, this term does not mean tough or resistant to insect pests or disease.

Haustorium (hò-stôr´-ê-em)—A modified hyphal branch of a parasitic plant. Grows into a host plant's cell to absorb food and water.

Head—(1) To cut off part of a shoot or limb rather than removing it completely at a branch point. (2) The part of a tree from which the main scaffold limbs originate.

Heartwood—The center cylinder of xylem tissue in a woody stem.

Heeling in—The temporary burying of a newly dug plant's roots to prevent their drying until a new planting site is prepared. Nurseries heel in bare-root berries, trees, and shrubs.

Hemiptera (hì-mìp´-ter-e)—An insect family made up of species generally having sucking mouthparts and four wings. Wings are thick at the base and membranous at the free end. Includes true bugs, stink bugs, assassin bugs, and back swimmers.

Herbaceous (hûr-bâ´-shes)—A soft, pliable, usually barkless shoot or plant. Distinct from stiff, woody growth.

Herbaceous perennial—A plant that dies back in the winter and regrows from the crown in spring.

Herbicide—A chemical used to kill undesirable plants.

Heterozygous (hèt´-er-o-zī´-ges)—Having mixed hereditary factors, not a pure line.

Homoptera (ho-mòp´-ter-e)—An insect family made up of species having sucking mouthparts and usually two pairs of wings. Includes aphids, scales, leafhoppers, and cicadas.

Homozygous (hom´-o-zī´-ges)—Having purity of type, a pure line.

Honeydew—A sticky substance excreted by aphids and some other insects.

Hormone—A naturally occurring compound that alters plant growth in a specific manner. (See also Growth regulator.)

Horticultural oil—An oil made from petroleum products, vegetable oil, or fish oil, used to control insect pests and diseases. Oils work by smothering insects and their eggs and by protectively coating buds against pathogen entry.

Horticulture—The branch of the science of agriculture that relates to cultivating gardens or orchards, including the growing of vegetables, fruits, flowers, and ornamental shrubs and trees.

Host—A plant on which an insect or disease completes all or part of its life cycle.

Hot composting—A fast composting process that produces finished compost in 6 to 8 weeks. High temperatures are maintained by mixing balanced volumes of energy materials and bulking agents, by keeping the pile moist, and by turning it frequently to keep it aerated.

Hotbed—An enclosed bed for propagating or protecting plants. Has a source of heat to supplement solar energy.

Humus—The end product of decomposed animal or vegetable matter. (See also Compost.)

Hybrid—A cross between two varieties or species, whether of the same genus or two genera.

Hydroponics—A method of growing plants without soil. Plants usually are suspended in water or polymers, and plant nutrients are supplied in dilute solutions.

Hymenoptera (hì´-me-nòp´-ter-e)—An insect family made up of species having four membranous wings, of which the front pair are larger. Includes bees, wasps, sawflies, and ants.

Hypha—A single filament of a fungus.

Hypocotyl (hī´-pe-kät´-el)—The first leaf-like structure that appears on a germinating seed. Grows upward in response to light.

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.

Immune—A plant that does not become diseased by a specific pathogen. (See also Resistant, Tolerant.)

Incompatible—Kinds or varieties of a species that do not successfully cross-pollinate or intergraft.

Incomplete metamorphosis—See Simple metamorphosis.

Incubation—A period of development during which a pathogen changes to a form that can penetrate or infect a new host plant.

Indeterminate—A plant growth habit in which stems keep growing in length indefinitely. For example, indeterminate tomatoes are tall, late-fruiting, and require staking for improved yield. (See also Determinate.)

Infection—The condition reached when a pathogen has invaded plant tissue and established a parasitic relationship between itself and its host.

Infiltration—The movement of water into soil.

Inflorescence collective (ĭn´-fle-rès´-ens)—A group of individual flowers. The grouping can take many forms, such as a spike (flowers closely packed along a vertical stem, e.g., snapdragons), an umbel or corymb (flowers forming a flattened dome, e.g., yarrow), a panicle (a complex hierarchical arrangement of flowers, e.g., hydrangeas), or a capitulum (tightly packed disc flowers, e.g., the center of a daisy).

Inoculation—The introduction of a pathogen to a host plant's tissue.

Inoculum—The parts of a pathogen that infect plants.

Insectary plant (ĭn-sèk´-te-rê)**—**A plant that attracts beneficial insects.

Insecticidal soap—A specially formulated soap that is only minimally damaging to plants, but kills insects. Usually works by causing an insect's outer shell to crack, resulting in drying out of its interior organs.

Insecticide—Any material that kills insects. Includes numerous botanical, mineral, and chemical products, both organic and synthetic.

Instar—The stage of an insect's life between molts.

Integrated pest management—A method of managing pests that combines cultural, biological, mechanical, and chemical controls, while taking into account the impact of control methods on the environment.

Intensive gardening—The practice of maximizing use of garden space, for example by using trellises, intercropping, succession planting, and raised beds.

Intercropping, interplanting—The practice of mixing plants to break up pure stands of a single crop.

Internode, interstem—The portion of a stem between two nodes.

Interstem, interstock—The middle piece of a graft combination made up of more than two parts, i.e., the piece between the scion and the rootstock. Often has a dwarfing effect.

Invasive—Growing vigorously and outcompeting other plants in the same area; difficult to control.

Ion—An atom or molecule with either positive or negative charges. (See also Anion, Cation.)

Isoptera (ī-sòp´-ter-e)**—**An insect family made up of species having soft bodies, strong mandibles, and well-developed claws. Workers and soldiers are wingless and sterile. Termites are an example.

Joint—A node; the place on a stem where a bud, leaf, or branch forms.

Juvenile stage—(1) The early or vegetative phase of plant growth characterized by carbohydrate utilization. (2) The first stage of an insect's life cycle, either a larva or a nymph.

K—See Potassium.

Key—A tool for plant or animal classification and identification. Consists of a series of paired statements that move from general to specific descriptions.

Knot garden—A formal garden in which two or more kinds of plants with different-colored foliage, often herbs, are planted and pruned so they interweave and form a knot pattern.

Larva—The immature form of an insect that undergoes complete metamorphosis. Different from the adult in form. Also called caterpillar.

Latent bud—A bud that does not break during the season after it is formed. Usually found on the lower portion of a shoot, it does not expand under normal growth stimuli. It will be stimulated into breaking if the growth above it is damaged or pruned away.

Lateral—A branch attached to and subordinate to another branch or trunk.

Lateral bud—A bud on the side, rather than the tip, of a stem.

Layering—A method of stimulating adventitious roots to form on a stem. There are two primary methods of layering. In ground layering, a low-growing branch is bent to the ground and covered by soil. In air layering, moist rooting medium is wrapped around a node on an aboveground stem.

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

Leader—A developing stem or trunk that is longer and more vigorous than laterals. (See also Central leader.)

Leaf scar—A visible, thickened crescent or line on a stem where a leaf was attached.

Leaflet—A single division of a compound leaf.

Lenticel (lènt´-e-sèl)—A small opening on the surface of fruits, stems, and roots that allows exchange of gases between internal tissues and the atmosphere.

Lepidoptera (lèp´-ì-dòp´-ter-e)—An insect family made up of species having four wings covered with minute scales. Members undergo complete metamorphosis through the egg, larva, pupa, and adult stages. Includes butterflies and moths.

Lime—A rock powder consisting primarily of calcium carbonate. Used to raise soil pH (decrease acidity).

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

Lodge—To fall over, usually due to rain or wind. Corn and tall grasses are examples of plants susceptible to lodging.

Long-day plant—A plant requiring more than 12 hours of continuous daylight to stimulate a change in growth, e.g., a shift from the vegetative to reproductive phase. (See also Short-day plant, Day-neutral plant.)

Macronutrient—Collectively, primary and secondary nutrients.

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

Mandible—The first pair of jaws on insects: stout and tooth-like in chewing insects, needle- or sword-shaped in sucking insects; the lateral (left and right) upper jaws of biting insects.

Maturity—Ripeness, usually the state of development that results in maximum quality.

Meristem (mèr´-e-stèm)—Plant tissue in the process of formation; vegetative cells in a state of active division and growth, e.g., those at the apex of growing stems and roots.

Mesophyll (mèz´-e-fìl´)—A leaf's inner tissue, located between the upper and lower epidermis, where raw materials (carbon dioxide and water vapor) are held for use in photosynthesis.

Metamorphosis—The process by which an insect develops. (See also Complete metamorphosis, Simple metamorphosis.)

Microclimate—The climate of a small area within a larger climate area. For example, a backyard can have a climate different from that of the surrounding neighborhood, or there may be climate differences within a backyard. Microclimates can influence plant growth and should be considered in plant selection and care.

Micronutrient—A nutrient used by plants in small amounts, less than 1 part per million (boron, chlorine, copper, iron, manganese, molybdenum, and zinc). 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.

Modified central leader, modified leader—A system of pruning used primarily on fruit trees. The central leader is encouraged for the first few years, then suppressed. This system allows for well-placed scaffolds and strong crotches, but keeps the tree's crown relatively close to the ground for easy harvesting.

Molt—The shedding of skin during insect growth. The form assumed between molts is called an instar.

Monocotyledon, monocot (mòn´e-kòt´l-êd´-n)—A plant having one cotyledon (seed leaf).

Monoecious (me-nê´-shes)—A species having both male and female flowers on the same plant. Pecans, avocados, and squash are examples of monoecious plants. (See also Dioecious.)

Morphology (môr-fòl´-e-jê)—The study of the form of plants or plant parts.

Mosaic—Nonuniform foliage coloration with a more or less distinct intermingling of normal green and light green or yellowish patches.

Mottle—An irregular pattern of light and dark areas.

Mulch—Any material placed on the soil surface to conserve soil moisture, moderate soil temperature, and/or control weeds. Wood chips, bark chips, and shredded leaves are examples; inorganic materials such as rocks or newspapers also are used.

Mutation—A genetic change within an organism or its parts that changes its characteristics. Also called a bud sport or sport.

Mycelia (mî-sê´-lê-e)—Masses of fungal threads (hyphae) that make up the vegetative body of a fungus.

Mycology (mì-kòl´-e-jê)—The study of fungi.

Mycoplasma—See Phytoplasma.

Mycorrhizae (mî-ke-rî´-zê)—Beneficial fungi that infect plant roots and increase their ability to take up nutrients from the soil.

N—See Nitrogen.

Native plant—A plant indigenous to a specific habitat or area.

Naturalize—(1) To design a garden with the aim of creating a natural scene. Planting generally is done randomly, and space is left for plants to spread at will. (2) The process whereby plants spread and fill in naturally.

Necrosis (ne-kro´-sìs)—Tissue death.

Nematocide (nì-màt´-e-sîd)—A material that kills or protects against nematodes.

Nematode—A microscopic roundworm, usually living in the soil. Many feed on plant roots and can be disease pathogens or vectors. Others are beneficial parasites of insect pests.

Nitrate (NO_3^-)—A plant-available form of nitrogen contained in many fertilizers and generated in the soil by the breakdown of organic matter. Excess nitrate in soil can leach to groundwater. (See also Nitrogen cycle.)

Nitrifier—A microbe that converts ammonium to nitrate.

Nitrogen (N)—A primary plant nutrient, especially important for foliage and stem growth.

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 living on the roots of legumes.

Node—The point on a plant where a branch, bud, or leaf develops. On younger branches, it usually is marked by a slight swelling. The space on the stem between nodes is an internode.

Nonpoint source—A relatively small, nonspecific source of pollutants that, when added to other sources, may pose a significant threat to the environment. (See also Point source.)

Nonselective pesticide—A pesticide that kills most plants or animals.

N-P-K—Acronym for the three major plant nutrients contained in manure, compost, and fertilizers. N stands for nitrogen, P for phosphorus, and K for potassium.

Nucleus—The organelle within a cell that contains chromosomes and thus controls various cellular processes, including division into new cells.

Nutrient—Any substance, especially in the soil, that is essential for and promotes plant growth. (See also Macronutrient, Micronutrient.)

Nymph—The immature stage of an insect that undergoes simple metamorphosis. Usually similar in form to the adult.

Offset—A new shoot that forms at the base of a plant or in a leaf axil.

Oil—See Horticultural oil.

Open-pollinated seed—Seed produced from natural, random pollination so that the resulting plants are varied.

Organelle (ôr´ge-nèl´)**—**A structure within a cell, such as a chloroplast, that performs a specific function.

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

Organic matter—Any material originating from a living organism (peat moss, plant residue, compost, ground bark, manure, etc.).

Ornamental plant—A plant grown for beautification, screening, accent, specimen, color, or other aesthetic reasons.

Orthoptera (ôr-thòp´-ter-e)**—**An insect family made up of species having a tough, leathery shell, membranous hindwings, and straight forewings. Includes locusts, crickets, grasshoppers, and katydids.

Osmosis (äs-mo´-ses)**—**Passage of materials through a membrane from an area of high concentration to an area of lower concentration.

Ovary—The part of a flower containing ovules that will develop into seeds upon fertilization. Along with the style and stigma, it makes up the pistil (female sexual organ).

Ovule—Within the ovary, a body that will develop into seed after fertilization.

Oxidation—The chemical process by which sugars and starches are converted to energy. In plants, known as respiration.

P—See Phosphorus.

Palisade mesophyll (mèz´-e-fil´)**—**The cells just beneath a leaf's upper epidermis that contain most of the leaf's chlorophyll and are responsible for most photosynthesis.

Palmate (pàl´-mât´)**—**(1) A leaf whose veins radiate outward from a single point somewhat like the fingers of a hand. (2) A form of espalier training.

Parasite—Any animal or plant that lives in or on another animal or plant and withdraws nutrients from its host.

Parasitic seed plant—A plant that lives parasitically on other seed plants. An example is mistletoe.

Parterre (pär-târ´)**—**A formal garden in which shrubs, flowers, and paths form a geometric pattern of matched pairs.

Parthenocarpic (pär´-the-no-kär´-pìk)**—**Development of fruit without fertilization.

Pathogen—Any organism that causes disease. Generally applied to bacteria, viruses, fungi, nematodes, and parasitic plants.

Pathology—The study of diseases.

Ped—A cluster of individual soil particles.

Pedicel (pèd´-ì-sel)**—**The stem of an individual flower.

Peduncle (pì-dùng´-kel)—The main stem supporting a cluster of flowers (as opposed to a pedicel, which is the stem of an individual flower).

Pendulous—More or less hanging or declined.

Perennial—A plant that lives 2 or more years and produces new foliage, flowers, and seeds each growing season.

Perianth (pèr´-ê-ànth´)—Collectively, all external flower parts.

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

Persistent—(1) Adhering to a position instead of falling, whether dead or alive, e.g., flowers or leaves. (2) A pesticide that retains its chemical properties in the soil for a long time.

Petals—The usually showy structures around a flower's reproductive organs.

Petiole (pèt´-ê-ol´)—The stalk of a leaf.

pH —A measure of acidity or alkalinity. The scale is logarithmic; a change in 1 pH unit is a 10-fold change. Values from 0 to 7 indicate acidity, and values from 7 to 14 indicate alkalinity. For example, 7 is neutral, 6 is acid (10 times the hydrogen ion concentration of pH 7), and 5 is very strongly acid (100 times the hydrogen ion concentration of pH 7).

Phenological stage (fê-ne-lò´-jì-kel)—Crop development stage.

Pheromone (fèr´-e-mon)—A vapor or liquid emitted by an insect that causes a specific response from a receiving insect. Some pheromones are used to find a mate. Synthetic pheromones are used as attractants in insect traps.

Phloem (flo´-èm´)—Photosynthate-conducting tissue. (See also Xylem.)

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

Phosphorus (P)—A primary plant nutrient, especially important for flower production. In fertilizer, usually expressed as phosphate (P_2O_5).

Photoperiod—The amount of time a plant is exposed to light.

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

Photosynthesis (fo´to-sìn´-thì-sìs)—The process in green plants of converting water and carbon dioxide into sugar using energy from sunlight.

Phototropism (fo-tòt´-re-pìz´-em)—A growth response to light. Growth of a plant toward a light source is the most common example.

Phytoplasma (fît´-o-plaz´-me)—A microscopic, bacteria-like organism that lacks a cell wall. Previously called mycoplasma.

Phytotoxic—Toxic to a plant (phyto = plant).

Picotee (pìk´e-tê´)—A pattern of flower petal coloration in which the edges of the petal are a contrasting color to the body.

Pinch—To remove a growing tip from a stem, thus causing axillary shoots or buds to develop. (See also Deadhead, Shear.)

Pistil (pìs´-tel)—The female sexual organ of a flowering plant, made up of the stigma, style, and ovary.

Plant growth regulator—See Growth regulator.

Plant nutrition—A plant's need for and use of basic chemical elements. (See also Macronutrient, Micronutrient.)

Pleach—To intertwine branches of trees, vines, or shrubs to form an arbor or hedge.

Pleniflora, pleno, plena—A term used in botanical names to indicate a double-flowered variety. (See also Double.)

Point source—A single, identifiable source of pollutants such as a factory or municipal sewage system. (See also Nonpoint source.)

Pollard—A method of tree pruning that involves heading back severely to main branches each year so as to produce a thick, close growth of young branches.

Pollen—A plant's male sex cells, which are held on the anther for transfer to a stigma by insects, wind, or some other mechanism.

Pollenizer—A plant whose pollen sets fruit on another plant. (See also Cross-pollination.)

Pollination—The transfer of pollen from a male anther to a female stigma, enabling fruits to set and develop.

Pollinator—An agent such as an insect that transfers pollen from a male anther to a female stigma.

Pome fruit—A fruit having a core, such as an apple, pear, or quince.

Pomology (po-mòl´-e-jê)—The science of fruits and the art of fruit culture, especially tree fruits.

Postemergent—A product applied after crops or weeds emerge from the soil.

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

Potassium (K)—A primary plant nutrient, especially important for developing strong roots and stems. In fertilizers, usually expressed as potash (K_20).

Predator—An animal that eats another animal.

Preemergent—A product applied before crops or weeds emerge from the soil.

Preharvest interval—The period of time that must pass from the time a pesticide is applied to a crop until the crop is safe to pick and use.

Preplant—A product applied before a crop is planted.

Prickle—A rigid, straight, or hooked outgrowth of bark or stems. Often called a thorn, but technically different. Roses are examples of plants with prickles. (See also Thorn.)

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

Primocane—First-year growth, usually vegetative, on caneberries. Only fall-bearing raspberries produce fruit on primocanes in late summer.

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

Propagate—To start new plants by seeding, budding, grafting, dividing, etc.

Prune—To remove plant parts to improve a plant's health, appearance, or productivity.

Pseudobulb (soo´-do-bùlb´)—A thickened, aboveground, modified stem that serves as a storage organ. Found in some orchids.

Pubescent (pyoo-bès´-ent)**—**Hairy.

Pupa—The stage between larva and adult in insects that go through complete metamorphosis.

Quarantine—A regulation forbidding sale or shipment of plants or plant parts, usually to prevent disease, insect, nematode, or weed invasion of an area.

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

Raceme (râ-sêm´)—A flower stalk on which the florets start blooming from the bottom of the stem and progress toward the top.

Radial spacing—The horizontal spacing of branches around a trunk.

Radicle—The first part of a seedling to emerge from the seed. Grows downward and develops into the primary root.

Relative humidity—The ratio of water vapor in the air to the amount of water the air could hold at the current temperature and pressure.

Resistant—A plant having qualities that make it retard the activities of a pathogen or insect pest. (See also Immune, Tolerant.)

Respiration—The process within plants of converting sugars and starches into energy. (See also Oxidation.)

Reversion growth—A stem that originates from and has the characteristics of the plant's rootstock. (See also Sucker.)

***Rhizobia* bacteria** (rî-zo´-bê-e)—Bacteria that live in association with roots of legumes and convert atmospheric nitrogen to plant-available forms, a process known as nitrogen fixation.

Rhizome (rî´-zom´)—A thickened underground stem that grows horizontally with bud eyes on top and roots below. Bearded iris is an example of a plant that produces rhizomes.

Rhizosphere (rî´-ze-sfîr´)—The thin layer of soil immediately surrounding plant roots.

Root cutting—A section of root prepared for the purpose of vegetative propagation.

Root hair—A delicate, elongated epidermal cell that occurs just behind a root's growing tip. Root hairs increase the root's surface area and absorptive capacity.

Root pruning—The cutting or removal of some of a plant's roots.

Root sucker—See Sucker.

Root-bound—A condition in which a plant's roots have completely filled its container. Typically, the roots begin to encircle the pot's outer edge. Further growth is prevented until the plant is removed from the container.

Rootstock—The root or stem onto which a scion or interstock is grafted.

Rosette—A small cluster of leaves radially arranged in an overlapping pattern.

Rot—Decomposition and destruction of tissue.

Rotation—The practice of growing different plants in different locations each year to prevent the buildup of soilborne diseases and insect pests.

Row cover—A sheet of synthetic material used to cover plants in order to retain heat and exclude insect pests.

Rugose (roo´-gos)—Wrinkled.

Runner—See Stolon.

Russet—Yellowish-brown or reddish-brown scar tissue on a fruit's surface.

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

Sanitation—The process of removing sources of plant pathogens from a growing area, for example, by cleaning up plant debris and sterilizing tools and growing media.

Scab—(1) A crust-like disease lesion. (2) A specific disease that causes scab lesions.

Scaffold, scaffold branches—The principal branches of a tree or shrub arising from the trunk or another main branch to form the plant's framework.

Scale—(1) A modified leaf that protects a bud. (2) A type of insect pest.

Scarification (skàr´-e-fî-kâ´-shen)—Nicking, sanding, or otherwise compromising the hard outer coating of a seed to increase its water intake and thus promote germination. Sometimes incorrectly called scarfing.

Scion—A cutting or bud that is grafted to the stock of another plant.

Secondary nutrient—A nutrient needed by plants in a moderate amount: calcium, magnesium, and sulfur. (See also Macronutrient, Primary nutrient.)

Seed coat—A hard outer covering that protects a seed from disease and insects. Also prevents water from entering the seed and initiating germination before the proper time.

Seed leaf—See Cotyledon.

Selective pesticide—A pesticide that kills only certain kinds of plants or animals; for example, 2,4-D kills broadleaf lawn weeds but leaves grass largely unharmed.

Self-fruitful—A plant that bears fruit through self-pollination.

Self-unfruitful—A plant that requires another variety for pollination. (See also Pollenizer.)

Senescence (sì-nès´-ens)—The aging process. Also used to describe a plant that is in the process of going dormant for the season, although technically only the parts that are dying (the leaves) are becoming senescent.

Sepal (sêp´-el)—An appendage at a flower's base, typically green or greenish and more or less leafy in appearance. Collectively, the calyx.

Separation—The process of removing new bulbs or corms from their parent for purposes of propagation.

Sessile (sès´-ìl´)—Stalkless and attached directly at the base, as in sessile leaves.

Shear—To cut back a plant (as opposed to selective pruning or deadheading). Often used to regenerate plants with many small stems, where deadheading would be too time-consuming.

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.

Short-day plant—A plant requiring more than 12 hours of continuous darkness to stimulate a change in growth, e.g., a shift from the vegetative to reproductive phase. (See also Long-day plant, Day-neutral plant.)

Shoulder ring—One of the ridges around the base of a branch where it attaches to a trunk or to another branch. (See also Collar.)

Shrub—A woody plant that grows to a height of 3 to 12 feet. May have one or several stems with foliage extending nearly to the ground.

Side-dress—To apply fertilizer to the soil around a growing plant.

Sign—Direct evidence of a damaging factor (for example, a pest or pathogen itself, secretions, insect webbing, or chemical residue).

Signal word—An indication of toxicity on pesticide labels. Pesticides labeled "Caution" are the least toxic, those labeled "Warning" are more so, and those labeled "Danger" are the most toxic.

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

Simple metamorphosis—A type of insect development in which the insect passes through the stages of egg, nymph, and adult. The nymph usually resembles the adult. (See also Complete metamorphosis.)

Slow-release fertilizer—A fertilizer material that must be converted into a plant-available form by soil microorganisms.

Soft pinch—To remove only the succulent tip of a shoot, usually with the fingertips.

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.

Soilless mix—A sterile potting medium consisting of ingredients such as sphagnum peat moss and vermiculite.

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

Sonic repeller—A sonic-wave-emitting unit said to disrupt the activities of small mammals. Not proven to be effective.

Species—The basic unit of plant or animal classification. Plants within a species have several characteristics in common. Most important, they can cross with one another, but normally not with members of other species. Classification of species is quite fluid, with periodic revision by botanists.

Specific epithet—The second word in a plant name. (The word "species" refers to plants, not the word in the name.)

Specimen—An individual plant with outstanding characteristics (leaves, flowers, or bark), generally used as a focal point in a landscape.

Spore—(1) The reproductive body of a fungus or other lower plant, containing one or more cells. (2) A bacterial cell modified to survive in an adverse environment.

Sport—See Mutation.

Spot treatment—To apply a pesticide to a small section or area of a crop.

Spur—On fruit trees, a short, compact twig with little or no internodal development on which flowers and fruit are borne.

Stamen (stâ´-men)—The male, pollen-producing part of a flower consisting of the anther and its supporting filament.

Standard—A plant pruned so that it consists of a single bare, vertical stem, atop which a shaped mass of foliage, usually globular, is maintained.

Stem cutting—A section of a stem prepared for vegetative propagation.

Sterile—(1) Material that is free of disease organisms (pathogens), as in potting medium. (2) A plant that is unable to produce viable seeds.

Stigma—The part of a female sex organ that receives pollen. Supported by the style, through which it is connected to the ovary. Often sticky when receptive.

Stipules—A pair of appendages found on many leaves where the petiole meets the stem.

Stock—See Rootstock.

Stolon (sto´-lòn´, -len)—A horizontal stem running along, but above, the soil surface and producing roots and leaves where its nodes contact the soil. Strawberries are an example of a plant with stolons. Also called a runner.

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

Stone fruit—A fleshy fruit, such as a peach, plum, or cherry, usually having a single hard stone that encloses a seed. Also called a drupe.

Strain—A variation within a cultivar or variety.

Stratification—The exposure of seeds to moisture and low temperature to overcome dormancy.

Style—The part of a plant's female sex organ that supports the stigma and connects it to the ovary.

Stylet—A nematode's lance-like or needle-like mouthpart. Used to puncture and feed from plant cells.

Subspecies—A major division of a species, more general in classification than a cultivar or variety.

Succession—The progression of a plant community to a stable mixture of plants.

Succession planting—The practice of planting new crops in areas vacated by harvested crops.

Sucker—A shoot or stem that originates underground from a plant's roots or trunk, or from a rootstock below the graft union. (See also Reversion growth.)

Summer oil—A light, refined horticultural oil used during the growing season to control insect pests and diseases.

Sunscald—Winter or summer injury to the trunk of a woody plant caused by hot sun and fluctuating temperatures. Typically, sunscalded bark splits and separates from the trunk.

Surfactant—See Additive.

Sustainable gardening—Gardening practices that allow plants to thrive with minimal inputs of labor, water, fertilizer, and pesticides.

Symbiotic—Mutually beneficial.

Symptom—A change in a plant's growth or appearance in response to living or nonliving damaging factors.

Systemic pesticide—A pesticide that moves throughout a target organism's system to cause death.

Taproot—A thick central root attached directly to a plant's crown. Taproots branch little if at all.

Taxonomy (tàk-sän´-e-mê)**—**Classification or naming of plants or animals.

Temporary branch—(1) A small shoot or branch left on a young tree's trunk for protection and nourishment. (2) A low lateral allowed to remain until a tree is tall enough to have scaffolds at the desired height.

Tender—Not tolerant of frost and cold temperatures. In horticulture, tender does not mean weak or susceptible to insect pests or diseases.

Tendril—A slender projection used for clinging, usually a modified leaf. Easily seen on vines such as grapes and clematis.

Terminal—The tip (apex), usually of a branch or shoot.

Terminal bud—The bud at the tip of a stem, trunk, or branch. Its development extends the plant's growth.

Thatch—A tightly intermingled layer of stems, leaves, and roots, living and dead, that forms between the soil surface and green vegetation of grass.

Thermoperiod—The change in temperature from day to night.

Thermophilic (ther-me-fil´-ìk)**—**High-temperature, as in microorganisms that break down organic matter in a hot compost pile.

Thin—(1) To remove an entire shoot or limb where it originates. (2) To selectively remove plants or fruits to allow remaining plants or fruits to develop.

Thorn—A hard, sharp-pointed, leafless branch. Hawthorn is an example of a plant that produces thorns. (See also Prickle.)

Tiller—A shoot that arises from a plant's crown. Generally associated with grass species.

Tissue culture—The process of generating new plants by placing small pieces of plant material onto a sterile medium. Also called embryo culture.

Tolerant—A plant that will produce a normal yield even if infested by a disease or insect pest. (See also Immune, Resistant.)

Topiary (to´-pê-èr´-ê)**—**A tree or shrub shaped and sheared into an ornamental, unnatural form, usually a geometric shape or the shape of an animal.

Totipotency (tot-e-pot´en-sê)**—**The ability of any cell to develop into a complete plant.

Trace element—See Micronutrient.

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

Tree—A woody plant that typically grows more than 12 feet tall and has only one main stem or trunk.

Tropism (tro´-pìz´-em)**—**The tendency of a plant part to turn in response to an external stimulus, either by attraction or repulsion, as a leaf turns toward light. (See also Geotropism, Phototropism.)

Trunk—The main stem of a tree. Also called a bole.

Truss—A flower cluster, usually growing at the terminal of a stem or branch.

Tuber—An underground storage organ made up of stem tissue. Contains buds on the surface, from which shoots may arise. Potatoes are an example.

Tuberous root—An underground storage organ made up of root tissue. Sprouts only from the point at which it was attached to the stem of the parent plant. Dahlias are an example.

Turgor (ter´-ger)—Cellular water pressure; responsible for keeping cells firm.

Twig—A young stem (1 year old or less) that is in the dormant winter stage (has no leaves).

Umbel (em´-bel)—A group of flowers growing from a common point on a stem.

Understock—See Rootstock.

Vaporization—The evaporation of the active ingredient in a pesticide during or after application.

Variety—A strain of a plant having distinctive features that persist over successive generations in the absence of human intervention. Generally, variety applies to naturally occurring strains, while cultivar applies to horticulturally developed strains.

Vascular tissue—Water-, nutrient-, and photosynthate-conducting tissue. (See also Xylem, Phloem.)

Vector—A transmitter or carrier of disease.

Vegetative propagation—The increase of plants by asexual means using vegetative parts. Normally results in a population of identical individuals. Can occur by either natural means (e.g., bulblets, cormels, offsets, plantlets, or runners) or artificial means (e.g., cuttings, division, budding, grafting, or layering).

Venation (vè-nâ´-shen)—The arrangement of veins in a leaf.

Vernation (ver-nâ´-shen)—The arrangement of new leaves within an older leaf sheath (e.g., on a grass plant).

Vertical spacing—The vertical space between branches on a tree.

Viability—A seed's ability to germinate.

Virus—An infectious agent too small to see with a compound microscope. Multiplies only in living cells.

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

Water sprout—A vigorous shoot originating above ground on a plant's trunk, older wood, or bud union. Usually breaks from a latent bud. Often the result of heavy pruning.

Water-soaking—Lesions that appear wet and dark and usually are sunken and/or translucent. Often a symptom of bacterial disease.

Weed-and-feed—A combination fertilizer and herbicide sometimes used on lawns.

Wilt—(1) Lack of freshness and turgor and drooping of leaves from lack of water. (2) A vascular disease that interrupts a plant's normal uptake and distribution of water.

Wilting point (WP)—The point at which water content within plant cells is low enough that cellular turgor is lost and the plant wilts.

Witches' broom—Abnormal brush-like development of many weak shoots.

Woody perennial—A plant that goes dormant in the winter and begins growth in spring from aboveground stems.

Xeric (zèr´-ìk)—A plant or landscape that conserves water. Most xeric plants need minimal supplemental water after an establishment period (18 to 24 months after planting) unless there is extreme drought.

Xylem (zî´-lem)—Water- and nutrient-conducting tissue. (See also Phloem.)