Category

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Ornamental, Turf, and Greenhouse Pest Management

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A Guide for Commercial Pesticide Applicators

Ornamental, Turf, and Greenhouse Pest Management

Category 3

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This manual has been developed for individuals who want to become certified in commercial pesticide applicator Category 3–Ornamental, Turf, and Greenhouse Pest Management. The manual contains specific information that an individual must know before becoming certified in one of the subcategories of Category 3. The manual has been designed to supplement the general information contained in the *Iowa Core Manual* (IC-445) and should not be used for certification preparation without referring to the *Iowa Core Manual* as well.

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Introduction

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Integrated pest management

Integrated pest management (IPM), as defined and described in the *Iowa Core Manual* (IC 445), applies to ornamental crops such as turfgrass, trees, shrubs, and greenhouse plants, as well as to field crops, fruits, and vegetables. IPM is a system that uses all suitable pest control tactics to reduce pest populations to tolerable levels while minimizing adverse environmental side effects. This approach to pest problems seeks to replace eradication practices that can cause overuse and misuse of pesticides for quick relief from every perceived pest problem.

IPM as a complete management program provides the most effective solution to pest problems. As in other areas, IPM of ornamental crops covers the entire range of pests: insects and their relatives, plant pathogens, weeds, vertebrates, and nematodes. Ornamental IPM uses cultural, physical, biological, chemical, and other practices to manage pest problems.

Ornamental, turfgrass, and greenhouse IPM differs from traditional agricultural IPM in several important ways. Establishment of ornamental crop injury levels and treatment threshold levels requires consideration of tolerance, personal comfort, taste, and aesthetics, in addition to economics. This management strategy depends heavily on customer education.

One of the most important tactics in IPM is promoting and maintaining plant health and vigor. In general, healthy plants are better able to withstand pests

and are less likely to be attacked by insects and diseases. Therefore, the first step in an IPM program is to understand each plant's requirements and then to meet those requirements with proper cultural practices. The guidelines can serve as a preventive maintenance program that minimizes pest problems and the need for pesticides. Specific cultural controls are mentioned in the ornamental, turfgrass, and greenhouse subcategories.

Timely detection of problems to prevent significant plant injury requires a well-planned inspection or monitoring system. Monitoring requires knowing what to look for (that is, being able to identify the various stages or symptoms of common pest problems), where to look, and when the different stages are likely to be present.

The key to successful pesticide use is correct diagnosis of a pest problem. Proper diagnosis depends on knowledge of the natural growth patterns of a plant to determine whether a problem exists. Once a problem is diagnosed, potential damage also must be estimated. By knowing the potential damage, as well as the cost and effectiveness of a pesticide application, a decision can be made as to whether a pesticide should be applied.

Injury levels and thresholds on ornamental crops vary greatly, depending on the situation and environmental conditions. Landscape plantings, for example, can tolerate low-level pest populations, but nurseries that must sell only pest-free plants can permit only very low injury levels. Healthy, vigorously growing lawns may have much higher thresholds

than weakened, drought-stressed lawns. Although there are IPM tactics that can be used in every situation, the exact use varies from one situation to the next, necessitating greater management skills on the part of the IPM practitioner.

Effective and efficient pesticide use requires proper timing of pesticide applications. Pesticides vary in their mode of action; some can be used before the pest is present, but others must be applied after the pest is present. Proper timing to match pesticides to the presence of a vulnerable stage of the pest life cycle is critical.

In spite of the emphasis on IPM and the use of a variety of control tactics, the application of pesticides is an important part of ornamental, turfgrass, and greenhouse pest management. Certain pests can be controlled only with chemicals, some can be controlled equally well with other practices, and some cannot be controlled at all with pesticides.

Pesticide applicator training is not designed to endorse pesticide use as a solution to all pest problems. An IPM program provides the most effective solutions to pest problems.

Special note. There are four subcategories in this Category 3 manual: 3O, 3T, 3OT, and 3G. Read the pages for the subcategory that applies to you to prepare for the certification test. In addition, the Category 3 test may include material taken from the *Iowa Core Manual* (IC 445).

Ornamental pest management

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Integrated pest management

IPM of woody ornamental plant species involves monitoring for pests, several biological controls, cultural controls, and judicious use of pesticides. Pesticide use alone cannot keep woody ornamental plants vigorous for long periods or overcome poor cultural care. An IPM program not only controls existing pests but also helps prevent the establishment and reoccurrence of pests.

Monitoring and Documentation

Scouting for pests of ornamental plants should be done regularly using predetermined guidelines and a combination of research results from regional or land-grant universities and individual preferences of the IPM practitioner. A successful monitoring program must include the following to be effective:

- accurate identification of pests and nonpest/beneficial organisms,
- quantification of pest numbers,
- knowledge of pest involvement, and
- neat and accurate records for each property.

Some techniques and tools needed for scouting include sweep nets, hand lens, hand trowel, white paper, good observational skills, light traps, pheromone traps, and specimen vials.

Cultural controls

Cultural controls should consider planting environment, plant hardiness, host plant resistance, and maintenance concerns such as planting, watering, fertilization, and pruning.

Environment

Plant species should be matched to the environmental conditions to which they are adapted. The less suited a plant is to its environment, the less likely it is to become established and remain pest-free. Therefore, before selecting a landscape plant, it is important to determine the soil texture, drainage, exposure, and other characteristics of the site and match plant species and varieties to these conditions. For example, some woody plants thrive in moist, undrained lowlands, but others cannot tolerate waterlogged soil.

Plant hardiness

All landscape plants are assigned a hardiness rating to indicate the coldest zone in which they can be expected to thrive. Iowa has United States Department of Agriculture (USDA) hardiness zones 4 and 5. By selecting plants that are sufficiently hardy for this area, an important source of stress is eliminated. The landscape itself can create slight changes in climate. Such small-area conditions are called **microclimates**. Structures or plantings that reduce exposure to wind may warm a micro-climate to the next higher hardiness zone, allowing tender species to survive. Conversely, buildings may trap heat and make a microclimate too hot for certain plants.

Host plant resistance

Some plants are more often attacked by pests than others. Plant breeding programs have developed resistant varieties of some susceptible species. Diseases and insect pests can be avoided by selecting these resistant cultivars. This approach minimizes plant maintenance and maxi-

mizes beauty and longevity. For example, varieties of honeysuckle are available that avoid the deformation caused by the honeysuckle aphid. Similarly, selecting resistant crabapple cultivars avoids the common problems of apple scab and cedar-apple rust.

Planting

Proper planting can be just as important as plant selection to the long-term health and beauty of ornamental plants. There are many planting considerations that ensure a rapid, healthy start for the plant:

- preparing the soil by digging a sufficiently large hole and amending hard or compacted soil as necessary;
- setting the plants at the same level at which they were originally growing;
- backfilling carefully to prevent air pockets and excessive settling;
- watering;
- mulching to prevent weed and grass competition and to preserve water; and
- pruning to remove dead, diseased, or broken branches.

Film-forming materials called antitranspirants can be sprayed on foliage to reduce the rate of evaporation on newly transplanted material.

Watering

Different plants have different moisture requirements, but on average, woody ornamentals need at least 1 inch of water from rainfall or irrigation each week during the growing season. Watering, coupled with mulching, helps prevent drought stress, one of the most important plant health protection considerations.

Fertilization

Vigorously growing plants have high nutritional requirements. Fortunately, most Iowa soils are sufficiently fertile to support vigorous growth of ornamental plants. If nutrient deficiency symptoms are observed on plants, a soil or tissue test can confirm the need for fertilizer. Some nutrient deficiency symptoms are similar to disease symptoms, thus careful diagnosis is necessary.

Pruning

Removal of dead, dying, and broken branches not only helps maintain tree appearance but also can be important to tree vigor. Crossing or rubbing branches should be removed to prevent bark wounds that may serve as entry sites for insects and diseases.

Biological control

Not all insects, mites, and pathogens are harmful to plants. Parasitoids lay eggs in or on plant pests and their immature stages consume the pest. Pathogens such as bacteria, fungi, and nematodes destroy the pest by causing a specific disease. Biological control is the use of living organisms to reduce or prevent plant damage. One way to practice biological control is to protect the natural enemies already present in managed landscapes by learning how to distinguish between pests and natural enemies; avoiding the use of long-lasting broad-spectrum pesticides; and providing alternative foods such as flowering- and nectar-producing plants.

Chemical control

The pest manager should recognize the use of pesticides as one aspect of a balanced IPM program. Pesticides should be chosen based on the specific pest involved, the plant species affected, and the

potential impact on humans, nontarget organisms, and the environment. Read the entire product label and follow all of its directions explicitly during use of the pesticide.

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Plant diseases of trees and woody ornamentals

Diseases of trees and woody ornamentals can be divided into two basic groups: abiotic (noninfectious) and biotic (infectious). Pinpointing causes of plant disease requires close observation, examination of site conditions, and development of a case history for the plant disease. Correct identification of causal agents must precede any effort to manage the plant disease.

Abiotic disorders

Abiotic (nonliving) factors that cause plant problems include the following:
- winter injury, sun scald, or frost cracks;
- too little, too much, or imbalanced fertilizer;
- pesticide injury;
- improper planting and pruning;
- root girdling;
- soil conditions (such as improper soil moisture, salt toxicities, or compaction);
- mechanical damage (done by earth-moving equipment, mowers, and hand tools);
- pollution damage; and
- natural aging of plants (often mistaken for damage caused by insects and diseases).

A few of the more common abiotic diseases are described here.

Iron chlorosis

Iron chlorosis is common on pin oaks and occurs when iron is not available to the tree. Iron chlorosis develops as a yellowing of tissue between leaf veins, with the veins remaining green. In a severe case, leaves curl and turn brown along the margins or develop angular, brown spots between the veins. Eventually, the leaves and twigs may die. The affected tree may be stunted. Iron chlorosis may develop because of unfavorable soil conditions for the use of iron. In alkaline conditions or at pHs above 6.7, iron changes into insoluble forms that cannot be used by trees. Iron is most available at a pH range of 5.0 to 6.5. Deficiency of available iron is aggravated by low temperature and high soil moisture. Sometimes, trees recover from chlorosis when they are supplied with iron.

Scorch

Scorch causes a marginal or interveinal browning of leaf tissue. Scorch is a common problem on warm, windy days when trees lose more water through transpiration than they can replace through their root system.

Mechanical damage

Mechanical damage to a tree or shrub may cause symptoms similar to those produced by canker diseases. Strings or wires used to stake trees may cause stem constriction. Portions of the tree above the constricted or girdled area may die. Another common source of mechanical injury to trees is lawn mower and string trimmer injury to the base of the tree.

Herbicide drift

Certain herbicides may cause injury to trees and woody ornamentals. For example, drift of phenoxy-type herbicides, such as 2,4-D and MCPP, may cause leaf

curling or cupping, distortion of veins, and curling of petioles on sensitive species.

Biotic diseases

Biotic diseases are caused by fungi, bacteria, viruses, nematodes, and other pathogens. In Iowa, the majority of the common biotic diseases of trees and woody ornamentals are fungal diseases.

Fungal diseases

A few of the more common fungal diseases are described here.

Anthracnose: Anthracnose is the common name for certain plant diseases characterized by sharply defined areas of dead tissue caused by a specific group of fungi. Anthracnose usually occurs early in the growing season as trees are leafing out and is more severe in wet and humid rather than dry seasons.

Sycamore anthracnose is familiar to most Iowans. Symptoms of sycamore anthracnose include irregular brown-to-light tan areas adjacent to or centering on midribs and veins of expanding or mature leaves. During cool, wet springs, severe shoot and twig blight also develops. A single season's infection of anthracnose usually does not cause permanent damage to sycamores. However, repeated annual killing of twigs and shoots results in gnarled or bushy branch growth.

On particularly valuable shade or ornamental sycamores, control measures may be warranted. Infected branches and dead twigs should be pruned whenever possible. Trees should be watered during dry spells to prevent further stress and fertilized to stimulate late growth. During cool, wet springs, fungicide applications may help control anthracnose. Timing of sprays is important. A recommended fungicide should be applied at bud swell and again 10 to 14 days later. If favorable weather conditions continue, a third application should be made 10 to 14 days after the second. Recent research has shown that sycamores injected with a systemic fungicide at the base of the trunk in September can be protected from anthracnose for several years. However, this technique is unproven under Iowa conditions.

Other examples of anthracnose include maple anthracnose, oak anthracnose, and ash anthracnose. Control is seldom warranted.

Leaf Spot: Many leaf spot diseases can be found on trees and woody ornamentals. Examples include tar spot of maple and black leaf spot of elm. Typical symptoms of maple tar spot are shiny, black, circular, slightly raised spots on the upper leaf surface. These spots resemble drops of dried tar. Black leaf spot of elm is characterized by small, slightly raised black spots. Numerous spots may develop on a single leaf, and severely infected leaves may yellow and drop prematurely.

On well-established, vigorously growing trees, leaf spots cause little permanent damage and seldom warrant control. As with anthracnose, the leaf spot diseases are more severe in wet seasons.

Scab: Scab is a foliage disease on apples and flowering crabapples. Initial symptoms are small, olive-green to gray-green spots with indefinite margins. As scab infections age, the individual scab lesions become larger and darker, and develop a more definite margin. Severely infected leaves yellow and drop prematurely.

For effective control of scab it is important to understand the disease cycle. The fungus that causes scab survives the winter on fallen leaves. In the spring, spores (primary inoculum) are produced on these infected fallen leaves. These spores are carried by the wind to leaves, flowers, and fruit, where they cause new infections. The fungus sporulates on these newly infected tissues and produces a second type of spore that is blown to other parts of the same tree or neighboring trees, causing additional infections. If weather is favorable, spores may be produced throughout the growing season. Scab-resistant cultivars of flowering crabapple should be planted whenever possible. Fungicide sprays also help control scab. Spray trees with a recommended fungicide two to three times beginning before bud break and continue spraying until 2 weeks after petal fall. The time between sprays varies with weather conditions.

Needle Blight, Needle Cast, and Tip Blight: Conifers (evergreens) also are susceptible to fungal foliage diseases. One fungal disease on pine is *Dothistroma needle blight.* Symptoms of needle infection develop slowly. They are first visible as small, water-soaked spots on the needles in late October. These spots soon become yellow to tan, then brown to reddish brown. The spots are usually circular to somewhat oblong and grow into a band encircling the needle. The band eventually girdles the needle, killing it from the affected area to the tip.

Dothistroma needle blight occurs first (and is usually most severe) on the oldest needles of the oldest branches. As the vigor of the tree declines, needles on progressively higher branches are affected. Austrian, ponderosa, and mugho pine are most common hosts. Trees in poor condition are more prone to attack than vigorously growing trees.

Rhizosphaera Needle Cast: Another fungal disease of evergreens is *Rhizosphaera needle cast*. Symptoms typically begin on lower branches and spread to upper branches. Needles turn purplish brown and fall from the tree during summer and autumn. Symptoms are most obvious on second-year needles. Small, black fruiting structures (pycnidia) of the fungus can be seen in the stomata (small openings for gas exchange) of infected needles. These fruiting structures occur in rows along the length of the needle. A hand lens or magnifying glass is helpful in viewing these structures.

The causative fungus overwinters in infected needles that release spores in late spring during wet weather and infect newly emerging needles. Spores are primarily spread by rain splash. The course of disease from infection to needle drop typically takes 12 to 15 months. After 3 to 4 years of early needle loss, host branches may be killed. Rhizosphaera needle cast is primarily found on Colorado blue spruce and Black Hills spruce. Trees of any age may become ifected, especially those that are stressed.

Sphaeropsis Tip Blight: S*phaeropsis tip blight* (also referred to as *Diplodia tip blight*) is a fungal disease affecting mature two- and three-needled pines (Austrian, ponderosa, Scots, mugho, red, and Japanese black). The most conspicuous symptom is brown, stunted new shoots with short, brown needles. Needles on infected shoots often become discolored while still encased in fascicle sheaths (bundles). The fungus may kill the entire new shoots rapidly. Damage is generally

first evident in the lower crown, but new shoots throughout the tree may be affected. In addition to blighting of the tips, resinous cankers on the main stem and branches, misshappen host canopy, cone death, seedling blight, basal cankers, and host death may occur.

Fungal spores are spread during rainy periods from early spring until late in the growing season. New shoots are most susceptible during a 2-week period starting when buds begin to open. Infection occurs primarily on the new shoots and second-year cones. Close examination of infected needles, twigs, and cones reveals numerous pinpoint-sized, flask-shaped black pycnidia erupting through the plant tissue. Although normally spread by rain splashing, Sphaeropsis tip blight also can be spread by insects, birds, or pruning tools.

Control of fungal diseases on evergreens consists of the following: selecting disease-free plant material or disease-resistant stock; promoting good air circulation by adequate spacing, pruning, and weed control; maintaining good tree vigor; avoiding shearing and pruning when foliage is wet; and using properly timed fungicides as preventive sprays.

Rust: Rusts are another type of fungal disease of trees and woody ornamentals. Many rust diseases have very complicated life cycles requiring two separate hosts. Examples of rust diseases that are prevalent in Iowa are cedar-apple rust and pine needle rust.

Cedar-Apple Rust: Cedar-apple and related rusts are common problems on apple, crab apple, and hawthorn. On crab apple trees, the first symptom of cedar-apple rust is bright yellow-to-orange

spots with red borders on the upper leaf surface. As the season progresses, the spots increase in size, and white, brush-like projections form beneath the spots on the lower leaf surface. These brush-like structures produce spores that are carried by the wind and they cause new infections on susceptible red cedars and junipers.

On junipers, cedar-apple rust infections develop into twig galls. It takes more than a year for a mature gall to develop. Mature galls are large, solid, brown structures. In the spring after periods of rain, heavy dew, or high humidity, bright orange, gelatinous spore horns exude from the gall. The horns, or tendrils, are composed of fungal spores in a gelatinous matrix. The spores are carried by the wind to apples and crabapples where they cause infections of leaves and young fruit. Spores produced on red cedar or juniper do not reinfect the red cedar or juniper. They infect only apples or crabapples. The length of time that the spores are produced by these galls depends on spring weather conditions. Wet weather is conducive to spore production.

Cedar-apple rust management involves a combination of strategies. First, rust-resistant cultivars of apple and crabapple, as well as certain junipers, should be planted whenever possible. Second, rust-susceptible cultivars of red cedar and juniper should not be planted close to apple or crabapple. The spores of this rust can travel several miles on air currents; thus, the only practical recommendation is to separate the two alternate hosts as far as possible. Avoid planting a cedar around rust-susceptible hosts. Third, mature galls should be pruned out of red cedar and juniper in the spring before

spore horns are formed. Finally, fungicide sprays may be used to protect susceptible hosts from cedar-apple rust. Recommended fungicides should be applied several times during the spring to maintain a protective coating on developing leaves, twigs, and fruits. A similar rust attacks hawthorn and causes symptoms similar to those of cedar-apple rust.

Pine Needle Rust: Pine needle rust is most obvious in May and June when orange, blister-like structures develop on the needles of red, jack, or Scots pine. The blisters rupture under wet or windy conditions, releasing orange spores. These spores are carried by the wind to the alternate hosts goldenrod or aster. Infection of goldenrod or aster results in the formation of orange spore pustules on the undersides of leaves. Spores produced on the alternate hosts are spread by wind and cause infection on susceptible pine species. Pine needle rust is most common on young trees. The disease usually does not seriously damage trees, but in certain situations it can kill older needles, slowing growth and causing unsightly foliage.

Pine needle rust may be prevented by not planting susceptible pine species where goldenrods and aster grow abundantly, by eliminating goldenrod or aster from within 1,000 feet of susceptible pines before August each year, or by planting spruce, fir, or nonsusceptible pines.

Canker: Fungi also cause several different canker diseases of trees and woody ornamentals. Canker diseases produce localized dead areas in the bark of twigs, branches, or trunks. Cankers may develop as conspicuous sunken areas, discolored areas of bark that are not depressed, or diseased areas so incon-

spicuous that they cannot be detected without careful examination of the bark surface. Cankers may enlarge until they girdle an affected stem, causing the part of the stem beyond the canker to die.

Eutypella: An example of a very conspicuous canker is Eutypella canker of maple. The cankers usually develop on the main trunk from the ground up to 10 feet. A sunken fissure or crack in the bark is surrounded by extensive callus growth.

Phomopsis: A less conspicuous canker disease is Phomopsis canker of Russian olive. Phomopsis causes oval to elongated cankers from 1 to 6 inches in length on branches and main trunks of Russian olives. The cankers are usually not noticeably depressed. The infected bark turns reddish brown with dark brown margins. Fruiting bodies of the fungus are slightly raised, round pustules located in the dead bark. Sap may ooze through fissures in the dead bark and especially at the margins of the cankers to form gum-like deposits on the bark surface.

Cytospora: Cytospora canker of spruce is evident as a slightly sunken crack or depressed area in the bark of lower branches or the main trunk of older spruces. The cankered areas frequently are covered with accumulations of a white, sap-like exudate.

The fungi that cause many of these various canker diseases sporulate in the cankered tissue. Spores may be spread by wind, splashing water, or mechanical means. For most canker diseases of trees and woody ornamentals, the only practical control measures are pruning out infected portions of the plant, preventing further injury to the plant, and maintaining overall plant vigor. If pruning is done

during the growing season, pruning equipment should be disinfected between each cut. Dip the cutting surface in rubbing alcohol or a 10% bleach solution and wipe with a soft cloth.

Vascular Wilts: Another type of fungal disease of trees and woody ornamentals is the vascular wilt diseases such as Dutch elm disease, oak wilt and verticillium wilt. The causal fungus grows primarily in the vascular tissue of the plant. This growth limits or blocks water movement in the plant and results in the wilting symptoms characteristic of these diseases.

Oak Wilt: Oak wilt is a vascular wilt disease that can affect all species of oak but is more severe in red, black, or pin oaks than in white or bur oaks. The leaves of susceptible oaks turn a dull green or bronze from the tip toward the base of the leaf. The symptoms progress very rapidly over the tree, usually beginning at or near the top. Oak wilt is capable of killing a tree within several weeks.

White and bur oaks are more resistant to oak wilt. Their leaves also turn brown from the tip toward the base. Infected branches may be found scattered through the crown of the tree. The trees usually die slowly within the next few years.

Spores of the oak wilt fungus may be spread by insects such as sap-feeding beetles. The disease also may be spread through root grafts. If large oaks are within 50 to 60 feet of each other, their roots may come in contact and fuse. This fused area, or root graft, allows movement of the fungus from one tree to another. Control of oak wilt centers on early detection, disruption of root grafts, and prompt removal of infected trees.

VerticilliumWilt: Verticillium wilt is a vascular disease that can affect more than 130 species of plants. Susceptible woody ornamental hosts in Iowa include maples (silver, Norway, red, Japanese, and sugar), catalpa, redbud, ash, and elms (American and slippery). Weed hosts include lambsquarters, pigweed, night-shade, and ground cherry. Two soilborne fungi that gain access through host roots cause this disease.

Once inside the host, the fungus generally spreads upward in the trunk via the sapwood and interferes with water movement. Wilting, browning between leaf veins, and leaf drop are typical symptoms, which begin on one branch or section and progress through the host. Reduced twig growth, crown sparseness, and dead branches are frequently observed. Drought, inadequate nutrients, and poor site drainage can accentuate the symptoms. *Verticillium* species can cause discolored streaks in the sapwood that run parallel to the wood grain. This streaking commonly extends from the roots to the branches.

Management of verticillium wilt includes obtaining a positive laboratory diagnosis, controlling verticillium-susceptible weeds on the property, pruning out dead branches, and replacing severely infected or dead trees with wilt-resistant species. Certain plant-parasitic nematodes are capable of increasing the incidence and severity of verticillium wilt in shade tree seedlings. Controlling nematodes is recommended in ornamental nurseries where wilt is known to occur.

Bacterial diseases
There are relatively few bacterial diseases of trees and woody ornamentals in Iowa. However, the bacterial disease fire blight

can cause serious losses on apple, pear, mountain ash, and other members of the rose family.

Fire Blight: Early in the season, fire blight may initiate as a blossom blight. As the disease progresses, a typical shoot blight may develop. The tip of the shoot may curl, giving the branch a shepherd's crook appearance. The bacteria that cause fire blight may spread by splashing rain, wind, and pollinators. Development of the disease is favored by warm, wet weather. Under favorable conditions, fire blight can move through a host quickly.

Bacteria that cause fire blight may survive the winter in cankers on larger branches or on the tree's main trunk. Any holdover cankers should be removed during the dormant season. Fire blight infections during bloom can be severe. Applications of the antibiotic streptomycin during bloom may be of value on apples and crabapples. Fire blight is most severe on lush, succulent growth. Fertilizing carefully but avoiding excessive nitrogen may help prevent tissue losses. Infected branches should be pruned out during the dormant season, but, if necessary, pruning may be done during the growing season, provided the pruning equipment is disinfected between each cut.

Viral diseases

Viral diseases in trees and woody ornamentals primarily produce symptoms such as chlorosis, mottling, ring spots, and occasionally dying tissue. Infection is usually caused by insects, mechanical means, damage, or infected planting stock. Insects (especially aphids) feeding on an infected plant and then moving to a healthy plant may spread the virus to the healthy plant. Virus particles also may be spread from plant to plant on pruning equipment. Currently, control of virus diseases relies on disease-free planting stock, good insect control, and good sanitation practices. Roses are commonly attacked by viruses.

Nematode diseases

Nematodes are microscopic roundworms that, for the most part, live in the soil and feed in or on plant roots. Some nematodes cause small swellings on roots; others may not cause swelling but simply kill the tips of the feeder roots. The aboveground symptoms of this type of nematode damage may include yellowing of foliage, stunting, and a general decline of the plant. It is difficult to distinguish between the symptoms of nematode damage and root rot infection. Laboratory analysis of soil from the affected plant is essential for a definite diagnosis.

Pine wilt is an example of a destructive nematode disease affecting ornamental plants. This disease is caused by the pine wood nematode and spread from host to host by a longhorned beetle (also called a sawyer beetle). As adult beetles feed on succulent twigs, nematodes leave their carrier's breathing ducts and enter fresh host wounds. Once inside the host, pine wood nematodes enter water-conducting resin ducts and reproduce. The resultant billions of nematodes plug these passages, cutting off water flow to the host, and death occurs. Pine wilt disease is primarily associated with Scots and mugho pines, and it is rare in Austrian, ponderosa, red, and white pines, as well as balsam fir, Colorado blue spruce, and white spruce.

Initial symptoms include needle color changing from green to gray-green to completely brown in a short time. These

symptoms may occur uniformly or progress branch by branch. Brown needles usually remain on the tree. Trees die suddenly, often within 3 months of infection. The only known control measure is sanitation: cut down the tree and chip, burn, or bury the wood. Obtain a positive laboratory diagnosis for a tree suspected of having pine wilt disease.

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Insect pests of trees and woody ornamentals

The following section describes the insect and mite pests commonly encountered on ornamental trees and shrubs in Iowa. Enjoyment, beauty, and value of popular ornamental plants can be ruined or severely diminished by these pests. Most of the time natural enemies and other factors keep these pests at sufficiently low levels so plants are not damaged. However, a pest can develop under certain conditions and create a situation that requires remedial measures to prevent serious injury to the plant.

A frustrating problem in controlling insects and mites on ornamentals is determining the identity and importance of any pest found feeding on trees and shrubs. Literally thousands of insects and mites can be seen on ornamentals. Most of them are uncommon, occasional, harmless, or beneficial, and of no threat to the plants. It is important to be able to identify the common injurious or potentially destructive insects. Several reference books are available to help identify common pests. You also can contact your county extension office or the office of the extension urban entomologist at Iowa State University for additional help.

After a pest has been properly identified, information can be obtained about its life cycle, damage potential, and control options. Early detection achieved through frequent and regular plant inspection provides time to correct the problem before permanent injury occurs.

To be most effective, an insecticide must be applied at a time when pests are present and vulnerable. That is, application must be matched to pests' life cycles. For example, scale insects are vulnerable after the eggs have hatched and the insects are in the "crawler" stage. Once the nymph secretes a protective covering over itself, contact insecticides are ineffective.

All parts of ornamental plants are subject to attack by insect pests. The injury insects cause to a plant or the plant's response to the presence of the insects is called a **symptom**. Typical symptoms of insect attack include chewed foliage; bleached, speckled, or streaked leaves; distortion of plant parts; holes in the bark with wood dust, frass (excrement), or pitch; and dieback of shoots, branches, or the entire plant. A given insect species may produce more than one symptom; in contrast, the same symptom may be produced by several unrelated organisms or by the environment (e.g., insects, pathogens, and drought stress). The damage symptoms an insect pest can cause are determined by how that insect feeds on the plant, which in turn is determined by the type of mouthparts that the insect has (chewing or piercing/sucking; refer to the *Iowa Core Manual* for details on specific insects). Common insect pests of trees and shrubs described here are separated by mouthpart type or damage symptoms.

Leaf feeders

Insects with chewing mouthparts can consume foliage, fruits, or flowers. These insects may skeletonize the foliage by eating the leaf material from between the veins but leave the network of veins (the "skeleton") of the leaf, or they may consume the entire leaf.

Eastern Tent Caterpillar: One of the first pests seen in the spring in Iowa is the eastern tent caterpillar. Larvae become active in April. The caterpillars form web tents at the fork of branches in apple, crabapple, cherry, and related trees. The caterpillars work together to make this tent, where they rest at night and on cloudy days. During the day, they leave the tent to feed on the foliage. Defoliation is unsightly but generally is not fatal to the trees. Several natural controls (predators and pathogens) help keep eastern tent caterpillar populations in check. Other control methods include pruning out the tents from infested trees or removing tents by hand. Foliar sprays prevent defoliation when caterpillars are small.
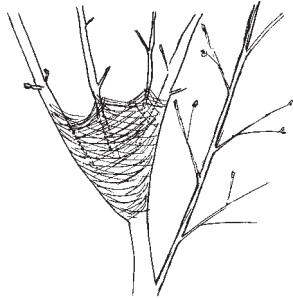
Bagworm: The bagworm is not a common pest in Iowa but occasionally develops large populations and can cause serious defoliation of arborvitae, red cedar, other junipers, white pine, and crabapple. The name accurately describes this unique pest. A small bag of tough silk encrusted with pieces of host plant material encases the dark brown caterpillar. This bag is carried wherever the caterpillar crawls to feed. The wingless adult female remains inside this bag. In the fall, after the bag is firmly attached to tree twigs, the female deposits eggs in it. Control on small trees and shrubs can be achieved by handpicking the overwintering bags before larvae hatch in late May. Otherwise, pesticide applications should be applied in early summer while caterpillars are still small.

Mimosa Webworm: Mimosa webworm is an occasional pest on honeylocust, a popular tree in Iowa. In late June and early August, mimosa webworm caterpillars begin to feed on the foliage. The caterpillars create a simple nest by pulling together leaflets with silk webbing. As the caterpillars feed, the protective webbing is expanded and the damaged foliage turns brown. The second generation of mimosa webworm causes more severe defoliation. To prevent serious injury, honeylocust trees should be treated when the webbing and feeding damage are just beginning (late June and early August). By the time the foliage turns brown, treatment is ineffective.

Yellownecked Caterpillar: Yellownecked caterpillars sometimes defoliate shade trees, especially crabapple, pin oak, and birch. Damage is seldom serious to large trees. The gregarious caterpillars can be removed by pruning and destroying infested branches. Otherwise, treat with an insecticide when caterpillars are small.

Walnut Caterpillar: walnut caterpillars frequently cause severe defoliation to walnut trees, but damage is detrimental only to very young or newly transplanted trees. The caterpillars can be controlled by insecticidal sprays or removed by hand when they crawl down trunks in one large mass and shed their skins.
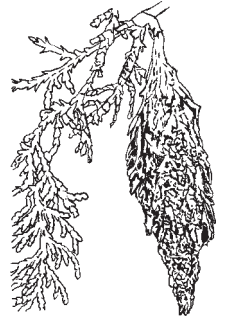
Fall Webworm: Fall webworm is another tent-making caterpillar typically found on walnut , crabapple, and other trees during August and September. The caterpillars construct loose, gray tents or webs over the ends of the branches and enlarge the tents as the foliage is consumed. Control on small plants can be achieved by pruning infested branch ends or spraying into the webs while the webs and caterpillars are small.

Japanese beetle: Japanese beetle is a new pest in Iowa that is expected to cause serious defoliation of woody ornamentals. This pest feeds on more than 300 plant species, including roses, shrubs, trees, grapes, and agronomic crops. The adult beetles are most active from late June through July. In areas of heavy infestation, adults skeletonize foliage and consume the flowers and fruits. Beetle larvae (grubs) are pests of turfgrasses. Insecticide applications to susceptible plants should be made during peak flight periods. Two treatments are usually required, but IPM practitioners should inspect plants for additional beetle activity to verify the need for a second application.

Sawfly: Sawflies look like caterpillars but are the immature stage of small, nonstinging wasps. The characteristics that distinguish them from caterpillars are a single pair of large eyes and more than five pairs of abdominal legs. There are many different kinds of sawflies. The most common are foliage feeders on pines, ash, and pin oak. Others are leafminers, such as the common leafminer found on birch.

European pine sawfly is common on mugho and white pine and feeds during May. Injury is mostly aesthetic (although some stunting can occur) because the larvae feed only on old needles. Defoliated branches have a bottle-brush appearance. Other species of pine sawflies (white pine, red headed, and introduced) eat both old and new needles and, therefore, are much more damaging.

Many sawflies are gregarious and can be found out in the open; thus, they are easy to control by pruning, dislodging, or spot treating. Larger infestations necessitate more thorough treatment.

Sap feeders

Sap-feeding insects have piercing/sucking mouthparts, i.e., they use a pointed beak to puncture plant tissues and suck out sap. Common symptoms of sap-feeder attack on plants include foliar spotting, browning, curling, wilting, and stunting. Severe sap loss may result in premature leaf drop or dieback of stems and limbs, or death of entire plants.

Aphids: Aphids are common sap-feeding pests found on plant foliage, stems, twigs, or roots. Aphids usually are not a problem on healthy, well-established trees. Small trees may be stunted and there may be some premature leaf drop but generally this is not serious. Aphids also may cause wilting, curling, leaf drop, or galls. Perhaps the most annoying aphid damage is caused by excretion of honeydew, a very sweet, sticky, shiny waste product. Honeydew falls on leaves, cars, patio furniture, and sidewalks during outbreaks of aphid populations. Black, sooty mold frequently grows on the honeydew.

Aphids can be different colors and sizes but are typically pear shaped and soft bodied. Most ornamental plants are subject to aphid attack but few are seriously damaged.
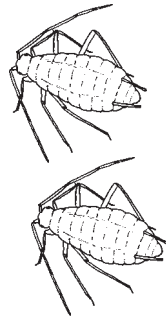
The *leafcurl ash aphid* feeds on the terminal growth of ash trees, causing twisting and curling of the foliage. Control offers little benefit after damage. Healthy ash trees can tolerate the deformation.

Another common aphid is the *honeysuckle aphid* that was found for the first time in Iowa in 1981 in Scott County. Since then the aphid has rapidly dispersed throughout the state. This originally European pest feeds on honeysuckle and has a marked preference for a few common varieties. Aphids feeding on the sap of new leaves cause characteristic disfigurations of the terminals called witches' brooms. These tassel-like deformations have stunted leaves that are folded up with the top sides together. The aphids feed inside the folded leaves and are well protected. This spectacular and obvious damage is disfiguring and may produce plant stunting and weakening; dieback and death are rare. A few resistant varieties are now available for long-term control. Several sprays of foliar systemic insecticide during early summer and other periods of new growth would be necessary for chemical control. Replacement of susceptible plants with pest-resistant plants may be the most economical solution to this problem.

Several other aphids are occasional pests of trees and shrubs in Iowa. Common aphids and their hosts include Norway maple aphid (Norway and sugar maples), witchhazel gall aphid (birch), snowball aphid (*Viburnum opulus* 'Roseum'), giant willow aphid (willow and pussy willow), pine bark aphid (white, Austrian, and Scots pines), and white pine aphid (eastern white pine).

Lace Bugs: Hackberry, hawthorn, oak, sycamore, and other trees may be infested with lace bugs. Damage in the form of speckled or "bleached" foliage is not usually a problem for large, well-established trees. Small, newly transplanted or stressed trees would benefit from a control application but only if the application is made early in the development of the pest population before leaf discoloration becomes pronounced or lace bug presence creates an annoyance.

Scales: Scales are common, occasionally abundant, sap feeders. Their bodies are protected with a waxy, powdery, or shell-like covering.

A large infestation of scale insects can cause stunting, wilting, foliage discoloration, or branch and stem dieback. Eggs are produced under the scale where the nymphs, called **crawlers**, hatch and move around on the plant before settling down and beginning shell formation. Pruning and discarding heavily infested branches is sometimes practical. Dormant oil sprays applied before bud break in early spring are effective against many scale insects. Contact sprays must be applied to coincide with crawler emergence.

Of the large number of scale insects found on ornamental trees, most are of limited destructiveness. However, two scales do cause serious damage: oystershell scale and pine needle scale.
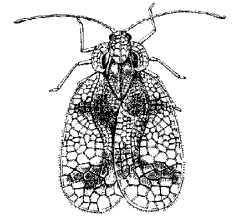
Oystershell scale is a common pest found on a variety of trees and shrubs, but particularly on lilac, dogwood, ash, poplar, and maple. Winter is passed in the egg stage under the scale cover. There is one generation of crawlers usually present in late May. Two forms of oystershell scale, the gray form and the brown form, differ slightly in appearance, seasonal development, and preferred host plants.

Pine needle scale is common on needles of pines and spruces. The cover of this scale is oval and white. Large populations of these scales are easily noticed because of the color contrast against the green needles. If left unchecked, they can cause discoloration, stunting, and twig dieback. There are two generations per year. The eggs are deposited under the scale cover where they spend the winter. The young usually begin to hatch in mid-May. Emergence can vary greatly from place to place. The second generation typically begins in early August. Second generation crawler emergence in staggered, compounding control effectiveness.

Spider mites: Spider mites are occasionally found on evergreens and less commonly on deciduous plants. A general brown or gray discoloration is the first symptom of heavy infestation. Continued attack can weaken or kill ornamental plants. Webbing among the needles and along the stems may occur on conifers attacked by *spruce spider mites*.

Spider mites are just barely visible to the naked eye. Magnification improves your chance to see them. Periods of drought promote population growth. Young or recently planted trees are especially subject to serious injury.

Gall makers

Galls are abnormal growths of plant tissue caused by the presence of tiny gall-making insects or mites. Gall formation is an amazing biological relationship where the plant produces a distinctive gall for each species of gall maker that attacks. The gall is made of plant tissue but the gall maker controls and directs the form and shape of the gall. The immature gall makers develop inside the gall, which provides shelter, protection, and food.

There are thousands of kinds of galls. Galls may form on leaves, stems, twigs, branches, trunks, or roots. Oaks in particular have a variety of twig galls. Not all galls are insect-related. A few may be caused by pathogens, fungi, bacteria, or viruses.

Most galls are harmless to the host plant. Galls are considered aesthetically displeasing but usually do not merit serious concern.

There is no "cure" for galls after they have formed. They cannot be eliminated by chemical treatment. Preventive treatments, tied to the onset of gall maker feeding (usually during leaf formation), are available but seldom practical.

Some common galls include maple bladder, hackberry nipple, and succulent oak galls.

The *maple bladder gall* is common on silver maple foliage. The red, wart-like, or bladder-like gall is caused by a tiny mite very early in the season and throughout the summer.
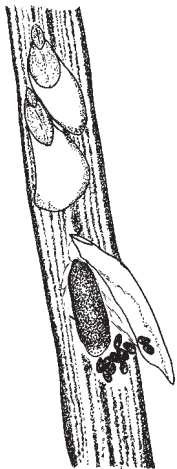
The *hackberry nipple gall* is found on the undersurface of hackberry leaves. The gall maker is a psyllid. Heavy infestations cause leaf distortion and early defoliation but little serious harm.

The *succulent oak gall* on pin oaks is a large, conspicuous gall that causes concern but does not harm the tree. The gall maker is a tiny, nonstinging wasp that lays eggs in developing leaf tissue. Succulent oak galls are large, hollow spheres imbedded in the leaf blade.

Wood borers

Wood borers feed within tree trunks, branches, and stems during at least part of their life cycle. Entrance into the woody tissues is gained by the insects eating their way into the wood, or more rarely, by having eggs thrust into the plant tissue by the female insect. The two major groups of internal feeders are borers and bark beetles.

Borers may attack any part of the plant large enough to contain their bodies. Internal feeding or tunneling in the woody tissues may stunt the plant's health, reduce vigor, or kill branches or the entire plant by interfering with water and nutrient transport or by disrupting cambium growth. Borers can weaken the structure of the tree, leading to breakage during storms.

The tunneling done by borers in ornamental plants is usually accomplished by the immature stages. The common borers are either beetle larvae or moth caterpillars. The major borer groups are the flatheaded borers (family Buprestidae), the roundheaded borers (family Cerambycidae), and the clearwing moth caterpillars (family Sessidae). Many borers are host-specific but others feed in a variety of host species.

Borers generally successfully colonize weakened or stressed trees. Therefore, newly transplanted trees are particularly susceptible to severe damage. Other factors that weaken trees and predispose them to borer attack are drought, sunscald, mechanical injuries, defoliation by diseases or insects, soil compaction or root severing from construction activity, and chemical injuries.

Preventing borer attack is preferable to, and generally easier than, controlling existing infestations. Selecting adapted species for the site and planting the ornamental correctly are key factors in borer prevention. Promoting good health and vigor through proper cultural practices, such as watering, fertilizing, and pruning, is also necessary. Furthermore, chemical protection can be effective by spraying tree trunks and branches at the time the borer adults are flying and laying eggs. Timing is critical for this preventive treatment, and control is not always achieved.

The beetle borers produce noticeable, sawdust-filled holes only when they emerge from the tree. Therefore, treating these exit holes is of no benefit. However, many of the caterpillar borers (for example, ash borer, and carpenterworm) maintain an opening to the outside. Probing these active, sawdust-producing holes with a flexible wire may stop borer activity. Systemic insecticides are only effective for the control of wood-boring insects when used before colonization.

Bronze Birch Borer: A common flatheaded borer in Iowa is the bronze

birch borer, found in ornamental white-barked birch trees. Most varieties of white birch are not adapted to Iowa soil and weather conditions and are, therefore, under stress from the time they are transplanted. Bronze birch borer adults are attracted to these un-healthy trees and lay eggs on the bark. Tiny white larvae bore into limbs and trunks and feed just under the bark in the cambium layer. Winding, sawdust-filled tunnels through this layer soon girdle branches, causing crown dieback and eventual death.
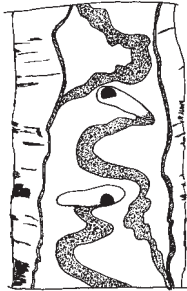
Larvae spend a year feeding inside the tree before transforming into adults via the pupal stage. The adults emerge from the tree by chewing characteristic D-shaped holes that are ¼ inch in length. The free-living adults eat and mate before laying eggs to start the cycle over.

The best defense against bronze birch borer is to not plant susceptible white birch or to plant only in carefully chosen locations where good tree vigor is en-sured. Some new white birch varieties claim bronze birch borer resistance, but these claims have not been proven in Iowa. Residual insecticide sprays applied to the bark during the egg-laying period have been recommended for bronze birch borer protection, but the efficacy of these treatments is questionable.

Twolined Chestnut Borer: Twolined chestnut borer is another flatheaded borer that feeds on oaks growing in disturbed sites such as parks and build-ing sites. Oak trees acclimate to new sites slowly and are under stress until they adapt to a site. Twolined chestnut borers can successfully colonize these weakened oak trees over a period of several years. The best prevention is to fastidiously avoid site disruption. The best control is to maintain tree health and vigor and to promptly remove dead, dying, and infested trees. There is no practical chemical control for this borer.

Ash Borer: Also known as the lilac borer, the ash borer is the larval stage of a clearwing moth. This borer is very com-mon in young, green ash trees used for landscaping and windbreaks. Adults fly during the day and resemble paper wasps. Adults fly in May and June and females lay eggs in cracks and wounds in the bark surface. Larvae initially tunnel just under the bark and later move into the sapwood. Active tunnels are marked on the bark surface by accumulation of frass (a mixture of fine boring dust, oozing sap, and caterpillar excrement). Larvae live for 1 year in the tree and spend the winter in the heartwood. Ash borer activity results in branch breakage during wind, general decline in vigor, decreased aesthetic value, or mortality.

Young trees are especially vulnerable to ash borer attack and should be carefully maintained to promote tree vigor. Insecti-cides can be applied to the trunk and major branches to kill newly hatched larvae before they become established in the tree. Timing of application can be pinpointed by monitoring male flight activity with pheromone traps. Other-wise, use insecticide sprays through the expected flight period of May and June. Individual borers can be killed by using a flexible wire probe in active tunnels.

Roundheaded Borers: Many trees are attacked by a variety of beetle species collectively known as roundheaded

borers. Locust, hickory, ash, elm, and crabapple are especially hard-hit by members of this group. The adult beetles are called longhorned beetles because of their long antennae. Beetle size may vary from $\frac{1}{4}$ to 3 inches, and many are beautifully marked with bands, stripes, or spots. Roundheaded borers commonly burrow in the heart-wood, tunneling holes as large or larger than the diameter of a pencil. The burrow is packed with a coarse, excelsior-like frass. The larvae (grubs) are white to yellowish with round bodies. Most species complete their life cycle in a year, some may require 2 to 3 years, and a few can take 10 or more years develop (usu-ally if conditions are unfavorable).
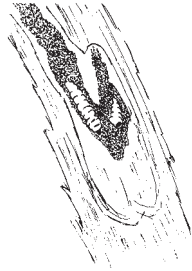
Bark Beetles: Bark beetles can be consid-ered wood borers because they are found in the area between the bark and the wood. The adults are small and brown or black ($\frac{1}{8}$ to $\frac{1}{4}$ inch in length), and the larvae are white, curved, and legless. Bark beetles successfully colonize trees that are weakened or dying. The adult female tunnels through the bark and constructs chamber in which she lays her eggs. Larvae tunnel under the bark approximately at right angles to the egg gallery. Pupation occurs under the bark at the end of the larval tunnel. There are at least two genera-tions per year in Iowa. Controls for bark beetles are the same as those for borers and include appropriate silviculture to promote vigor and sanitation. Seldom is chemical control practical.
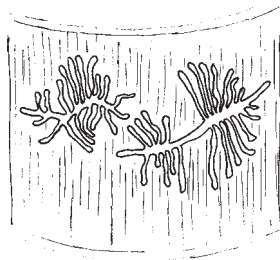
Summary of insect pests of ornamentals

Pest	Hosts	Vulnerable Stage for Chemical Control and Timing
Eastern tent caterpillar	Apple, crabapple, wild cherry, plum, ash, birch, maple,	Small larvae; April
Bagworm	Arborvitae, redcedar, junipers, crabapple, white pine, black locust, maple, sycamore	Small larvae; midsummer
Mimosa webworm	Honeylocust	Small larvae; late June (1st generation), early August (2nd generation)
Yellownecked caterpillar	Birch, pin oak crabapple, elm, linden, honeylocust, maple, fruit trees	Small larvae; July
Walnut caterpillar	Walnut, hickory, butternut, pecan	Small larvae; mid- to late summer
Fall webworm	Walnut, crabapple (>200 species)	Small larvae inside web; July
Japanese beetle	Linden, roses, birch, crabapple (>300 species)	Adults; late June through July
European pine sawfly	Scots, mugho, and red pine	Small larvae; early May
Honeysuckle aphid	Honeysuckle	April; repeatedly throughout summer
Lace bug	Hackberry, oak, sycamore, hawthorn	Nymphs and adults; as noticed
Oystershell scale (brown form)	Apple, dogwood, crabapple, many others	Eggs, (dormant oil) late March; crawlers, mid-May
Oystershell scale (gray form)	Lilac, ash, poplar, willow, maple	Eggs, (dormant oil) late March; crawlers; mid-May

Summary of insect pests of ornamentals (continued)

Pest	Hosts	Vulnerable Stage for Chemical Control and Timing
Pine needle scale	Pines, spruces, firs, hemlock, Douglas fir	Eggs, late March or early April (dormant oil); crawlers, mid-May
Spider mites	Many	Nymphs and adults; when present in damaging numbers
Galls	Many	Chemical control not practical
Bronze birch borer	White birch	Chemical control not practical
Twolined chestnut borer	Oak	Chemical control not practical
Ash borer	Ash, lilac, privet, mountain ash	Small larvae before entering tree; mid-May to late June
Roundheaded borer	Many	Chemical control not practical
Bark beetles	Many	Chemical control not practical

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Weed management in woody ornamentals

There are several reasons to control weeds in woody ornamentals. Weeds in a landscape detracts from the aesthetics of a formal or even an informal landscape. Besides the cosmetic aspect, undesirable plants can reduce the vigor and growth of ornamentals by competing for water, nutrients, and sun. Weeds also provide shelter or serve as hosts for insects that feed on ornamentals.

Identification of common weeds

The first step in managing weeds is identifying the undesirable plant(s). Improper identification can lead to choosing a herbicide that is ineffective against the weed(s). Refer to pages 44–47 for a description of common Iowa weeds.

Morphology

When weeds are classified by their form, they are usually separated into grasses, broadleaves, and sedges.

Grasses: Grasses are characterized by having narrow leaf blades with parallel veins; a fibrous root system; and often, jointed, hollow stems. Foxtail, nimblewill, and quackgrass are typical grasses.

Broadleaves: Broadleaf weeds are characterized by having broad leaves, as their name indicates. The leaves have a network of small veins originating from a principal vein (midrib) that divides the leaf in half. Virginia copperleaf, horseweed, purslane, and ground ivy are typical broadleaf species.

Sedges: Sedges are grass-like plants with three-cornered stems that bear leaves extending in three directions. They are neither true grasses nor true broadleaves. Yellow nutsedge is the most common sedge that may invade ornamental plantings.

Weed Life Cycle

Weeds can be further classified by their life cycle. Knowing the life cycle of a plant is important in selecting a control strategy, especially when the weed is morphologically similar to the ornamentals. Within the classification of life cycle, a weed is categorized as annual, biennial, or perennial.

Annual (summer annuals or winter annuals): Plants that live for one growing season only are annuals. Summer annuals germinate in the spring, grow and mature during the summer, and die in the fall. Foxtail, common ragweed, and purslane are examples of summer annuals. The seeds of winter annuals germinate from fall to early spring, grow and mature very early in the spring, and die in the summer. Shepherd's purse, common chickweed, and henbit are examples of winter annuals.

Biennial: Plants that live for two growing seasons are biennials. Seeds can germinate any time during the first year with the plants overwintering as a rosette. Exposure to cold (vernalization) induces the plant to flower during the summer of the second year and then die in the fall. Control methods are maximized when applied during the first year while the plant is still young (in the rosette stage). Burdock, musk thistle, and common mullein are examples of biennials.

Perennial (simple perennials and creeping perennials): Plants that produce vegetative structures that allow them to

live for more than 2 years are perennials. During the winter, many perennials die back to the ground level but come back from the rootstock the following spring. Simple perennials have a vegetative structure that overwinters, and allows the plant to come back year after year; however, they reproduce or spread almost entirely by seed. Dandelion, curly dock, and buckhorn plantain are examples of simple perennials. Creeping perennials can overwinter and produce new plants from vegetative structures. They also can reproduce by producing seed. The two main vegetative reproductive structures are rhizomes (underground stems) and stolons (aboveground stems). However, bulbs, creeping roots, and tubers also belong within this category. Ground ivy, milkweed, and quackgrass are examples of creeping perennials.

Types of control

The next decision in a weed control program is to determine the control strategy: nonchemical, chemical, or a combination of the two. With any of these methods there are advantages and disadvantages. Often, a combination strategy produces the best results.

Nonchemical control

Nonchemical control includes hand pulling, mulches, and cultivation. In small ornamental beds or in plantings with a variety of species, mulching is the most practical.

The use of a mulch can greatly reduce the number of emerging weeds while conserving soil moisture. There are several organic and synthetic mulches available. If using an organic mulch (bark chips, shredded bark, or pine needles), a 2- to 4-inch layer is needed. When placing the mulch around ornamentals, leave a space between the mulch and the stem or trunk of the ornamentals. This space allows the trunk to stay dry and discourages small rodents (nesting in the mulch) from feeding on the plants. Synthetic materials sometimes called weed fabric or weed barriers are occasionally used underneath an organic mulch. Black plastic is one synthetic mulch that should be avoided because it allows minimal water or air exchange from the soil surface and is often responsible for loss of plant vigor or death.

Cultivation is another effective method of controlling weeds. The greatest problem with this method is that people generally wait too long before tackling the problem. Shallow cultivation should be conducted while weeds are young and tender. Deep cultivation may injure the roots of desirable plants and often brings additional weed seeds to the surface. The use of cultivation to supplement chemical weed control generally provides the highest level of control.

Chemical control

Herbicides frequently are the most effective and economical method of controlling weeds in large ornamental plantings and nurseries. However, chemical control requires a broad knowledge of the herbicides available, their mode of action, the weeds controlled (selectivity), application timing and rates, need for spray additives, and appropriate precautions.

The following terms describe herbicide selectivity and time of application.

Selective Herbicides: Selective herbicides are more toxic to some plant species than to others. This selectivity depends upon many factors, including rate of

chemical applied; conditions of the plant; environment at the time of application; plant tolerance to the specific chemical; growth stage; and soil factors. Label information and manufacturers' literature are the best sources to determine which chemicals can be used most effectively in a given situation.

Nonselective herbicides: Nonselective herbicides are toxic to all plant species contacted. Some nonselective herbicides are very long lasting, preventing regrowth of weeds (and replanting of desirable plants) for up to 3 years.

Postemergence herbicides: Herbicides applied to the foliage of existing weeds are called postemergence herbicides. These pesticides are further classified as either contact or systemic herbicides. A contact herbicide does not move within a plant, therefore, it does not control perennial weeds and requires thorough coverage for plant kill. A systemic herbicide translocates (the chemical moves within the plant) and usually kills the roots of perennial plants.

Preemergence herbicides: Herbicides applied to the soil before the emergence of weeds are called preemergence herbicides. Soil applications generally require incorporation either with water (rain or irrigation) or by mechanical means (cultivating or tilling). Most preemergence herbicides do not kill established weeds. Preemergence herbicides should be the foundation of a chemical weed control program, but postemergence herbicides should be used to spot treat difficult-to-control annual and perennial weeds or to manage undesired vegetation around buildings and fences.

Preemergence herbicides for nursery–landscape use

The use of a preemergence herbicide is often the foundation of a chemical weed control program. Each herbicide is selective for a specific set of weeds and ornamentals. A single application of a preemergence herbicide usually does not provide adequate weed control for an entire season so combinations of a late fall and a late spring or early summer treatment are often used. These two applications may consist of different herbicides due to the different weed species present in fall and early summer. Tank mixes of two herbicides also can be used to widen the weed control spectrum. Therefore, before selecting a herbicide, consider the various factors that may affect the level of weed control obtained (i.e., weed species present, application rate, or incorporation requirement) and the tolerance of the ornamentals to the chemical. If a tank mix is desired, make sure the combination is a labeled tank mix. The label states all registered combinations and other important mixing information.

Plant tolerance

The level of tolerance to a particular herbicide varies widely among ornamentals. Therefore, a herbicide should only be used in plantings of species listed on the product label. Because ornamental plantings and nurseries usually contain several different species, special care must be taken to avoid applying a herbicide to plants for which it is not registered. Herbicides can cause severe damage to ornamentals not listed on the label. The previous herbicide used, the age of the plant, and the time since transplanting all determine plant tolerances.

Soil preparation

Because preemergence herbicides are only effective against germinating seeds or young plants that have not emerged from the soil, they must be present at toxic concentrations in the soil zone where weed seeds germinate. Material on the soil surface (established plants, leaves) can intercept the herbicide and reduce the amount reaching the soil. Although the activity of some herbicides may not be affected by plant residue on the soil surface, most herbicides provide better weed control when applied to a bare soil surface.

Herbicide incorporation

After a preemergence herbicide reaches the soil surface, it must move into the soil profile to the depth where weed seeds germinate: it is ineffective if it remains on the soil surface. Herbicide can move into the soil profile by water (rainfall and irrigation) or mechanical incorporation. While a herbicide is on the soil surface, it can be inactivated by many physical and environmental factors. A few herbicides are lost quickly from the soil surface due to photodegradation, volatility, or both. Therefore, these herbicides must be incorporated immediately after their application. Other herbicides are more resistant and can remain on the soil surface for 2 weeks without losing their activity. However, if rain does not occur within the period stated on the label, some type of incorporation must be used to ensure effective weed control.

A few other herbicides may be very specific in the type of incorporation method to use. Some may require only water incorporation because mechanical incorporation or cultivation may reduce weed control activity. Others may recommend a specific mechanical incorporation method. The label provides recommendations for incorporation that must be followed for consistent performance.

Soil type and organic matter

Many preemergence herbicides are influenced by the soil texture and the amount of organic matter present in the soil. Herbicides can be bound to soil colloids (clay plus organic matter) to varying degrees, depending on the herbicide and type of colloid. Herbicides that are tightly bound to colloids may require higher rates when applied to heavy soils with high levels of organic matter. Herbicides not appreciably influenced by soil colloids can be used at one rate over a wide range of soils.

Spectrum of control

None of the preemergence herbicides are effective against all weed species. Therefore, if a single herbicide is used continually, tolerant weed species may become established in the treated area. Rotating the herbicides used in a target area or making sure the herbicide chosen controls the majority of weeds present reduces the buildup of tolerant species. However, to control all weed species present, a spot cultivation or directed spray of a nonselective postemergence herbicide commonly is needed.

Postemergence herbicides for nursery–landscape use

Postemergence herbicides generally are used for spot/rescue treatments or for nonselective weed control around buildings, fences, and other areas. If applied with great caution, the nonselective herbicides also may be used beneath trees and in shrub plantings where foliage and stems are not contacted.

Contact herbicides result in a rapid kill of wetted areas. Because there is little movement of the herbicide in the plant, uniform coverage of the weed with the spray solution is required. Contact herbicides generally provide excellent control of annual species, but perennials may regrow quickly from rootstocks.

Translocated herbicides are moved in the plant to areas not directly contacted by the spray. These herbicides usually are slow acting but can result in the death of underground roots of perennial weeds. Repeat applications may be required for complete control of some perennials.

Preventing herbicide injury to nontarget plants

Although herbicides can be useful tools for managing weeds, improper application may result in injury to trees or other ornamentals. Selective herbicides possess a relatively small margin of safety, which increases the risk of phytotoxicity problems. The margin of safety is the difference between the rate of chemical that is required to control weeds and the rate that is toxic to ornamentals. Misapplication, resulting in a higher herbicide rate than stated on the label, may cause injury to the ornamentals.

Herbicide residues remaining in the soil may injure next year's planting, especially if the plants are started from seeds. Most herbicides lose their activity 2 or 3 months after application; however, certain herbicides may remain at toxic levels in the soil for periods up to a year or longer. Check the label for rotation restrictions.

The majority of herbicide injury cases result from the drift of postemergence herbicides onto sensitive, nontarget plants. Drift is the movement of airborne spray droplets from the target area. Drift of contact herbicides usually results in necrotic spotting of the foliage. Such injury is generally minimal. However, translocated chemicals can cause serious injury due to accumulation of the herbicide at the growing points of ornamentals. Reducing spray pressure, spraying only when wind speed is low, and avoiding areas with sensitive plants can reduce the risk of drift injury. Another possible problem with preemergence chemicals is herbicide movement in runoff water from treated areas into areas nearby where sensitive plants are located.

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Application equipment and calibration

Several types and sizes of equipment are available for applying pesticides to woody ornamental plants. Shrubs and small trees are often sprayed with manually operated sprayers; low-pressure power sprayers fitted with spray guns; or lightweight, powered mist blowers. Tall shade trees are normally sprayed with high-pressure, high-volume hydraulic sprayers or with air-carrier sprayers (air-blast sprayers). These sprayer types also are discussed in the *Iowa Core Manual*.

Sprayers

Manual sprayers commonly used to spray ornamental plants are relatively inexpensive, simple to operate, maneuverable, and easy to clean and store. Most manual sprayers use compressed air or carbon dioxide to apply pressure to the supply tank and to force the spray liquid through a nozzle. Several types of small power sprayers are available that deliver 1 to 3 gallons per minute at pressures of

up to 300 pounds per square inch (psi). Spray guns are normally used with these sprayers. Powered mist blowers use much less water and enable the operator to cover larger areas without refilling. Rotary nozzle sprayers are now available that deliver lower volumes and produce lower amounts of spray drift.

Pesticide applications to large shade trees require more energy than spraying small plants because the spray must be projected over greater distances and must cover larger surface areas (all leaf, stem, and trunk surfaces). Hydraulic sprayers use pressure to propel the spray solution, whereas air-carrier sprayers use an airstream to transport and distribute the spray solution.

Calibration

Regardless of the type of equipment used, the pesticide must be applied uniformly to all surfaces of an ornamental plant or tree. This task requires a competent operator. To ensure adequate coverage with pressure sprayers, ornamental plants and trees are usually sprayed to the point of runoff. The amount of spray required to reach that point depends on the size and shape of the plant, the density of the foliage, and the application techniques used by the operator. With air-carrier sprayers, the plants are not completely wetted, and extreme care must be taken to ensure that the proper rate of pesticide has been applied.

Recommendations for applying insecticides and fungicides to ornamental plants and trees are generally given as the amount of active ingredient (a.i.) or product to add to each gallon or 100 gallons of water, and the operator is usually directed to spray to the point of runoff. Simply add the recommended

concentration (tablespoons, ounces, gallons, or pounds of product) to each gallon or 100 gallons and spray until the solution is running off the tree. If recommendations are given as active ingredients, then the amount of active ingredient must be converted into the amount of formulated product that is needed.

Direct the spray to all parts of the plant until it begins to drip from the leaves and stems. Additional spray beyond the point of runoff washes pesticides from the plant and could damage vegetation under the drip line of the plant being sprayed.

To conserve materials and minimize environmental impact, estimate how much spray solution is required for a task. First, determine how long it takes to spray a representative tree with water to the point of runoff. Remember, a tree in full leaf takes longer to spray than the same tree in early spring.

Second, determine the flow rate from the nozzle by spraying water into a 5-gallon plastic bucket. Collect the material sprayed in 1 minute. If a nozzle fills to the 1-gallon mark in 2 minutes, the flow rate is ½ gallon per minute.

Third, determine the amount of spray needed per tree by multiplying the time to spray the tree by the flow rate. For example, if a spray gun on a small power sprayer delivers 2 gallons per minute and a shade tree requires 5 minutes to spray, 10 gallons of spray mix per tree is applied (2 gallons per minute × 5 minutes). The total solution required is the product of the number of trees to spray by the quantity of spray needed for each tree.

Example

You are hired to spray 25 tall shade trees. The insecticide label calls for 4 gallons of product per 100 gallons of solution. How much water and insecticide should you add to the spray tank to complete the job?

Answer

Following the recommended procedures, you determine that the spray required per tree is 12 gallons (6 minutes $\times$ 2 gallons per minute). For 25 trees, the total amount of spray required is 300 gallons (25 trees $\times$ 12 gallons per tree). The amount of insecticide required for the job is 12 gallons (4 gallons per 100 gallons $\times$ 3 batches of 100 gallons each). To complete the job, add 12 gallons of insecticide to 300 gallons of water and spray each tree for 6 minutes.

Concentrate spraying

Spraying to the point of runoff is called dilute spraying and is generally done with compressed air, backpack, or powered hydraulic sprayers that deliver high gallonage of moderate-to-high pressure spray. Air-blast sprayers or mist blowers use both air and water to dilute the pesticide and to deliver a concentrated solution of pesticide in a high-volume, high-velocity airstream. Concentrate or low-volume spraying equipment accomplishes equal coverage with less water than hydraulic sprayers. Successful concentrate spraying requires special attention to operating procedures. Plant injury or poor distribution of the spray may result from an improperly operated machine. Carefully read and follow the spray equipment manufacturer's instructions and guidelines, and the pesticide label directions when using concentrate spraying. Off-target movement of the concentrate must be kept to a minimum.

Turfgrass pest management

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Integrated pest management

A healthy, vigorous, high-maintenance stand of turfgrass is best maintained by a combination of sound cultural practices, monitoring for pests, and judicious use of pesticides. In fact, pesticide use alone cannot keep turfgrass vigorous over long periods or overcome poor cultural care. An IPM system not only controls existing pests but also helps prevent the establishment and reoccurrence of pests.

Cultural control

Cultural factors to consider in turfgrass pest management include the selection of seed or sod, preparation and establishment procedures, and maintenance such as mowing, fertilizing, and irrigating. Controlling turf problems such as thatch, soil compaction, traffic wear, heaving, and excessive shade also are important.

Selecting seed or sod

The first step in turfgrass pest management is to select turfgrass species or varieties that are best suited to both the environment and the planned use of the site. Three species of turfgrass illustrate this point. *Kentucky bluegrass* is the most widely used turfgrass in Iowa. An attractive, healthy stand of Kentucky bluegrass is possible under a variety of conditions, although it does not tolerate shade or continued short mowing. *Creeping bentgrass,* on the other hand, requires close, frequent mowing and is limited in use because of its high maintenance requirements. *Tall fescue* is a bunch-type grass that may have an undesirable appearance, but it is extremely tolerant to heat, drought, and wear. It is a good choice for sites that have a lot of traffic and low level of maintenance.

Using the wrong grass for a particular environment or for the planned intensity of culture is likely to cause the turf to fail or be of low quality. Choose grass that is best adapted to the intended use of the area and purchase top-quality seed or vegetative plant material.

Preparation and establishment

Many pest problems encountered in caring for turf can be avoided if the turfgrass area is properly prepared. For example, perennial grasses such as quackgrass should be controlled before seeding or sodding. One or more applications of a nonselective herbicide may be necessary to eliminate all remnants of quackgrass.

Some grasses or turfgrass uses may require soil modification. Most soils can be modified to improve their physical properties to make the turfgrass healthier and more vigorous. Examples include improved drainage and aeration and reduced soil compaction.

Soil testing indicates whether the soil is deficient in phosphorus or potassium and, if so, the amount of nutrients needed. Soil pH as determined by soil testing is usually adequate in Iowa for most turfgrass species grown. Proper amounts of fertilizer can be incorporated into the soil during seed bed preparation.

Turfgrass planting beds should be worked to a depth of at least 6 inches by plowing, roto-tilling, or disking. A fine

seed bed helps establish a new planting. Seeding is most successful if done in late summer to early fall when soil moisture and temperature are favorable for rapid grass establishment, and weed competition is usually less severe. Sod can be installed anytime during the growing season after the soil has been prepared. A light rolling of the seeded or sodded area ensures close contact between the seed or sod and the soil. Some grasses are established by stolons, plugs, or sprigs.

Watering is essential to grass seed germination and sod establishment. The amount and frequency of watering depend upon soil type, wind, temperature, and intensity of sunlight. In new seedings, light watering two or three times a day for the first 3 or 4 weeks should be adequate. More frequent watering may be necessary on hot, windy days. Mulching with clean straw or other material to reduce drying of the seedbed may help in germination and early seedling development. Mulching also can reduce erosion caused by wind and rain.

Sod should be thoroughly watered as soon as possible after it is laid. Daily watering for the next 2 or 3 weeks provides adequate moisture during the rooting period.

Maintenance after planting

Mowing, fertilizing, and irrigating are important, ongoing considerations that determine turfgrass health and vigor. A quality turf requires regular mowing at the correct cutting height with suitable equipment. Proper mowing is essential to developing and maintaining a dense, uniform surface and effectively can reduce the number of weed species that may invade a turfgrass stand.

The correct cutting height depends upon the species of turfgrass, the intensity of management practiced, and the time of year. Appropriate cutting heights (in inches) for common turfgrasses are listed below.

Cutting heights (inches) for turfgrass		
Turfgrass species	Cool weather	High temperature periods
Kentucky bluegrass	1 ¾ –2 ¼	2 ¼ –3 ¼
Perennial ryegrass	1 ½ –2	2–3
Fine leaf fescue	1 ½ –2	2–3
Tall fescue	2 ¼ –3	2 ½ –3 ½

Cutting grass too short weakens the turf and increases susceptibility to weed invasion, diseases, insect damage, and injury from drought and temperature extremes. If the grass is cut too high, however, it has a shaggy appearance that greatly detracts from the area.

Cutting height and rate of growth should determine mowing frequency rather than some fixed time interval. Generally, do not remove more than one-third of the total leaf area at any single mowing.

It is not necessary to remove grass clippings if the lawn is mowed frequently. Only if there are large clumps of clippings that would smother the turf is it necessary to rake or collect them. The Iowa Waste Reduction and Recycling Act of 1986 prohibits certain materials from disposal in landfills, including yard waste such as grass clippings. If clippings are collected, it is necessary to look at disposal methods other than landfills (use as mulch or compost). Therefore, leaving the clippings on the lawn is recommended.

A newly planted turfgrass area should be mowed as soon as the foliage has grown to about 50 percent higher than the desired height.

Proper fertilization is important for the production of a healthy, dense stand of turfgrass that can resist weeds and recover quickly from disease and insect injury. The amount of fertilizer to apply and the number of applications per year are determined by the maintenance level of the turfgrass area. A high-maintenance turfgrass receives three or four fertilizer applications each year, whereas a low-maintenance lawn receives one or two applications per year. Each fertilizer application is equivalent to 1 pound of nitrogen per 1,000 square feet.

Natural rainfall usually provides adequate moisture for turfgrass during cool spring and fall weather, but extended drought periods in the summer may cause the grass to wilt and turn brown. Although a turfgrass area that is brown and dormant in summer may look unattractive, it usually recovers with the return of cooler weather.

For a high-quality appearance throughout the summer, irrigate as soon as the grass shows signs of wilting. The amount of water that is needed depends upon the soil type and the rate at which water is applied. The general rule is to water deeply and infrequently. Sandy soils need to receive between 1 and 2 inches of water per week. Clay soils need approximately 1 inch of water per week. To reduce the potential fir diseases, it is preferable to water from early morning to midday.

Turf problems

Several additional problems or concerns can increase the likelihood of pest problems or create symptoms similar to pest damage: thatch, soil compaction, traffic wear, heaving, and excessive shade.

Thatch

Thatch is a tightly intermingled layer of living and dead stems, leaves, and roots of grasses that develops between the green vegetation and the soil. Thatch accumulation is most abundant in high-maintenance turf areas. Excessive thatch (greater than ½ inch) increases disease susceptibility; reduces tolerance to drought, cold, and heat; impairs the movement of water, air, fertilizer, and some pesticides; and decreases the turf's capacity for vigorous growth.

If thatch is more than ½ inch thick it should be controlled. Methods of removal vary from vigorous hand raking to the use of power-driven dethatching machines. Thatch should be removed when climatic conditions favor quick recovery. Severe dethatching in late spring opens the turf for invasion by crabgrass and other annual weeds. Cultivation and aeration methods that introduce soil into the thatch layer aid in thatch control.

Soil compaction

Compacted soils have poor aeration and drainage, low water infiltration capacity, and shallow root growth; thus, compacted soils produce turf of reduced quality. Mechanical cultivators such as coring machines, spikers, and slicers reduce soil compaction and help improve turf quality on compacted soils.

Traffic wear

Traffic wear occurs from rubbing and abrasion by people and animals walking or playing on the turfgrass. In high-traffic areas, plant grass species tolerant of wear.

Heaving

Small undulations of the turf surface may result from winter freeze and thawing as well as from the activities of earthworms, moles, ants, and other creatures. Slight improvements in lawn unevenness can be achieved by light rolling or cultivation as used for thatch control. However, major leveling and excessive rolling should be avoided as these can decrease turf health.

Excessive shade

Shaded turf areas are usually shallow rooted, less dense, and more prone to disease than turf in sunny areas. Only shade-tolerant grasses such as fine fescue should be planted in moderately shady areas. Otherwise, gradual deterioration of the turfgrass can be expected. Several good ornamental ground covers or mulch can be used in areas that are too shady for turfgrass establishment.

Monitoring

Scouting for turfgrass pests should be done regularly by using predetermined guidelines based on a combination of research results from regional or land-grant universities and individual preferences of the turf manager. Any successful monitoring program must include the following to be effective:
• accurate identification of pests and nonpest/beneficial organisms,
• quantification of pest numbers,
•location of the extent of pest involvement, and
•neat and accurate recordkeeping of each turfgrass area.

Some tools and techniques needed for scouting turfgrass include sod lifter, cup cutter, sweep nets, hand lens, hand trowel, good observational skills, soap or insecticidal flushes, light traps, pheromone traps, and specimen vials.

Biological control

Not all insects, mites, and disease organisms in turfgrasses are harmful. Some are predators that eat plant pests. Others are parasitoids that lay eggs in or on pests; their immature stages develop in and consume these pests. Pathogens (bacteria, fungi, and nematodes) destroy pests by causing a specific disease. Biological control is the use of living organisms to reduce or prevent plant damage. One way to practice this management tool is to protect the natural enemies already present in managed turfgrass areas. Practically, this means learning how to distinguish between pests and natural enemies, being more selective in the types of pesticides used, and receiving regular updates from extension on the effectiveness of new biological control agents for turfgrass pests.

Pesticides

The turfgrass manager should recognize the use of pesticides as one aspect of a balanced IPM program. Pesticides should be chosen based on the specific pest involved, the turfgrass species, and the potential impact on humans, nontarget organisms, and the environment. The product label should be read completely and then followed explicitly during use.

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Plant diseases of turfgrass

There are relatively few common diseases on turf in Iowa. Diseases may occur

throughout the growing season, but certain diseases are more likely to occur at specific times of the year.

Fungal diseases

The common diseases of turfgrass in Iowa are caused by fungi (microscopic plants that lack chlorophyll and cannot produce their own food by photosynthesis). Parasitic fungi attack living turfgrass plants during periods of favorable temperature and humidity. Some disease-causing fungi damage weakened or injured plants that have lost much of their natural resistance to fungi, but other fungi cause disease on vigorously growing grass. Fungal diseases are managed through good cultural practices outlined earlier, by planting adapted or resistant species and cultivars, and by timely application of fungicides.

Snow mold

A turf disease that may occur very early in the season is snow mold. Snow molds include the gray or Typhula snow mold and pink or Fusarium snow mold. Snow mold is particularly active under a snow cover and usually is first noticed during spring thaw when light gray areas of matted mycelial growth are found in the grass. Frequently, the damage from snow mold is superficial and the turf recovers quickly. Occasionally damage is severe, killing the crowns and making recovery slow. Reseeding or resodding affected areas may be necessary.

Snow mold may be controlled by applying recommended fungicides in the fall before the first snow that stays.

Other early-season problems that might be mistaken for snow mold include salt damage and winter desiccation. High concentrations of salts from deicing compounds may kill turf, especially along sidewalks or roadways that are salted heavily. Browning due to winter desiccation or winter burn of turf is common on exposed sites that lack protective snow cover.

Leaf spot and melting-out

This group of diseases was formerly known as Helminthosporium leaf spot. The name was changed recently because the fungi causing the diseases were reclassified as species of *Bipolaris* and *Drechslera*. At least three species in this group can cause disease on Kentucky bluegrass. All three fungi cause similar symptoms, and they can occur at any time during the growing season. Initial symptoms are diamond-shaped spots with light tan-to-brown centers and dark red to purple-brown borders. When confined to the leaf spot stage, the fungi do not cause severe losses. However, the disease may move from the blades down into the crown area, causing a reddish brown discoloration of the crown and killing large, irregular-shaped areas of a lawn. This stage is known as melting-out. Leaf spot may be controlled by proper watering and fertilization, mowing at the correct height, controlling thatch, and applying recommended fungicides.

Dollar spot

Dollar spot is most active during warm days, cool nights, and high humidity. Dollar spot can be recognized by its round, brownish, or bleached tan spots in the turf that are up to 4 to 6 inches in diameter. If left unchecked, the spots may merge to form large, irregular, straw-colored patches of dead grass. Individual blades are girdled with yellow-to-light tan lesions. These lesions may have reddish brown borders. When dollar spot is active, a white, cobwebby growth

(mycelium) sometimes can be seen on the grass leaves while dew is still present. Dollar spot may be controlled by maintaining adequate fertility, watering properly, and applying recommended fungicides as soon as the disease is first evident.

Summer patch and necrotic ring spot

This pair of diseases was formerly known as Fusarium blight. They are now known to be caused by two different species of fungi. The fungus that causes summer patch is favored by high temperatures and high humidity, so the disease occurs only during the summer in Iowa. Necrotic ring spot can occur in cool as well as warm weather, so it can attack turfgrass from spring through fall. The symptoms of summer patch and necrotic ring spot are the same. Initially, patches of blue-gray wilted grass occur in the lawn. Later, the color changes to a dull reddish brown, then tan, and finally a light straw. The patches may form circles, crescents, or elongated streaks. Apparently healthy grass may occur within the center of patches of dead grass, giving a frog-eye pattern. Poor cultural practices may weaken the turf and predispose it to these diseases. To control this disease, make sure the lawn is watered properly, avoid excessive fertilization, control thatch, and plant resistant cultivars. Several fungicides are labeled for use against summer patch and necrotic ring spot, but these materials can be effective only when applied in combination with an integrated management program.

Pythium blight

Pythium blight is a hot-weather disease. The fungus that causes this disease is most active when daytime temperatures are 85 to 95°F, when nighttime temperatures remain above 68°F, and when relative humidity is high. Initially, round to irregular spots form on the leaf blade. The plants in these areas are water soaked and dark, then fade to a light brown as the leaves dry out and wither. A dark, greasy border may surround the spot. When the fungus is active, a cottony mass of fungal mycelium may cover the matted grass blades. The patches enlarge rapidly and can kill large areas of turf in a short time, thus making Pythium blight a very destructive turfgrass disease. It may be controlled by following a balanced fertility program, providing good surface and subsurface soil drainage, watering properly, and applying recommended fungicides when conditions are favorable for Pythium blight.

Rust

Rust usually occurs late in the summer when grass growth is slow because of extended dry periods or low fertility. Grass infected with rust becomes reddish brown or yellow-orange. Close examination of the blades reveals powdery, rusty red, or yellowish orange spots on the blades. The powdery material, which rubs off easily, consists of masses of fungal spores. The best control for rust is to maintain good vigor in turf throughout the season. Fungicide applications when rust is first seen aid in control.

Powdery mildew

Powdery mildew occurs chiefly in late summer and fall, although it also may occur in early spring. With powdery mildew, blades are covered with a whitish, powdery-like growth. This disease is most severe on Kentucky bluegrass grown in the shade. Management strategies for this disease include planting shade-adapted cultivars in

shady sites, keeping the lawn actively growing by adequately balancing fertilization and watering, mowing frequently to the recommended height, increasing air circulation, and reducing shade by properly pruning dense trees and shrubs. The disease may be checked by thorough application of a recommended fungicide as soon as mildew first occurs.

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Insect pests of turfgrass

In Iowa, several insects inhabit the turfgrass but relatively few are serious pests. All parts of the turfgrass—roots, crown, and leaves—can be eaten by insects. Proper management to promote good turfgrass health is the best defense against serious damage by turfgrass insects.

Soil-inhabiting pests

Damage to the roots occurs by insects that live for at least part of their life in the soil and feed on living root tissue. The noticeable symptom of extensive root-feeding damage is usually an irregular area of dead turf.

Annual white grub

Several species of beetles have soil-dwelling larvae called white grubs. In Iowa, the common white grub is called the annual white grub because the entire life cycle is completed in 1 year. Wilting and light tan discoloration are early symptoms of white grub damage. Extensive feeding causes large, irregular areas of the turf to die in late summer.

The larvae overwinter deep in the soil but come up to the root zone to feed in the spring. Adults, called masked chafers, emerge in June to mate and lay eggs. Adults feed on foliage of shade trees, but

rarely cause noticeable damage. Larvae begin feeding in mid-July, and damage becomes apparent during August or September. Rolling back the damaged turf exposes the white grubs. They are usually located in the top 2 inches of soil. If the grubs are not found in the soil during this inspection procedure, some other problem is the cause of the dying turf. The amount of damage caused by white grubs varies with the health and vigor of the turfgrass and the amount of water available to the grass. Healthy, well-watered turf can withstand populations as large as 20 grubs per square foot, but weakened, drought-stressed grass may be killed by populations half that size.
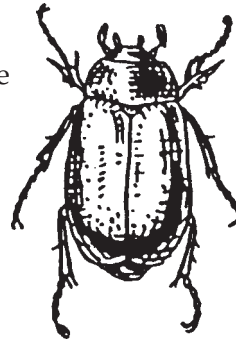
Management of white grubs is often difficult because population size is variable from year to year, and damage is nearly impossible to predict. Strategies involving insecticide use fall into two categories: preventive or curative. The preventive approach is to treat the whole lawn every year. A turfgrass manager considers the heavy use of a high-priced insecticide preferable to any white grub damage. The insecticide must be applied before the first week of August to be effective. Monitoring in late July and August will determine whether a curative insecticide treatment is warranted for a turfgrass area. The best control is achieved when grubs are small. Treatments applied after grubs are large and damage is severe usually are less effective. Insecticide controls must be watered into the turf to carry the insecticide to

where the grubs live. If a spray treatment is used, watering must follow the application immediately.

Japanese beetle

A species new to Iowa is the Japanese beetle. Extensive damage to turfgrass and woody ornamentals has occurred in states where this pest has become established. The grubs feed on turfgrass roots and the adults cause defoliation of several trees and shrubs. Larvae can reach ¾ inch in length and have a V-shaped rastral pattern.

Adults are ½ inch in length, have a metallic green and copper body, and six sets of white hair tufts along the side margin of the abdomen. The Japanese beetle has a 1-year life cycle beginning with egg-laying in mid-July and larval feeding beginning by mid-August.

See the appendix (page 77) for a key to identifying turfgrass beetle pests as grubs (using the raster) or adults (page 78).

Stem- and leaf-feeding pests

The second group of turfgrass insect pests feeds above ground. These pests have chewing mouthparts and consume all or part of the stem or leaf blade.

Bluegrass billbug

Many areas in Iowa are troubled by bluegrass billbugs. Damage is caused by the larvae feeding inside the grass blades and crowns during early summer. Characteristic damage includes dead and dying plants that pull from the ground easily, and the presence of sawdust-like frass (excrement) in the crown area. By the time these symptoms are observed in midsummer, treatment would be too late. Billbug adults are active during late summer and early spring.

Control of bluegrass billbug is preventive. Sprays are timed to control the adults before females lay eggs in the grass crowns. Insecticide applications must be made very early in the spring, usually late March or April.

Sod webworm

Although infrequent and widely scattered in Iowa, severe damage occasionally occurs by sod webworms.

Sod webworm is a surface-feeding pest. The caterpillars live in the thatch, often in small burrows or tunnels lined with silk-like webbing. These pests leave their burrow at night and eat turfgrass foliage. Early sod webworm damage can be recognized by the presence of small, circular, brown patches of turf. These small patches run together to cause destruction of large areas.

Fully grown sod webworms are about 1 inch in length and are light tan with rows of dark spots. There are two generations of sod webworms each summer; one in early June and the second, more destructive generation, in early August. The low-flying sod webworm adults are usually noticeable in large numbers in the lawn before a damaging outbreak of caterpillars. A major difficulty in turfgrass maintenance is correctly diagnosing sod webworm infestations. Assumptions are made that any brown discoloration of turf is caused by sod webworms, whether the caterpillars are found or not. A careful site inspection is needed to determine the cause of turfgrass browning.

If an insecticide application is warranted from monitoring results, apply the spray to adhere to the turfgrass foliage. Avoid application before rain and DO NOT

irrigate in treated turf for several days postapplication. Treatment should be delayed until 2 weeks after a peak number of adults is observed and once caterpillars are present. Chemical efforts when adult moths are flying are wasteful and ineffective.

Cutworms

Several species of cutworms, such as the black cutworm and bronzed cutworm, occasionally are pests in turfgrass, especially in golf course greens. The cutworms feed on the grass surface, causing small, close-clipped dead areas. Controls should be applied only if cutworms are present. Effective control is achieved with evening treatments that just precede caterpillar activity.

Armyworm

Armyworms also may be an occasional problem on turfgrass. It is unusual for widespread or serious destruction of the turfgrass to occur, although localized feeding by large numbers of armyworm caterpillars may cause serious damage to stressed turfgrass.

Sap-feeding pests

Insects with piercing/sucking mouthparts feed on turfgrass by sucking plant sap from the leaves and stems. Although several sap-feeding insect pests occur on turfgrass in other parts of the United States, only the greenbug aphid is common in Iowa.

Greenbug aphid

The greenbug aphid is an occasional turfgrass pest in Iowa, with scattered incidences of severe damage reported. Suspect areas should be examined carefully to confirm the aphid's presence. Infestations generally occur in shady areas but can occur in full sun as well.

Damage from greenbug shows as orange or yellow discolored patches in circular or slightly irregular shapes. Continued aphid damage may lead to circular dead turfgrass patches surrounded by a narrow band of orange grass.

This small (2- to 3-mm), soft-bodied, light to dark green aphid is unmistakable. Close examination of leaf blades reveals the presence of the pest, frequently in densities of up to 30 aphids per grass blade. Kentucky bluegrass is the primary grass host species of the greenbug aphid.

Control is needed only while the greenbugs are present, which can be any time during mid-to-late summer. Under most situations, spot treatments are sufficient for control.

Nuisance pests

Turfgrass pest management frequently calls for attention to insects that inhabit the grass and create a nuisance but do not cause direct harm to the turf. Managing these nuisance pests is often important to the enjoyment and appreciation of the turfgrass.

Ants

Ants are generally beneficial in turfgrass, although they occasionally become objectionable because of their mounds or their accidental invasion of residences or buildings. In these situations, spot treatment of individual ant hills may be appropriate.

Clover mites

Clover mites are very tiny, red, and have eight legs. They feed on clover and other lawn plants but are not considered harmful to turf. Clover mites can become a nuisance when they enter residences and buildings or are present in large
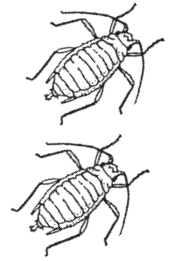
numbers. Migrations of clover mites usually are in the spring or fall. They are harmless when indoors but create an annoyance and may leave stains when crushed. A bare 18-inch-wide border around the foundation discourages clover mites from entering buildings. A foundation and perimeter treatment can be made at the first sign of accidental invasion.

Chiggers, fleas, and ticks

Biting pests such as chiggers, fleas, and ticks may infest turfgrass and diminish the use and enjoyment of the area. Although a well-kept lawn is not the usual habitat for these biters of people and pets, they can establish themselves in a lawn by dropping from rodents and pets, invading from adjacent grassy or woody areas, or spreading from nearby animal quarters. Carefully consider possible sources of biting pests before treating a lawn to control these nuisances.

Earthworms

Earthworms are highly beneficial organisms in turfgrass areas but are sometimes responsible for bumpiness or unevenness of the turf. Although it would be desirable to reduce or limit populations in these situations, there are no pesticides labeled for chemical control of earthworms. Unevenness caused by earthworms can be removed by power raking or light rolling in the spring or in the fall during periods of rapid grass growth.

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Weed management in turfgrass

Controlling undesirable weeds is the primary objective of many lawn management programs. This goal can only be achieved by using a season-long approach. Depending on a one-shot application of a herbicide as the sole means of weed control leads to unacceptable results. Once the weed has been identified, the three components of a successful management program include cultural, mechanical, and chemical control.

A competitive stand of turf is the basic requirement for preventive weed control. A dense, actively growing lawn is able to prevent the invasion of many undesired weeds.

Mowing at the recommend heights (page 34) shades the soil and protects grass roots from damaging effects of summer heat. In addition, the higher mowing heights are an excellent deterrent to the germination and growth of many annual weed species.

Proper fertilization and watering to furnish the turfgrass with food and water throughout the growing season may discourage weeds through competition.

When starting or renovating a turf area, use seed and sod that is free of weed seed. Many lawns contain undesirable coarse grasses and weeds because they were present in the sod or seed. If you buy grass seed, read the label to make certain undesirable weeds and grasses are not present. Inspect sod before purchase, if possible, and avoid sod with perennial grass weeds such as quackgrass or nimblewill.

Digging or pulling weeds is an effective method of controlling a few scattered weeds. With perennial weeds, such as dandelion and quackgrass, it is important to remove as much of the root as possible to reduce quick regrowth from the

rootstock. If a patch of turf is left bare due to digging out weeds, be sure to reseed or place a patch of sod in this area to prevent reinvasion of weeds.

Herbicide use is frequently the most effective and economical method of removing undesired plants. When used properly, these chemicals can control a broad spectrum of weeds with little risk of injury to the turfgrass or to nearby ornamentals and trees. Remember that the performance of a herbicide depends on the environmental conditions before, during, and after application. Occasionally, conditions occur that can reduce the level of control achieved.

Successful chemical weed control depends on correct weed identification and proper herbicide selection and application, according to the label.

Identification of common weeds

The first step in managing weeds is identifying the undesirable plant. Improper identification can lead to choosing a herbicide that is ineffective against the weed.

Morphology

There are three basic kinds of weeds: grasses, broadleaves, and sedges.

Grasses: True grasses have jointed, hollow stems. The leaf blades have parallel veins and are several times longer than they are wide. Crabgrass and quackgrass are typical grasses.

Broadleaves: Broadleaf weeds often have showy flowers, and the leaves have a network of small veins originating from a principal vein that divides the leaf in half. Dandelion, knotweed, and plantain are typical broadleaves.

Sedges: Sedges are grass-like plants with three-cornered stems that bear leaves extending in three directions. They are neither true grasses nor true broadleaves. Yellow nutsedge is an example of a sedge that may invade turfgrass.

Weed life cycle

Weeds can be further classified by their life cycle into the categories annual, biennial, or perennial. Knowing the life cycle of a plant is important in selecting a control strategy, especially when attempting to rid turf of undesirable grasses.

Annual: An annual plant begins growth each year from a seed, produces flowers, and dies in less than a year. Crabgrass and knotweed are examples of annuals. Most annuals germinate in the spring and complete their life cycle during the summer; however, winter annuals germinate in the fall and flower the following spring. Annual bluegrass can act as a winter or summer annual, which makes it difficult to control.

Biennial: A biennial requires 2 years to complete its life cycle. The first year the plant forms a rosette and develops a large root system. In the second year the plant produces flowers and then dies. Control methods are most effective when applied during the first year while the plant is still young. Wild carrot and mullein are examples of biennials.

Perennial: Perennials are plants that live for more than 2 years. During the winter many perennials die back to ground level but come back from the rootstock the following spring. Simple perennials, such as dandelion and plantain, reproduce only by seed. Creeping perennials can reproduce both from seeds and vegeta-

tive structures such as stolons or rhizomes. Ground ivy and quackgrass are examples of creeping perennials.

Relatively few species of weeds are adapted for competition with turfgrass; therefore, identification is fairly simple because the same weeds are found in most situations. The most common annual grasses are large crabgrass and goosegrass. The perennial grass weeds typically found in bluegrass turf are tall fescue, nimblewill, and quackgrass. Dandelion, ground ivy or creeping charlie, plantain, and black medic are perennial broadleaves commonly found in lawns. Annual broadleaves include common chickweed, prostrate spurge, and knotweed.

Identification of turfgrass weeds
Annual grasses
Annual bluegrass (*Poa annua*) is a winter annual or short-lived perennial that may predominate in closely mowed turf growing on compacted soils under moist, shaded conditions. It frequently occurs in dense, light-green patches. The seedheads are produced through most of the growing season and are especially abundant in mid-spring. Closely mowed perennial-type annual bluegrass is extremely susceptible to winter damage.

Crabgrasses (*Digitaria ischaemum* and *Digitaria sanguinalis*) are late-germinating annuals that reproduce by seed. The seedheads consist of several fingerlike projections at the terminals of the seed stalks. The spreading growth of crabgrass tends to crowd out desirable grasses. Like other summer annuals, crabgrass is killed by the first frost, leaving unsightly dead patches in turf.

Fall panicum (*Panicum dichotomiflorum*) is a late-germinating annual grass with short, purplish sheaths. The seedhead is an open, spreading panicle.

Goosegrass or silver crabgrass (*Eleusine indica*) begins germinating several weeks after crabgrass. It is similar to crabgrass except that the center of the plant is silver and the seedheads are zipper-like. It frequently occurs in compacted and poorly drained soils.
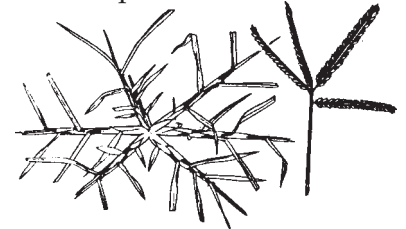
Yellow foxtail (*Setaria glauca*) is an annual grass that often occurs in newly seeded turfs. It can be identified by the presence of long hairs on the upper surface of the leaf blade near the base and by the cylindrical, yellow seedheads.
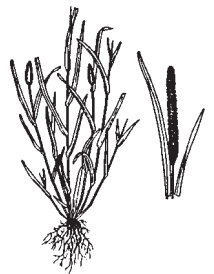
Perennial Grasses
Bermudagrass (*Cynodon dactylon*) is a perennial grass commonly grown in the southern United States. Because of its vigorous,

dense growth, it is a troublesome weed in bluegrass turf. The leaves are hairy at the junction between the blade and the sheath and on both sides of the blades.

Creeping bentgrass (*Agrostis palustris*) is a perennial grass that spreads by aboveground stems (stolons). It forms puffy, dense patches that may take over the turf. If creeping bentgrass receives close, frequent mowing and meticulous care, it makes a very attractive turf. When bentgrass occurs where it does not belong, however, it is considered a weed.

Nimblewill (*Muhlenbergia schreberi*) is a creeping perennial grass that forms patches resembling bentgrass. The leaf blades are short and flat.

Tall fescue (*Festuca arundinaceae*) is a coarse-textured perennial that often grows in unsightly clumps in the turf. In pure stands, however, tall fescue makes an acceptable turfgrass because of its good wear resistance and low maintenance requirements.
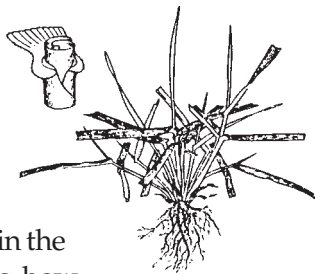
Quackgrass (*Agropyron repens*) is a perennial grass that spreads by underground stems (rhizomes). It may be identified in the turf by its dull green color and rapid foliar growth.
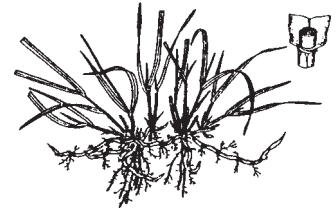
Broadleaf weeds and sedges

Black medic (*Medicago lupulina*) is an annual, biennial, or perennial that closely resembles white clover. It can be distinguished from white clover by its yellow flowers and the arrangement of its leaflets on the stem–the middle leaflet is borne on a short petiole and the lateral leaflets are close to the stem.

Carpetweed (*Mollugo verticillata*) is an annual with smooth, tongue-like leaves. The stems branch in all directions, forming flat, circular mats.

Chicory (*Cichorium intybus*) is a perennial that reproduces by seed. The taproot is large and fleshy. A rosette of leaves resembling dandelion leaves forms at the base. The bright blue flowers are born on rigid stalks that resist mowing.

Common chickweed (*Stellaria media*) is a creeping winter annual with small, pale green leaves. Its hairy stems branch and take root, enabling the plant to spread over large areas and crowd out turfgrasses. The white, star-like flowers bloom during cool seasons.

Curly dock (*Rumex crispus*) is a perennial that reproduces by seed. It has a fleshy taproot and large, smooth leaves that are crinkled on the edges.
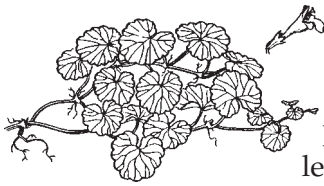
Dandelion (*Taraxacum officinale*) is a perennial that reproduces by parachute-like seeds. It is easily recognized by its sharply lobed leaves. The bright yellow flowers turn into fluffy, white seedheads.
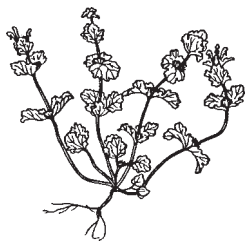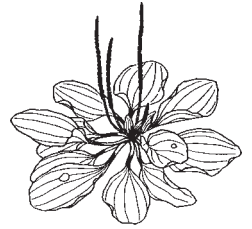
Ground ivy or creeping charlie (*Glechoma hederacea*) is a creeping perennial that forms dense patches in turf. Its bright green leaves are round with scalloped edges. The bluish-purple flowers are borne on four-sided stems. This plant grows well in shady areas where soils are poorly drained.

Henbit (*Lamium amplexicaule*) is an annual that reproduces by seed. It has a fleshy taproot and large, smooth leaves that are crinkled on the edges.
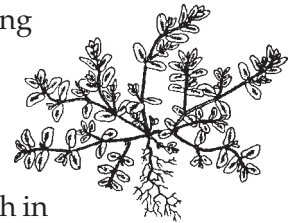
Knotweed (*Polygonum aviculare*) is a low-growing annual that first occurs in early spring. Its appearance is variable, depending upon the stage of maturity. Young plants have long, slender, dark green leaves that occur alternatively along the knotty stem. Mature plants have smaller, dull green leaves and inconspicuous white flowers. Knotweed grows well on heavily trafficked, compacted soils.

Mouse-ear chickweed (*Cerastium vulgatum*) is a perennial that reproduces mainly by seed but also by creeping stems. It can be identified by its small, fuzzy, dark green leaves and dense growth habit.

Nutsedge (*Cyperus esculentus*) is a perennial sedge that reproduces by seed, rhizomes, and small, hard tubers (nutlets). It can be identified by its triangular stems and yellow-green color. Nutlets may persist in the soil for several years, ensuring regeneration of the plants.

Plantains (*Plantago major* and *Plantago rugelii*) are perennials that reproduce by seed. The leaves form a basal rosette, with finger-like flower stalks protruding upward.

Buckhorn (*Plantago lanceolata*) is a perennial with lance-like leaves and bullet-shaped seeds on long, slender stems.

Spotted spurge (*Euphorbia maculata*) is a low-growing annual that usually occurs in mid-season. The small leaves are opposite and frequently have a red blotch in the center. The stem oozes a milky sap when broken.

Purslane (*Portulaca oleracea*) is a fleshy annual weed with smooth reddish stems. It may be particularly troublesome in new turf seedings.

Red sorrel or **sheep sorrel** (*Rumex acetosella*) is a clump-type weed with arrow-shaped leaves. It often grows in acidic soils that have low fertility.
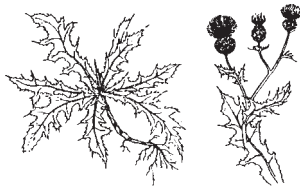
Roundleaved mallow (*Malva neglecta*) is an annual or biennial that reproduces by seed. It has a long taproot and rounded leaves with five distinct lobes. The white flowers first bloom in the late spring and then continuously throughout the growing season.
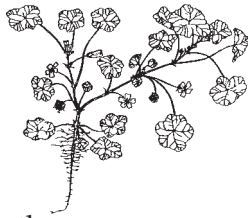
Thistles (*Cirsium* species) are perennials or biennials with spiny, serrated leaves. A rosette-type growth typically occurs when the turf is mowed. The numerous, sharp spines make these weeds particularly objectionable in turf.

White clover (*Trifolium repens*) is a creeping perennial that competes aggressively with established turfgrasses, especially under moist conditions in soils with low fertility. It can be identified by its three short-stalked leaflets and globular, white flowers.

Wild onion and wild garlic (*Allium* species) are perennial weeds with slender, cylindrical leaves. Wild garlic leaves are hollow; those of wild onion are not.

Yarrow (*Achillea millefolium*) is a fernlike perennial weed that spreads by rhizomes.

Under close mowing, it forms a dense mat and is wear-resistant and drought-tolerant.

Yellow woodsorrel (*Oxalis stricta*) is a pale green annual or perennial that reproduces by seed. It has heart-shaped leaves and yellow flowers with five petals.
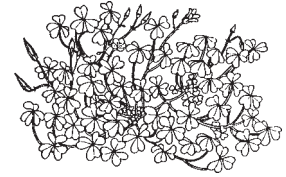
Herbicide selection

After a weed has been identified, the next step is to select the best herbicide to control the specific plant. Frequently, two or more herbicides are available that provide effective control of the weed. To choose the best chemical for this situation, the applicator must consider the stage of growth of the weed, risk of injury to the turf or nearby ornamentals and trees, type of application equipment needed, and the cost of treatment. In other cases, combinations of two or more herbicides are required to control the different weeds present in the lawn. Carefully read the herbicide labels for any restrictions regarding mixing.

Turf composed of bentgrass or warm-season grasses, such as buffalograss or zoysiagrass, may require different weed control programs from a bluegrass turf. For example, buffalograss, bentgrass, and seedlings are sensitive to 2,4-D. Check the herbicide label for restrictions concerning use on a specific turfgrass species.

Preemergence herbicides for annual grass control

Annual grasses such as crabgrass, annual bluegrass, barnyardgrass, and goosegrass are some of the most difficult weed problems in turf areas. Because of their similarity to desirable turfgrass species, control of these grassy weeds is difficult once they become established in the lawn.

However, several preemergence herbicides can effectively control these grasses when applied at the proper time. Preemergence herbicides are applied to the soil before the emergence of the weeds. Because these herbicides are effective only against grasses just beginning growth from seeds, the chemicals must be applied early in the spring before the seeds begin germinating. Because turfgrasses are perennials and resume growth from established roots, the turf is unaffected.

For control of crabgrass, preemergence herbicides should be applied before soil temperatures reach 65°F. Goosegrass germinates 2 to 3 weeks later than crabgrass, so if goosegrass is the only problem, applications can be delayed slightly for an extended period of control. Annual bluegrass germinates both in the spring and in the fall, which makes this weed especially difficult to control. A suitable preemergence herbicide must be applied in the fall, followed by a second treatment in the spring.

Two simple steps can ensure consistent performance from preemergence herbicides. First, before applying the herbicide, remove trash, leaves, and dead grass from the lawn. These materials reduce the amount of herbicide reaching the soil. Second, if rain is not expected soon after the application, watering the treated area moves the chemical into the soil where it can act against the germinating seeds.

Iowa State University researchers discovered a natural preemergence herbicide in the late 1980s. Corn gluten meal was found to prevent grass and broadleaf weed growth when applied before weed germination. This product also contains nitrogen, thus it can provide a portion of the fertilizer need of the turfgrass over a season. Corn gluten meal also is labeled for use in flowerbeds and vegetable plots.

Postemergence herbicides for annual grass control

Although the preferred method for control of annual grasses in turf is the use of preemergence herbicides, chemicals for postemergence control of crabgrass and other problem grasses are available. Postemergence herbicides are those that are applied to the foliage of weeds that have already germinated.

Some postemergence herbicides for annual grasses contain organic arsenicals that should not be confused with the more toxic inorganic arsenicals. DSMA and MSMA are the most common products. For effective control, weeds must be actively growing. Repeat applications at 7- to 14-day intervals are often required. Formulations that combine these arsenicals with 2,4-D provide broad-spectrum control of grasses and broadleaves.

Another postemergence herbicide is fenoxyprop (Acclaim). The best control is achieved when it is applied to actively growing grassy weeds in the three-leaf to one-tiller stage of growth. Do not use it in bentgrass and do not mix it with other pesticides or with fertilizers.

Postemergence herbicides for broadleaf weed control

A large number of herbicides and formulations to control annual and perennial broadleaves in turfgrass are available. To select the best herbicide for a specific situation, correct identification of the weed is critical. Usually, no single herbicide can control all the weeds that are present on turf . Thus, combinations of two or more herbicides are frequently

required. The most common formulations available are emulsifiable concentrates and granules. A liquid application generally provides better control of weeds than a granular formulation. However, there is a greater risk of injury to sensitive ornamentals and to gardens with a spray treatment due to drift. Weigh the risks and benefits when selecting the formulation to be used.

Postemergence treatments for the control of biennial and perennial weeds are generally most effective when applied in spring to early summer or fall. Whenever possible, fall applications are preferred to spring or summer applications because of the lower risk of injury to desirable ornamental and garden plants from herbicide spray or vapor drift.

Nonselective postemergence control of perennial grasses

Undesirable perennial grasses such as bermudagrass, tall fescue, nimblewill, and quackgrass frequently become established in turf areas. Because these species begin growth each year from established roots, they are unaffected by the preemergence herbicides used to control annual grasses such as crabgrass. The inorganic arsenicals also are ineffective against these weeds. Often, the most effective method of killing these weeds is the use of nonselective herbicides because few herbicides selectively control these grasses. These chemicals also kill the desired turfgrass; thus, they are only used to spot treat the infested area. If only small scattered areas of the weeds are present, manual removal of these weeds is practical. However, if the entire turf area is heavily infested, complete lawn renovation may be the best choice.

Preventing herbicide injury to nontarget plants

Due to the proximity of gardens, ornamental trees, and shrubs to most turf areas, certain precautions must be taken with weed control measures to avoid contacting these desirable plants with herbicides. Several of the commonly used turf herbicides are toxic to ornamentals. Small amounts of these chemicals can severely damage or kill trees, shrubs, and garden plants growing near the application area. Understanding the factors that cause herbicide movement from the target area helps the applicator control weeds without injuring desirable plants.

Drift

Spray drift is the movement of airborne spray particles from the target area. Factors that affect the amount of drift include size of spray droplets, height of the nozzle above the ground, and wind speed.

The size of the spray droplet is the most important factor in determining the amount of drift. The smaller the droplets, the greater the risk of drift and injury to nontarget plants. Very small droplets can travel great distances even if there is little wind at the time of spraying. The size of the droplets emitted by a sprayer is determined by the spray pressure, type of nozzle, and the characteristics of the spray solution. A hand-held spray gun is the most common method of applying herbicides in urban areas. A spray gun provides the largest droplet size, thereby reducing the chance of drift. In general, high spray pressures increase the number of small droplets. Pressures near 20 psi are recommended when using flat-fan nozzles near susceptible plants.

The design of the nozzle also affects droplet size. Flat-fan nozzles are commonly used to apply herbicides. These tips are available with various sizes of orifices that regulate the rate of liquid delivered. A nozzle that delivers a higher volume at a given air pressure produces a smaller percentage of small droplets than the same type nozzle with a lower capacity. Although it is difficult to determine the size of spray droplets delivered by a sprayer, an applicator can reduce the risk of drift by keeping a close watch on the nozzles. A shroud of fog surrounding the nozzles indicates that the nozzles are putting out a large number of small droplets. In certain situations, special nozzles (Floodjet or Rainbird) or a drift-reducing spray additive (Nalco-Trol) may be required to reduce the risk of drift.

The height of the nozzle or boom can affect drift in two ways. First, as the height of the boom is increased, the time required for a spray droplet to reach the ground is increased. Second, wind speeds usually are much lower closer to the ground than at higher elevations. The higher the boom or nozzle is placed, the greater the risk of drift. Remember that if the boom is lowered, the nozzles must be changed or respaced. If the nozzles are changed, the sprayer must be recalibrated.

The third factor affecting drift is wind. Growth-regulator type herbicides should not be sprayed in areas near susceptible plants when the wind speed is greater than 5 mph. In general, the air is calmest in the early morning and just before sunset. If possible, spraying operations should be conducted at these times.

Volatilization
Herbicides also can move from the target area and injure plants by volatilization.

Volatility refers to the tendency of a chemical to vaporize (change into a gas). These fumes can move from the target area long after the spraying operation is completed. The difference between drift and volatilization is that drift refers to the movement of spray droplets from the target area before they reach the ground or target plant. During volatilization, herbicide fumes are released from the target area after the spray solution reaches the target. All herbicides are subject to drift if applied improperly, but only herbicides with a high vapor pressure are susceptible to volatilization. The turf herbicides that are susceptible to volatilization are 2,4-D and dicamba. These herbicides can severely injure nontarget plants if conditions are favorable for volatilization. The risk of injury is directly related to temperature. Dicamba or 2,4-D should not be applied if temperatures are expected to go above 85°F the day of application.

Phenoxy herbicides, such as 2,4-D, can be formulated to alter their volatility. Choosing a nonvolatile formulation is important for weed control in turf. Formulations of 2,4-D commonly available are esters, low-volatility esters, and amines. Esters are the most active forms of 2,4-D; however, due to their high volatility they should not be used in turf areas. Only amine formulations are recommended for use on turf. Amine formulations are as effective against most herbaceous weeds as esters, and their low volatility reduces risk of injury to desirable plants.

Root uptake
Another method in which a herbicide can injure nontarget plants is by movement of the herbicide into the root zone of trees and ornamentals where it can be absorbed. The primary turf herbicide that

normally causes this problem is dicamba. Because of this danger, dicamba should only be used as a spot treatment to control weeds not susceptible to 2,4-D or MCPP. Never apply dicamba under the drip lines of trees or shrubs growing in turf areas.

Growth regulators for turfgrass
Chemical growth regulators that slow the growth rate of grasses may be used in turf to reduce the amount of mowing. These chemicals **should not** be used in areas that receive heavy traffic because turf regrowth is required to replace the worn grass.

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Application equipment and calibration
Many types and sizes of equipment, ranging from aerosol cans to airplanes, are used to apply pesticides to lawns, golf courses, and other turf areas. Despite the many possible variations and combinations of equipment, most pesticides are applied to turf with manually operated sprayers, power-operated spray booms or spray guns, and granular applicators. Each of these application devices has its distinct uses and features.

Manual sprayers
Manual sprayers, such as compressed-air and knapsack sprayers, are designed for spot treatment and for areas unsuitable for larger units. They are relatively inexpensive, simple to operate, maneuverable, and easy to clean and store. Compressed air or carbon dioxide is used in most manual sprayers to apply pressure to the supply tank and force the spray liquid through a nozzle. Adjustable spray guns are commonly used with these units, but small spray booms are available on some models.

Calibration of manual sprayers
Because hand sprayers are generally used to spray limited areas, the amount of spray volume should be determined on small areas such as 1,000 square feet.

Most manual compressed air sprayers do not have pressure gauges or pressure controls. The pressure in the tank drops as the material is sprayed. This pressure drop can be partially overcome by the following methods:
1. Fill the tank only two-thirds full so that considerable air space remains for initial expansion; and
2. Repressurize the tank frequently. If the sprayer has a pressure gauge, repressurize when the pressure drops approximately 10 psi from the initial reading.

When spraying, either hold the nozzle steady at a constant height and walk back and forth, or swing the nozzle in a sweeping, overlapping motion. Maintain a uniform walking speed during application.

Step 1. Measure and mark off an area of 1,000 square feet (for example, 20 feet by 50 feet). Practice spraying the area with water. To obtain the most uniform application, spray an area twice, with the second application at right angles to the first application.

Step 2. Once you are able to maintain a uniform spray, add a measured amount of water to the tank, spray the area, and then measure the amount of water remaining in the tank. The difference between the amount in the tank before and after spraying is the amount used.

For example, 2 gallons added to the tank minus ½ gallon remaining equals 1½ gallons used per 1,000 square feet.

Power sprayers

Most sprayers for applying pesticides to turf areas use a power source to develop the pressure required to meter and distribute the spray solution. Spray pressures range from nearly 0 to more than 500 psi, and application rates vary from less than 1 quart per 1,000 square feet to more than 100 gallons per acre. All power sprayers used by turf applicators have several basic components: a pump, a tank, an agitation system, a flow-control assembly, and a distribution system.

Large turfgrass areas can be sprayed with a boom or hand boom sprayer with conventional nozzles or a spray gun.

The proper selection of nozzle type and size is of primary importance in applying pesticides to turf. The nozzle determines how much spray is applied to a particular area, the uniformity of the applied spray, the coverage obtained on the sprayed surface, and the amount of drift. You can minimize drift by selecting nozzles that give the largest drop size while providing adequate coverage at the intended application rate and pressure. Although nozzles have been developed for practically every kind of spray application, only a few types are commonly used for applying pesticides to turfgrass areas: regular flat-fan nozzles, hollow-cone nozzles, off-center, flat-fan nozzles, broadcast nozzles, raindrop nozzles, and flood nozzles.

Spray guns for spraying turf range from those that can produce a low flow rate with a wide-cone spray pattern to those that can produce a high flow rate with a straight-stream spray pattern. It is difficult to obtain uniform coverage from a spray gun on turf areas, without extra skill and practice.

Calibration of power sprayers

The performance of any pesticide depends upon the proper application of the correct amount of chemical. Most performance complaints are directly related to errors in dosage or to improper application. The purpose of calibration is to ensure that your sprayer is applying the correct amount of material uniformly over a given area.

Three variables affect the amount of spray mixture applied per 1,000 square feet or per acre:
1. nozzle flow rate,
2. ground speed of the sprayer, and
3. spray width per nozzle.

To calibrate and operate your sprayer properly, you must know how each of these variables affects sprayer output.

There are many methods for calibrating power sprayers, but they all involve the variables mentioned above. Any technique for calibration that provides accurate and uniform application is acceptable. No single method is best for everyone.

Refer to the *Iowa Core Manual* for additional information on power sprayer calibration.

Mixing pesticides

To determine the amount of pesticide to add to the spray tank, you need to know the recommended rate of pesticide, the capacity of the spray tank, and the calibrated output of the sprayer.

The recommended application rate of the pesticide is given on the label. The rate is usually indicated as pounds per acre or ounces per 1,000 square feet for dry formulations, and as pints, quarts, or gallons per acre for liquids. Sometimes the recommendation is given as pounds of active ingredient (lb a.i.) per acre. The active ingredient must be converted to actual formulated product to calculate the amount of product to add to the spray tank.

Granular applicators

Many turf-care applicators use granular products as a part of their pest control programs. Proper selection, care, calibration, and use of granular applicators can minimize costs and maximize the results obtained. Improper use of granular applicators can reduce pest control, cause injury to turf, increase costs, and damage the spreaders.

Drop (gravity) and rotary (centrifugal) spreaders are available for applying granules to turf. There are advantages and disadvantages associated with each spreader. Drop spreaders are usually more precise and deliver a more uniform pattern than rotary spreaders. Because the granules drop straight down, there is also less chemical drift. Some drop spreaders cannot handle larger granules, uneven ground, or wet turf. Moreover, because the edges of a drop-spreader pattern are sharp, any steering error causes missed or doubled strips. Drop spreaders also usually require more effort to push than rotary spreaders.

Operating procedures

Experienced turf-care operators are familiar with the proper use of granular applicators, but new operators need to review the basic operating procedures.

First, read the operator's manual and follow the manufacturer's instructions carefully. Second, read the product label and select the appropriate rate and pattern settings for specific conditions.

Header strips provide an area in which to turn around and realign the spreader. An operator should always move the spreader at normal operating speed on the header strip and then activate the spreader as it enters the untreated turf . When the operator reaches the other end, the spreader should be shut off while moving and then stopped and turned while in the header strip. A spreader should never be open while stopped because an excessive amount of product will be applied to a small area. In addition, the end turns should not be made with the spreader open because the pattern will be irregular while the spreader is turning.

Occasionally, it may be impossible to obtain a completely acceptable pattern with a rotary spreader, and streaking of the turf may result. A common reaction to this problem is to reduce the setting by half and go over the area twice at right angles. Instead of "averaging out" the pattern, as is generally believed, this procedure usually changes the streaks into a diagonal checkerboard. **It is better to reduce the setting and swath width by half and go back and forth in parallel swaths.**

Do not operate your spreader backwards. When pulled backwards, most rotary spreaders deliver an unacceptable pattern. Drop spreaders do not maintain a constant application rate if operated backwards.

Finally, set and fill the spreader on a paved surface rather than on a turf area. If a spill occurs, a driveway is much easier to sweep clean than turf. Some rotary spreaders shut off one side of the pattern. This feature is desirable when edging a driveway, sidewalk, or other nonturf area.

Uniform application

There are two important aspects to the precision application of granular products. The first is the product application rate (the amount of product applied in pounds per 1,000 square feet). Every product, whether a fertilizer or pesticide, is designed and recommended for application at a specific rate. Overapplication is costly, increases the risk of plant injury, and may be illegal if label recommendations are exceeded. Underapplication can reduce pest control.

The flow rate from granular applicators does not change in the same proportion as changes in speed. For example, doubling the speed does not double the flow rate. A constant ground speed is necessary to maintain a uniform application rate.

Second, even distribution of the product is as important as the application rate. For example, the pesticide label may indicate an application rate of 4 pounds per 1,000 square feet, and a spreader may apply that amount; however, the pesticide may not be applied uniformly over the 1,000 square feet. It is especially important to obtain uniform distribution of granules on turf because even small differences in application rate can result in obvious streaks.

The pattern applied by a rotary spreader depends upon impeller characteristics (height, angle, speed, shape, and roughness), ground speed, the drop point of the product on the impeller, the physical properties of the product, and environmental conditions (e.g., temperature, humidity, wind). Methods for adjusting the pattern include blocking off part of the metering ports on some units and moving the metering point or impeller on other units. If pattern skewing cannot be fully corrected by following the recommendations of the manufacturer , other means, such as varying the speed or tilting the impeller, can be used. When a product is so heavy or so light that skewing cannot be eliminated, it may be necessary to use a wider swath width on one side than on the other.

Calibration of granular applicators

Many suppliers recommend spreader settings and swath widths for their products, but these should be used only as "initial guides" for calibration runs before actual use. Every drop or rotary spreader should be calibrated for proper delivery rate with a particular product and operator because of variability in the product, the operator's walking speed, and environmental conditions. Calibration should be checked and corrected according to the manufacturer's directions at least once a week, and more often if the spreader has received mechanical damage.

The easiest method for checking the delivery rate of a spreader is to spread a weighed amount of product on a measured area (at least 1,000 square feet for a drop spreader and 5,000 square feet for a rotary spreader), and then to weigh the product remaining in the spreader to determine the rate actually delivered.

To avoid contamination of the turf area during initial calibration, place the spreader on a support and try to spin the drive wheel at your walking speed but with the spreader remaining stationary. Another method is to hang a catch pan or bag under the spreader and push the spreader a measured distance at the proper speed. The container must be hung so that there is no interference with the shut-off bar or rate-control linkage.

It is necessary to check both the distribution pattern and the flow rate of a rotary spreader. The product manufacturer may recommend a particular swath width, but you should verify this width before treating a large number of turf areas. You can check the pattern by laying out a row of shallow pans on a line perpendicular to (at right angles to) the direction of travel. For commercial push-type rotary spreaders, the pans should be 1 to 2 inches in height, with an area of about 1 square foot, and spaced on 1-foot centers. The row of pans should cover 1½ to 2 times the anticipated effective swath width. Add granules to the spreader, set it at the recommended setting for rate and pattern, and make three passes over the pans, operating in the same direction each time. The material caught in the individual pans can then be weighed and a distribution pattern plotted.

A simpler method for checking the distribution pattern is to pour the material from each pan into a small bottle. When the bottles are placed side by side in the proper order, a plot of the pattern becomes apparent. This pattern can be used to detect the correct skewing and to determine the effective swath width (twice the distance out to the point where the rate is half the average rate at the center). For example, if the center three or four bottles have material 2 inches in depth, and the bottles 6 feet to the left and 6 feet to the right of the spreader centerline have material 1 inch in depth, the effective swath width is 12 feet.

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Measuring small land areas

It is essential to know the amount of area that you intend to cover when applying a pesticide or fertilizer. Turf areas such as home lawns and golf course greens, tees, and fairways should be measured in square feet or acres, depending upon the units needed.

Rectangular areas
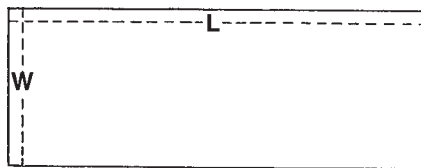
Area = length (l) × width (w)
43,560 = number of square feet in an acre

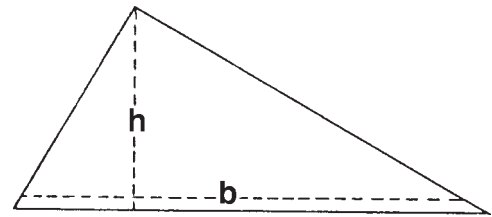Example: A fairway measures 980 feet long by 150 feet wide. What is the area?

Area = 980 feet × 150 feet = 147,000 square feet

To determine the area in acres, use the following equation:

Area in acres = $\dfrac{\text{area in square feet}}{43,560}$

Area in acres = $\dfrac{147,000 \text{ square feet}}{43,560}$ = 3.4

Triangular areas

Area = $\dfrac{\text{base (b)} \times \text{height (h)}}{2}$

Example: A lawn in a corner lot has a base of 500 feet and a "height" of 100 feet. What is the area?

Area = $\dfrac{500 \text{ feet} \times 100 \text{ feet}}{2}$ = 25,000 square feet

Area in acres = $\dfrac{25,000 \text{ square feet}}{43,560}$ = 0.6

Circular areas
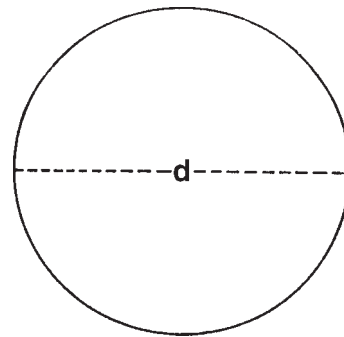
Area = $\dfrac{\pi d^2}{4}$ or πr^2
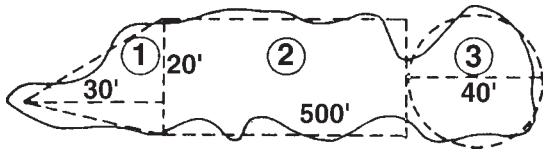
π = 3.14
d = diameter
r = radius (half the diameter)

Example: A golf course green has a diameter of 40 feet. What is the area?

Area = $\dfrac{3.14 \times (40)^2}{4}$ = $\dfrac{3.14 \times 1,600}{4}$ =

$\dfrac{5,024}{4}$ = 1,256 square feet

Irregular areas

Any irregularly shaped turf can usually be reduced to one or more geometric figures. The area of each figure is calculated and the areas are then added to obtain the total area.

Example: What is the total area of the Par-3 hole illustrated above? The area can be broken into a triangle (area 1), a rectangle (area 2), and a circle (area 3). To determine area 1, use the equation for area of a triangle.

$$\frac{30 \text{ feet} \times 20 \text{ feet}}{2} = 300 \text{ square feet}$$

To determine area 2, use the equation for area of a rectangle.

$$500 \text{ feet} \times 20 \text{ feet} = 10,000 \text{ square feet}$$

To determine area 3, use the equation for areas of a circle.

$$\frac{3.14 \times (40 \text{ ft})^2}{4} = 1,256 \text{ square feet}$$

To obtain the total area of the Par-3 hole, add areas 1, 2, and 3: $300 + 10,000 + 1,256 = 11,556$ square feet.

To determine the area of the Par-3 hole in acres, divide the number of square feet by 43,560.

$$\frac{11,556 \text{ square feet}}{43,560} = 0.27$$

Greenhouse pest management

Throughout much of the year a greenhouse exists as an oasis of green. Greenhouse crops know no winter, nor do they undergo prolonged droughts. Therefore, the greenhouse is the most favorable place for the existence, multiplication, and spread of insects, mites, and disease-causing agents. It is almost impossible to grow a commercially acceptable greenhouse crop without an effective pest management program.

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Integrated pest management

Pests gain entrance into greenhouses in many ways. During the summer, open vents and doors offer ready access. Moths are attracted by lights at night and readily enter if vents are open. Some pests are brought in on plants that are exchanged between growers. Poor-quality cutting material that is bought or salvaged at the end of the summer is commonly a source of pest problems. Finally, pests come in with soil, mulching materials, or equipment from outdoors.

Early detection and prompt action are the bases for successful management programs. If a pest is detected before it has an opportunity to spread or build up in large numbers, control measures can be applied with generally satisfactory results. Early action depends upon correct identification of the cause of the problem.

Diagnosis of a problem is simpler when the pests are present and visible on the plants, for example, aphid or powdery mildew infestations. Sometimes, however, the pest is invisible to the unaided eye, as is usually the case with disease-causing agents. In these instances, the symptoms or damage done by the pests must be recognized.

Symptoms may not be clear for pinpointing a disease or pest problem. Some symptoms are very general and can result from a number of causes; for example, stunting of growth from root-rotting organisms. Knowledge of the life cycles of the pests and of the environmental conditions helps in making a correct diagnosis of the problem.

All greenhouse growers should practice preventive pest management, which involves much more than insurance applications of pesticides. Nonchemical control methods should not be overlooked, particularly preventive measures such as quarantines on new plant material so that pests are not introduced into production areas. Keeping the plant under the best growing conditions takes advantage of any natural resistance it might have against insects or disease. Good greenhouse sanitation helps to keep crops free of pests. Weeds and leftover plants can harbor pests and may be a source of reinfestation. Manipulating greenhouse conditions to not favor pests also aids in preventive pest control.

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Pesticide use

Many pesticides, especially insecticides, are highly toxic and their use in the greenhouse can present a serious danger to both the applicator and plant material if handled carelessly or improperly.

These products include chemicals to control insects (insecticides), mites (acaricides), fungi (fungicides), weeds (herbicides), nematodes (nematicides), slugs and snails (molluscicides), algae (algicides), and soil sterilizers (fumigants).

However, if all precautions are followed meticulously, risks of using these chemicals are reduced. They should not be used by unsupervised, inexperienced personnel, or in greenhouses used for demonstrations, exhibits, teaching, or horticultural therapy. Restricted use pesticides must be applied by certified applicators.

To use a pesticide safely and effectively, the product label should be read thoroughly each time a control treatment is being considered. By law, pesticides must be used in accordance with label directions. Make sure the proper pesticide is being used. Review the label for key restrictions and information about potential plant injury and possible indirect effects of use. Treat only those plants indicated on the label at the correct dosage and mixing rates. Follow all directions relative to frequency of application, intervals between applications, and periods necessary before reentry or sale.

Review the *Iowa Core Manual* for a discussion of personal safety equipment. All routes of entry (dermal, ingestion, inhalation) must be protected adequately during greenhouse pesticide use. Especially important is respiratory protection (gas mask or respirator) during application of mists, aerosols, fogs, or vapors. Dermal protection (rubber gloves and boots) and eye protection (goggles or face shield) are essential when handling highly toxic pesticides.

Plant injury

Phytotoxicity is a term referring to plant injury caused by chemicals, particularly pesticides. Greenhouse plants seem to be especially prone to this problem, in part, because of the variety of plants often grown or held in one common area. Signs of phytotoxicity include the following:
- tips or marginal burn of leaves;
- chlorosis in spots, at tips, or on margins of the leaves;
- leaf distortion, including curling, twisting, or cupping;
- stunting or growth reduction in the size of entire plants or certain parts; and
- abnormal or excessive growth of certain plant parts.

Flowers and bracts (plant parts that are usually the most critical to sales) are especially sensitive to phytotoxins. New growth is most commonly affected when systemic chemicals are improperly used. Soil drenches and granular treatments may cause root injury, resulting in decline, stunting, and damage to older leaves.

Pesticide injury to the crop can be avoided by reading the cautions on the pesticide label and by using the recommended concentrations. Other precautions include the following:
- do not apply pesticides to plants under stress;
- avoid spraying under extremely hot, sunny, humid conditions;
- apply sprays in the morning between 6:00 and 10:00 AM;
- avoid treating when temperature extremes are likely;
- apply pesticides when foliage is dry and conditions are conducive to drying;
- use wettable powders rather than

emulsifiable concentrates when possible;

- do not mix pesticides without prior experience–check compatibility;
- keep nozzles of aerosols or mist blowers at least 18 to 24 inches from treated plants;
- never spray insecticides in equipment that has been used for applying herbicides (tanks, pumps, hoses, or guns);
- clean sprayer, tank, pump, hose, and gun after each use;
- do not let spray mixes stand in the sprayer;
- do not expose spray concentrates to extreme heat or freezing; and
- read **all** of the label directions every time you use each pesticide.

Biological control

Using living organisms to reduce or prevent plant damage is gaining acceptance in some greenhouse operations. Growers can release predators (consume pests directly), parasitoids (develop in and kill pests), and pathogens (cause pest-specific diseases) in their greenhouses. These releases replace insecticide and miticide applications because such pesticides also kill the pests' natural enemies. Biological control, however, requires a longer time to be most effective, several natural enemy releases, and greater plant damage compared with chemical management. Therefore, this program may have limited use in high-value ornamental crops.

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Plant diseases of greenhouse crops

Diseases of greenhouse plants are difficult to diagnose because most of the causative pathogens are microscopic. Diagnosis is further complicated by the number of environmental conditions (e.g., excessive soil moisture or salt toxicities) that produce symptoms similar to those caused by plant diseases. However, correct identification of the plant disease and the pathogen involved is crucial if effective control decisions are to be made.

Many greenhouse crop diseases may be identified accurately by carefully observing physical symptoms on affected plants, by carefully examining plants for signs of the pathogen involved (e.g., rust pustules on lower leaf surface), and by noting the pattern of symptom development in the greenhouse and the environmental conditions favoring development of the disease. Diseases of greenhouse crops may be caused by fungi, bacteria, viruses, and nematodes. The following description of common greenhouse diseases caused by these various pathogens should help growers diagnose disease problems in the greenhouse.

Fungal diseases

Many of the common diseases encountered in a greenhouse are caused by fungi. These microscopic plants lack chlorophyll and cannot produce their own food by photosynthesis. Therefore, they attack the living tissues of a plant to obtain necessary nutrients. The result is weakening, disfigurement, or death of the plant. Cultural practices such as sanitation, disease-free propagation material, proper plant spacing, and proper watering are important in preventing and

managing fungal diseases. Fungicides also are available for many of these diseases.

Soilborne diseases

The fungi responsible for soilborne diseases may cause seed decay, damping off (death of young seedlings), cutting rots, root and stem rots, and wilt diseases. Generally, the seed decay, damping off, and various rots are caused by either the water molds *Pythium* and *Phytophthora* or by other soil fungi such as *Rhizoctonia*, *Fusarium*, *Cylindrocladium*, *Thielaviopsis*, and *Sclerotinia*. Seed decay, damping off, and cutting rots are more readily identified than root rots. Symptoms of root rots on aboveground portions of affected plants include a general decline in plant vigor, wilting and yellowing of foliage, and eventual death of leaves and stems. Root rots are easier to identify when plants are removed from their containers so the root systems can be examined. Affected plants tend to have small, poorly developed root systems with few fine feeder roots. The roots present are discolored, deteriorated, and break easily.

The fungi *Fusarium oxysporum* and *Verticillium albo-atrum* cause wilt diseases of several greenhouse crops. These fungi invade through the root system and grow in the vascular (water-conducting) tissues of the plant. Typical symptoms are wilting of affected plants and brown discoloration of the vascular tissues.

Symptoms of the soilborne diseases vary depending on the plant species and the specific soil fungus. Furthermore, the environmental conditions favoring disease development vary with the different soilborne fungal pathogens.

Management: Prevention is the key to controlling soilborne fungal diseases. Root rots, wilts, and damping off are much easier to prevent than to control. Methods for preventing soilborne diseases include proper soil or mix preparation, good cultural and sanitation practices, and, if needed, supplemental chemical treatments.

Soil or Mix Preparation: Because the fungi that cause soilborne diseases may be spread in infested soil or sand, proper treatment of soil, sand, or mixes containing soil or sand before planting is crucial. Treatment may be either steam pasteurization or chemical fumigation. When steam is used, the temperature of the soil should be raised to 180°F for 30 minutes. The temperature of the soil should be measured with a soil thermometer at the point in the pile that is the slowest to heat. When the temperature at that point reaches 180°F, begin timing the 30-minute interval. Steaming may be done to soil in bulk, in benches, or in flats or pots, but is most successful if soil is either in a confined space or covered. Steam treatment may be done by using a steam boiler, hot water boiler, or portable steam generator. Soil being steamed should be loosened and watered before the steam treatment. After steaming, the cover over the soil should be removed to prevent condensation from making the soil too wet.

If the soil is stacked in large piles in a moist condition after it has been steamed, nitrites may form. Nitrate formation is particularly common if manure is used. The amino acids and proteins in the manure are converted to ammonium by microorganisms. Under conditions of good aeration, the ammonium is changed to nitrites, then quickly to nitrates. However, if the soil is unduly moist, there may

not be sufficient oxygen except near the surface of a soil pile for conversion of nitrites to nitrates. Because nitrites in small quantities are very toxic to plants, the soil should neither be stacked in large piles nor maintained in an unduly moist condition. Tile or perforated pipe should be placed at intervals in the soil pile to permit air to enter.

Fumigants: Certain chemical fumigants (e.g., chloropicrin or methyl bromide) also are being used as energy-efficient methods of ensuring good soil sanitation. When using a fumigant, the temperature of the soil being treated should be 60°F or higher and the soil should be loosened and watered before fumigation. Let the fumigated pile stand undisturbed for 24 to 48 hours. Then remove the cover and let the media aerate for at least 72 hours. After 1 day, it can be worked or turned to speed aeration. Chloropicrin is extremely toxic to living plants and should not be used near them. Methyl bromide is extremely toxic to humans and must be used carefully. Residues of methyl bromide left in the soil after fumigation may cause poor germination of certain plant species. Once the soil, sand, or mix has been treated, great care should be taken to avoid reinoculation or contamination of the treated material.

Sanitation and Cultural Practices: Good sanitation practices are crucial in preventing soilborne fungal diseases of greenhouse crops. Good sanitation practices include the following:
- cleaning and disinfecting pots, flats, benches, and tools;
- keeping treated soil or equipment clean;
- keeping feet off benches;
- hanging up watering hoses;
- cleaning up walkways and under benches; and
- keeping animals out of greenhouses.

Good sanitation practices help to reduce the chances that soilborne pathogens will be introduced into the greenhouse operation and that soilborne diseases will develop in the greenhouse.

Proper cultural practices also are important in preventing the introduction of soilborne pathogens or the development of soilborne diseases. The value of disease-free cuttings, stock plants, or other propagative material cannot be overemphasized. The pathogens causing these diseases are readily spread in cuttings, stock plants, and soil adhering to roots. Culture-indexed or disease-free material is worth the expense. Practices that maintain good plant vigor and minimize injury to plants help to reduce problems with soilborne diseases.

Proper cultural practices include the following:
- using disease-free seed or stock plants;
- using new seed or properly stored seed;
- planting at proper depth;
- handling seedlings and young plants carefully;
- fertilizing properly; and
- watering properly.

If soilborne diseases do occur or if conditions are favorable for their development, then fungicide treatments may be necessary.

Leaf spot and blight
The diseases caused by these fungi are usually characterized by distinct lesions of varying sizes, shapes, and colors. Lesions may develop on leaves, flower

parts, or even petioles and stems. These lesions may coalesce to form larger areas of dead tissue. Some of the more common leaf and flower spotting fungi are *Alternaria*, *Botrytis*, and *Septoria*.

Alternaria: *Alternaria* usually infects plants after seedlings are transplanted to growing flats. Petunia, zinnia, verbena, and a few other species are especially susceptible. *Alternaria* causes tan to bleached lesions on the margin of the leaves. These lesions enlarge to engulf the entire leaf or stem. The fungus sporulates in the lesions and the spores may be splashed or carried by air currents to other parts of the same plant or to other plants. Once the spore lands on a susceptible host, there must be a film of free water on the leaf surface for the spore to germinate and cause a new infection.

Botrytis: Botrytis blight, caused by the fungus *Botrytis cinerea*, is commonly called gray mold because of the fuzzy, gray growth that it produces on infected plant surfaces. *Botrytis* normally does not infect healthy plant tissue directly. Rather, the fungus establishes itself on dead or dying tissues. Its metabolic products then diffuse into and kill adjacent healthy tissue. The numerous spores of *Botrytis* are splashed or carried by air currents to other plants. *Botrytis* favors high humidity and warm temperatures. It is frequently a problem on plant surfaces that are wet for extended periods and where plants are crowded.

Septoria: Septoria is a slightly different type of leaf spot disease. *Septoria* produces small, tan-to-light brown spots on the leaf, petioles, or stems. The fungus does not produce spores freely across the plant surface but rather produces spores in flask-shaped structures called pyc-

nidia. The pycnidia are formed in the centers of the small, tan lesions and look like grains of pepper scattered in the lesion. Under moist conditions, the spores ooze out of these pycnidia and are splashed, disseminated, or wind blown to susceptible plants.

All of these leaf spot and blight diseases are favored by high humidity, free moisture on the leaf surface, and warm temperatures. The most efficient means of control is manipulating greenhouse conditions to avoid extended periods of high humidity. Venting greenhouses in the early evening to reduce humidity can be crucial in controlling these diseases. It also is important to avoid splashing water on leaf surfaces when watering. Water early in the day so plant surfaces do not remain wet for extended periods. Proper plant spacing reduces humidity and prevents spread of diseases. Strict sanitation is also important because many leaf spot and blight fungi can survive in plant debris. Finally, there are numerous fungicides that can be used for leaf spot and blight diseases.

Powdery mildew

Powdery mildew is one of the easiest plant diseases to identify. Powdery mildew forms a whitish, powdery growth on surfaces of leaves, stems, and flowers. The white material is composed of chains of spores. Millions of spores are produced, and these spores easily are detached and carried by air currents to surrounding plants. On some plants (e.g., dahlia, zinnia, and phlox), infection commonly is limited to older foliage and the chief damage is unsightliness. On other hosts, such as roses and delphiniums, the young foliage and stems often become severely distorted, as well as covered with mildew. Powdery mildews

are favored by cool temperatures, moderate to high humidity, and infrequent foliage wetting. Powdery mildews may be controlled by manipulating the greenhouse environment to reduce humidity and increase air circulation. Several chemicals can effectively control powdery mildews. However, when selecting chemicals for mildew control, it is important to use a material that is a mildewcide. Many of the fungicides effective for leaf spots and blights are not effective against powdery mildews.

Rust

Typical symptoms of rusts are blister-like areas on the leaf surface that rupture to release numerous spores visible as a reddish brown powder. These spores are air disseminated or water-splashed to spread the disease to other plants. Generally, rusts are host specific, meaning that the fungus that causes geranium rust attacks geraniums and not other plant species. Control of rust diseases depends on manipulating greenhouse conditions to reduce humidity and free moisture on leaf tissue. Cultural practices, such as proper spacing of plants, early and proper watering, as well as good sanitation, also are important. Chemicals are available, but it is important to select ones recommended for rusts.

Bacterial diseases

The most commonly encountered bacterial diseases of greenhouse crops include bacterial soft rot of cuttings, corms, and bulbs; bacterial leaf spots; and bacterial wilts. Bacterial soft rot, caused by *Erwinia chrysanthemi*, is characterized by a soft, wet rot of affected plant parts. Bacterial leaf spots, such as *Xanthomonas hederea* on English ivy, cause small, light green, water-soaked spots on the foliage. These spots may enlarge and become brown to

blackish brown and dry. Bacterial blight (*Xanthomonas pelargonii*) is a serious disease of geraniums. The pathogen invades the roots, stems, and leaves of infected plants, and colonizes the water-conducting tissues of the plant. This disease is difficult to control because complete colonization of the plant may occur without external symptoms. Symptoms are suppressed particularly during cool weather.

Once bacterial diseases are introduced into a greenhouse, they can be very difficult to control. Therefore, control of bacterial diseases uses preventive measures, including proper cultural practices and good sanitation. The use of disease-free planting material from reliable sources is important. Equipment, pots, flats, and benches should be kept clean and disinfected. Bacteria are spread readily by splashing water when crops are watered. If bacterial diseases have begun to develop, avoid overhead watering, avoid splashing water during watering, minimize periods of free moisture on plant surfaces, and space plants as far apart as possible.

Most chemicals used in greenhouses for disease control are fungicides, which have little effect on bacterial diseases. However, situations may occur when the use of a bactericide or a copper-containing fungicide is warranted.

Viral diseases

Symptoms produced by viruses include mottling or mosaic foliage, vein clearing, flecking or spotting, distorting of plant parts, and stunting of the entire plant. Most viruses are spread through infected plant material, plant contact, or insect vectors such as aphids and thrips.

Control of viral diseases begins with clean planting stock, especially culture-indexed material if it is available. Plants showing virus symptoms should be discarded. Spread of a viral disease in a greenhouse may be minimized by good insect control and by eliminating unnecessary handling of plants.

By far the most serious viral disease of greenhouse crops is ***impatiens necrotic spot virus*** (INSV), formerly named tomato spotted wilt virus. This disease occurred on a wide range of bedding plants, perennials, and vegetable seedlings during the late 1980s. INSV caused large economic losses for several commercial greenhouses in Iowa. Symptoms vary and infected plants sometimes show no symptoms. Symptoms can include irregular dead spots on leaves, concentric rings on leaves, discolored leaf veins, black streaks on stems. Symptoms caused by INSV make plants unsaleable. Because the symptoms are so varied and the potential for damage is so great, it is essential to confirm a diagnosis of INSV with laboratory tests. The vectors of INSV are thrips (see page 70). To avoid an INSV outbreak, the following steps are vital:
- inspect all incoming stock for symptoms—test and/or reject all shipments that have possible INSV symptoms or thrips populations;
- monitor for thrips by placing blue or yellow "sticky cards" in the greenhouse and inspect them regularly for thrips;
- use insecticides to control thrips; and
- control weeds in and near the greenhouse.

Nematode diseases
There are several types of nematodes (very small roundworms) that cause diseases on greenhouse crops. Lesion nematodes (*Pratylenchus*) and pin nematodes (*Paratylenchus*) cause plant stunting and poor growth because their feeding weakens the plant's root system. The root knot nematode (*Meloidogyne*) causes nodules to form on roots, thus impairing root functions and stunting the plant. The foliar nematode (*Aphelenchoides*) lives within the leaf tissue of many flower crops and causes death of leaf tissue, resulting in brown lesions on older leaves. Laboratory tests of soil or growing media and plant samples are usually necessary to identify these nematode diseases.

The principal means of controlling nematode diseases is through good sanitation. Soil sterilization with fumigants or steam kills all nematode life stages. If nematodes are detected in a greenhouse crop, certain nematicides may be applied.

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Insect pests of greenhouse crops
Many different insects and arthropods commonly infest greenhouse plants. These pests are a threat to the quality of greenhouse crops, and they may causes direct plant losses (stunted or deformed growth, or death). In addition, pests are disconcerting to consumers and their presence may be annoying and aesthetically intolerable, even though they have not significantly harmed the plants.

Arthropod pests of greenhouse plants are divided into groups called sap feeders (piercing/sucking mouthparts), leaf feeders (chewing or rasping mouthparts), soil dwellers, and nuisance pests.

Insect monitoring

Early detection of pest problems and prompt action are vitally important to successful greenhouse pest management, especially of the insect and mite pests.

Insect monitoring is an ongoing process for greenhouse managers. Purchased cuttings, seedlings, and plants should be carefully inspected for insects before they are brought into the greenhouse. Infested plants should not be brought in or should be isolated and treated until their pest problem is corrected.

Inspection of plants for pests is recommended as a daily management practice. Certain locations within a greenhouse and certain varieties of a crop are more likely to have insects than others. These should be closely checked on a regular, frequent basis. Effective inspection requires learning the habits of the various pests to know where and when to look for them and a thorough knowledge of signs and symptoms of the pests.

Insect traps have become an important IPM tool for many greenhouse growers. Sticky traps of wood or cardboard are typically yellow, though other colors may be used for specific insects. Sticky traps can be used to detect the early presence of insects in a greenhouse and also may assist in the control of certain pests at low population densities. Traps can intercept and capture immigrants entering a greenhouse from outside areas. They also may reduce population levels to a tolerable level or to a level where other controls (parasites, pesticides) keep pests from becoming a serious problem. The insects generally captured in sticky traps include aphids, fungus gnats, leafminer adults, thrips, and whiteflies.

For large, persistent pest populations, the traps do not eliminate the insects but provide guidance and timing for application of insecticides.

Traps are commercially available or can be self assembled. The number of traps needed varies with greenhouse design, crop, expected pests, pest density, and time of the year. One trap for every 20 feet of planter bench or one trap per 100 square feet throughout the greenhouse is a typical manufacturer's recommendation for trap placement. Traps are hung within the plant foliage for whiteflies and just above the top of the plant foliage for thrips and other insects.

Sap feeders

The most common and troublesome insect pests in greenhouses are sap feeders with piercing/sucking mouthparts. These insects damage plants by feeding on plant sap, thereby weakening the plants, causing discoloration or deformation; by producing a shiny, sticky excrement called honeydew; or by transmitting disease pathogens from infected to healthy plants.

Aphids: Aphids are small (1- to 3-mm long), soft-bodied, sluggish insects found on virtually every greenhouse crop. Aphid species differ in size, color, and food preferences. Sap feeding by aphids may cause plant stunting and other deformities. Aphids also may transmit viruses that cause disease. Aphid populations may increase explosively because individuals can mature and begin to reproduce in as few as 7 days. Although aphids have many natural enemies, these enemies are sometimes unable to keep pace with aphid populations in the greenhouse.
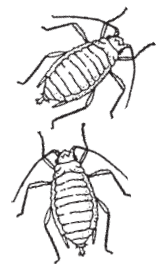
Aphids can be controlled with foliar sprays, aerosols, fogs, or soil-applied systemics. Careful inspection is needed to determine when aphid controls are to be applied. Careful, frequent inspection should be made after application to evaluate control efficacy and the need for retreatment.

Cyclamen mites: These very tiny, translucent mites are rarely seen, but their damage is obvious and frequently extensive. Unlike spider mites, cyclamen mites prefer high relative humidities and low temperatures. They are commonly found in plant crowns, buds, or flowers. Damage consists of growth distortion, including curling, stunting, deformity, and tissue blackening. Plants commonly attacked are cyclamen, African violet, ivy, mum, and begonia. Chemical controls are difficult because of the mites' seclusive habits. They are usually controlled with foliar spray applications, and repeated treatments are usually necessary.

Mealybugs: Mealybugs are common pests of numerous greenhouse crops. They are oval, sluggish insects about 3 mm in length with short spines on the body margin and a covering of white powder that is the source of their name. Sap feeding by mealybugs reduces plant vigor and also may cause distorted growth and leaf drop. Black, sooty mold may grow on the honeydew excreted by these insects. Wingless mealybug females lay eggs in waxy masses. Tiny crawlers leave the egg mass and move actively on the plant, seeking protected feeding sites. Adults emerge within 6 weeks of when the crawlers hatched.

As mealybugs feed, they secrete waxy filaments that eventually cover their bodies, giving them a white, dusty appearance. This wax covering is water-repellent and protects the insects from insecticide sprays, and is one reason mealybugs are difficult to control. The newly emerged crawlers are more susceptible to control attempts, but repeated applications are essential to control those that hatch after spray residues are gone. All forms of insecticide application are commonly used for mealybug control.

Scales: Scales are closely related to mealybugs and whiteflies and cause similar damage. Several species occur on greenhouse plants. The one feature shared among the scale insects is the shell-like covering that they secrete as they feed and grow. This covering provides protective coloration and also makes it virtually impossible to directly contact the organism with insecticides. Eggs produced by the female are usually concealed beneath the shell. The newly hatched nymphs are called crawlers and emerge from beneath the female's scale to seek a suitable location to settle and begin feeding. Once they settle they do not move again. They remain and develop in one location. The length of life cycle varies considerably with each scale species, ranging from one to eight generations per year.

Scale control can be very difficult because of the protection afforded by the waxy covering. All formulations of insecticide can be used for scale control. Foliar sprays must be timed to kill the newly emerging crawlers. A practical solution to scale infestations is to destroy infested plants if there are only a few of them.
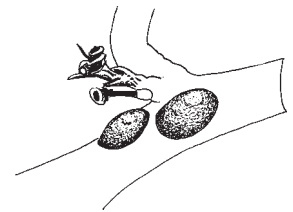
Spider Mites: Spider mites, also referred to as red spiders, are not spiders nor are they insects. These mites attack a wide range of greenhouse crops and feed on plant sap, generally from lower surfaces of leaves. Damage characteristically manifests as spotting or light mottling of the foliage and associated leaf drop. In severe infestations, the plants may be covered with webbing.
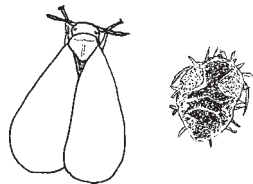
Spider mites are able to complete the egg to adult life cycle in as few as 7 days during hot, dry conditions. Also, each female may deposit up to 200 eggs, thus allowing for rapid population increase. All forms of miticide application are used in spider mite control, with a preference for soil systemics and foliar sprays. Pesticide resistance is a serious problem with spider mite control. Using miticides from different chemical classes may delay the onset of resistance.
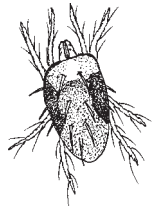
Greenhouse Whitefly: The greenhouse whitefly is a very common pest of many crops. These tiny, white nuisances are not flies at all but are related to scales, mealybugs, and aphids. The sap-feeding damage is similar to that produced by these relatives, and copious quantities of honeydew are produced by all stages of the whitefly except the eggs.

The greenhouse whitefly has a complex life cycle that can be completed in as few as 8 days. Eggs are usually laid on the undersides of leaves. Crawlers hatch and immediately select a feeding site. The crawlers soon become greatly flattened and nearly transparent, thus making them difficult to see. Their protective cover enables them to tolerate most insecticides. After a pupal or resting stage, the chalky white adults emerge.

Under greenhouse conditions, whitefly generations overlap, and all stages of the insect may be found on infested plants at any time. Because some of these stages are not controlled by insecticide sprays, repeated applications of the recommended pesticides may be needed. As with most of the sap feeders, all forms of insecticide can be used for whitefly control. Some degree of control also is achieved by placing yellow sticky boards in infested greenhouses. The adults, attracted to yellow, become entangled in the sticky material. Other developing management practices include the use of tiny wasps that parasitize and kill the immature whiteflies (biological control).

Leaf feeders
The insect pests that attack the foliage of greenhouse plants do so in several different ways. Caterpillars use their chewing mouthparts to tear and grind solid tissues. The common leafminers damage plant leaves not by chewing them but rather by forcing their way forward within the leaf and absorbing the sap released from damaged cells. Thrips rasp away the surface layer of leaf tissue and feed on the sap that accumulates at these wounds.

Caterpillars: Caterpillars are the immature forms (larvae) of butterflies and moths. Included within this diverse group are armyworms, cutworms, leaftiers, leafrollers, and loopers. Only the caterpillar stage is damaging. With chewing mouthparts, they tear off and

consume large pieces of foliage, stems, and flowers. Caterpillars are variable in size, appearance, and life cycle. All have complete life cycles but the size, duration, and location of the various stages differ with the species. Caterpillars are usually controlled with foliar sprays. A popular choice for caterpillar control is the microbial insecticide *Bacillus thuringiensis* (Bt). This selective insecticide is nontoxic to applicators and customers and does not harm beneficial insects and other nontarget organisms.

Leafminers: Several species of leafminers attack greenhouse crops. The most common are tiny fly maggots that feed between the upper and lower leaf surfaces, leaving narrow winding trails or mines. Small feeding and egg-laying punctures made by the adult can give foliage a speckled appearance, further reducing the plant's value. Larval feeding can be completed in as few as 5 days; then the larvae chew their way out of the leaf and drop to the soil to pupate. New adults emerge about 10 days later to repeat the life cycle.

Control of leafminers has become difficult, especially on chrysanthemums. Foliar sprays are usually used to control leafminers, with repeated applications being necessary. The best prevention against leafminer infestation is to refuse to accept infested plant material and to maintain strict weed control in and around the greenhouse (alternate hosts of leafminers).

Thrips. Thrips are small, slender insects about 3 mm in length. Their rasping feeding action on flowers and foliage causes a streaked, silvery appearance. Dull, gummy, black dots of excrement also are signs of thrips infestation. Foliar sprays, aerosols, and fogs are recommended for thrips control.
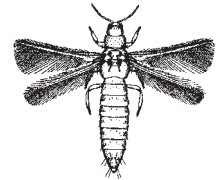
A growing concern over thrips is the spread of western flower thrips, the vector for INSV.

Soil dwellers

Some nuisance pests found in greenhouses spend part of their life cycle living within the soil of pots or benches. Little if any direct damage is done to healthy plants by these insects, though growers and customers are annoyed by their presence.

Fungus Gnats: Fungus gnats are tiny, fragile, black flies that frequently are abundant in greenhouses. The larvae feed on fungi and organic matter in the soil and may feed on roots or root hairs. The objectionable presence of the midge-like adults is usually worse than any physical injury to the roots caused by larvae. Soils or artificial mixes high in organic matter and moisture retention properties are prone to fungus gnat infestations. Aerosols or fogs are used to control the adult flies. Application of spray to the soil surface or a soil drench also is used.

Springtails: Springtails are another nuisance pest found in moist, high organic-matter soils. Soil sterilization with occasional soil drenches with insecticides

reduces objectionable populations of this harmless annoyance.

Noninsect nuisance pests

Slugs, snails, sowbugs (pillbugs), and millipedes are additional greenhouse nuisances likely to be encountered on soil surfaces, around pots and benches, or on the ground under the benches. These pests occasionally can cause damage to seedlings, cuttings, and other plants. It is frequently necessary to treat the ground and benches for control of these pests. Slugs and snails must be controlled with specific baits, sprays, or dusts.

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Weed management in greenhouses

The application of good cultural practices is the backbone of weed control in greenhouses. Chemical methods of weed control are limited in importance in these structures.

Nonchemical control

Preventing weed seed entry into the greenhouse is the most practical form of weed control. There are several methods by which seeds may move into greenhouses. Common sources are potting soil or crop seed that is contaminated with weed seed. Much labor can be saved by locating sources of seed and soil free of weed seed. Procedures to sterilize soil to prevent plant diseases also should be effective in killing weed seeds.

Another source of weed seeds is weeds growing in the vicinity of the greenhouse. These seeds can be carried into the greenhouse by the wind or on workers' or customers' clothing. Although controlling weeds in areas surrounding the buildings removes the source of the

majority of these weed seeds, a few weeds inevitably will establish inside the building. Eliminating these weeds before they mature and produce seeds reduces future weeds. A single plant may produce several thousand seeds. These seeds remain viable as a source of weeds for many years. Removing these weeds by hand is usually the most effective and safest means of control, although in some situations a herbicide may be used.

Chemical control

Herbicides commonly are used to control weeds in field- and container-grown ornamentals. These chemicals offer an economical and safe method of controlling undesired vegetation. But, the usefulness of these chemicals in the greenhouse is limited. A herbicide that can be used safely on an ornamental species grown outdoors often causes severe damage to that same plant grown under glass. The two major factors limiting herbicide use in greenhouses are the physical condition of a greenhouse-grown plant and herbicide volatility.

The environment inside a greenhouse is drastically different from that found outdoors. The warm, humid conditions in greenhouses tend to produce tender, succulent plants that are highly susceptible to herbicide injury.

The second limiting factor is volatility, the tendency of a herbicide to produce vapors that move from the soil or plant surface into the atmosphere. When herbicides vaporize outdoors, they normally are diluted in the atmosphere and cause limited problems. In the greenhouse, however, this dilution mechanism is eliminated and the herbicide can accumulate to phytotoxic concentrations.

Only herbicides with recommendations for greenhouses listed on their labels should be used under glass. A herbicide that is safe for use on roses in the field is not necessarily safe for roses in greenhouses. A few herbicides are labeled for use under production benches. Always follow label instructions to ensure safety to the applicator and plants.

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Application equipment and calibration

Greenhouse growers use several different methods of pesticide application. There may be two or more methods available for any given pest problem, but the grower must decide which one(s) to use. This decision is based on several factors, including existing equipment, environmental conditions, type and stage of development of the crop and pest, pest susceptibility, and economics. Effective treatment requires proper application and thorough coverage.

Methods of pesticide application

Major methods of greenhouse pesticide application are described in the following text. There is some overlap or variation in these methods when specific application equipment is considered; however, these definitions usually describe how greenhouse growers apply pesticides.

Foliar application

Foliar treatments leave a residue that prolongs control but may be unsightly. Extra effort is usually required to ensure complete plant coverage.

Aqueous Spray: Aqueous sprays (also called dilute sprays) are applied with hydraulic sprayers (pressurized tank sprayers or high-pressure, powered spraying machines). The spray consists of an emulsifiable concentrate (EC) or wettable powder (WP) mixed with water. WP sprays are safer on plants than EC sprays but EC sprays provide the longest-lasting residual deposits and the most resistance to washing off. Addition of surfactants, wetting agents, or spreader / stickers may improve application efficacy. Thorough, complete coverage is essential.

Mist: In a mist treatment, also called concentrate spray, very small quantities of high-concentration pesticide are diluted with air for delivery to the target. Special equipment is needed, such as motor-driven electric mist machines. These machines also are called mist blowers. Mist application is a complex technique requiring more operator skill. Overdosing is easy and can result in serious phototoxicity.

Dust: A dust treatment is a dry, dilute application to foliage. Few dust products are available and such treatment is not common. Dust residues are especially visible and easily dislodged by air currents.

Dip: A dip treatment requires immersing the foliage of an infested plant into a pesticide solution. Although a dip provides thorough coverage, it is slow or difficult to accomplish; depending on the number and size of the plants, it may be impractical.

Fine droplet application

Special equipment can produce very small droplets that disperse throughout a closed greenhouse and slowly settle onto upper surfaces of plants. These applications are simple to apply but provide little accumulation of residue. Application

should be done on calm days and the greenhouse should be sealed to eliminate drafts and air leaks. Application rates are based on air volume in the closed greenhouse. It is important to keep the greenhouse closed for the appropriate length of time, followed by adequate prescribed ventilation. Inhalation protection is required and coveralls are recommended.

Aerosol: In an aerosol application, small droplets (50 to 150 micrometers) are dispersed from cylinders that have been pressurized with a propellant. This application method is commonly called a "bomb" application. Aerosols work best when the temperature is 70° to 80°F and the foliage is dry.

Fog: Very small droplets (10 to 60 micrometers) are produced when oil-based carrier preparations are dispensed through special fogging devices or machines that use heat to vaporize the insecticidal liquid. These fogs are similar to an aerosol application and a white, visible fog is produced. Fog application should not be directed toward foliage.

Vapor: A vapor treatment also is called smoke application. Vaporization of the pesticide is accomplished by using a flame or hot pipes as a heat source. Only a few products are available for this simple application.

Root media application

Insecticides or fungicides can be applied directly to the root media to control medium-borne pests. This simple method also can provide systemic insect control.
Soil drench: There are a few pesticide uses where a water formulation of pesticide is applied to the root media.

Granules: A dry, granular formulation can be applied to pots, beds, or benches. Large-area application is made with mechanical spreaders. Small areas or individual pots are treated with small-volume measures such as a teaspoon. This method generally provides long residual control. Many granular insecticides are highly toxic and require extra caution.

Calibration considerations in greenhouse pesticide application

When foliar treatments are made, read and follow dosage and mixing rates as specified on the pesticide label. These instructions usually give the amount of pesticide active ingredient or product to add to each gallon or 100 gallons of water. This solution is then applied to the plants to the point of runoff. Coverage is an important aspect of foliar treatment. Complete coverage is the objective; be sure to thoroughly treat both upper and lower leaf surfaces.

Spraying to the point of runoff requires directing the spray, mist, or dust to all parts of the plant until the solution begins to drip from the leaves and stems. Additional spray beyond the point of runoff washes pesticide from the plant and increases the chances of phytotoxicity.

It is not always easy to determine how much pesticide solution is needed. Vague guidelines may be available to help you plan the amount of spray solution needed, but in general you must depend on your own or others' experience. The general method for determining the amount of pesticide to mix is to first determine the time or amount of product it takes to spray a small sample of plants of a particular size or foliage density and multiply this time or amount by the

number of plants or area to be treated. If an aerosol, smoke, or fumigant is to be used in the greenhouse, it is essential to know the volume of the greenhouse so that a proper rate can be applied. The formula for computing cubic contents varies with the style of the greenhouse. See page 75 for the formulas for three standard greenhouse designs. It is necessary to make certain measurements of the greenhouse before cubic contents can be calculated. Greenhouse width, height to the eaves, height to the ridge, and length must be measured. With these measurements, the number of square feet of surface area on the end of the greenhouse may be calculated and this amount multiplied by the length to determine cubic contents.

Methods for calculating greenhouse air volume
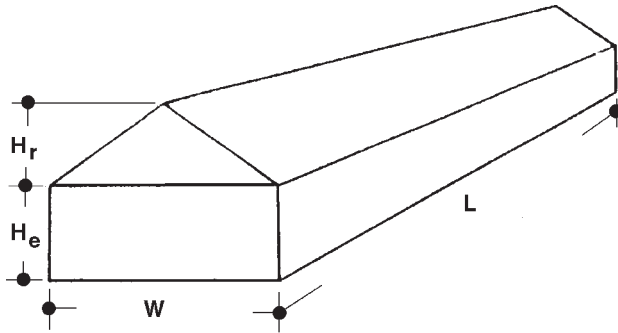
For even-span greenhouses:
greenhouse volume in cubic feet = $[\,(W \times H_e) + \dfrac{W \times H_r}{2}\,] \times L$
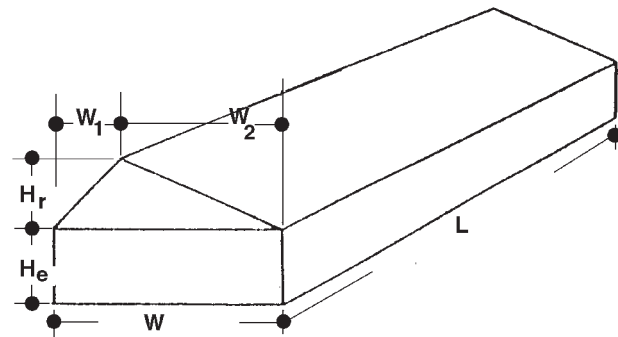
For uneven-span greenhouses:
greenhouse volume in cubic feet = $[\,(W \times H_e) + \dfrac{W_1 \times H_r}{2} + \dfrac{W_2 \times H_r}{2}\,] \times L$
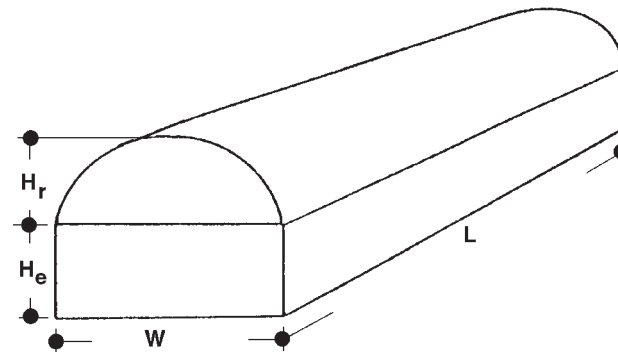
For quonset structures:
greenhouse volume in cubic feet = $[\,(H_e \times W) + \dfrac{3.14 \times H_r \times H_r}{2}\,] \times L$

Appendix

White grub rasters

May/June beetle

European chafer

Green June beetle

Asiatic garden beetle
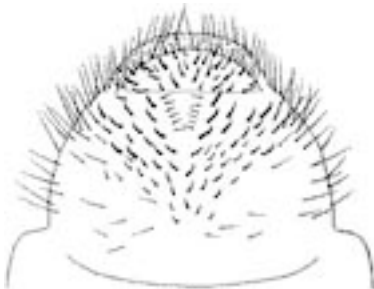
Japanese beetle
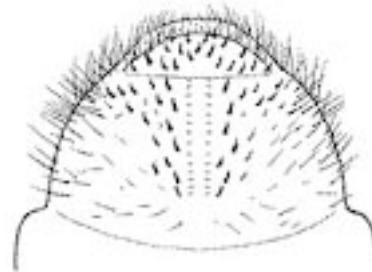
Oriental beetle
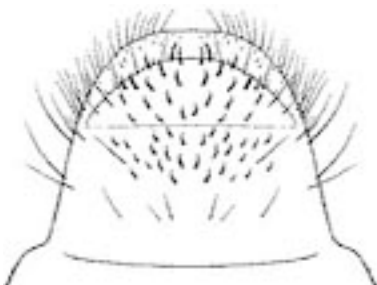
Typical masked chafer

Black turfgrass Ataenius
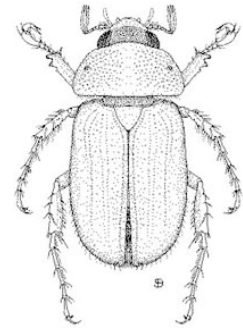
White grub adults
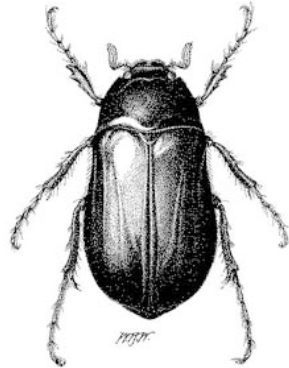
May/June beetle
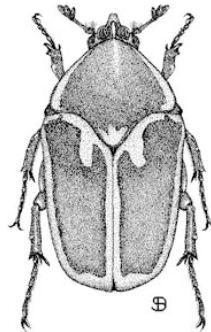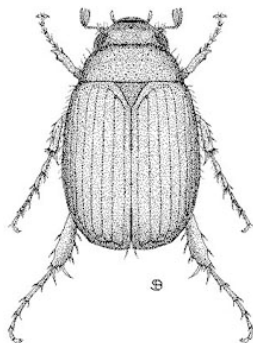
Green June beetle
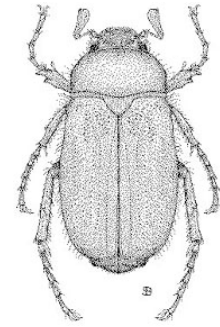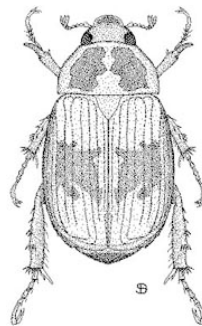
European chafer
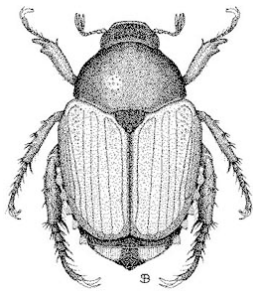
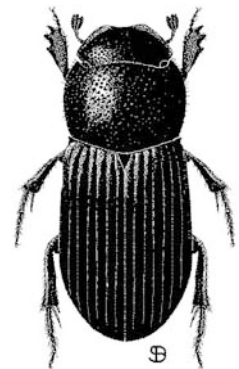**Japanese beetle**
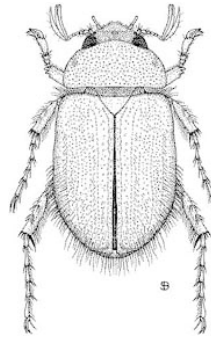
Northern masked chafer

Southern masked chafer

Asiatic garden beetle

Oriental beetle

Black turfgrass Ataenius

Raster and adult beetle drawings courtesy of Mark Shetlar (Department of Entomology, The Ohio State University, Columbus, OH). Original publication at http://ohioline.osu.edu/hyg-fact/2000/2510.html

Before Using Any Pesticide

STOP

READ THE LABEL

All pesticides can be harmful to
    health and environment if misused.

Read the label carefully
    and use only as directed.