TEXAS A&M AGRILIFE EXTENSION

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Landscape Maintenance/ Ornamental and Turf

Contents

Landscape Pest Management

Applicators who want to apply any pesticide (regardless of classification) **for hire** to grass, shrubs, trees, or other horticultural plants must be licensed by the Texas Department of Agriculture (TDA) in the 3A ag category or by the Structural Pest Control Service (SPCS), part of TDA. Applicators who apply only fertilizer do not need licenses from either agency.

To license with TDA in the 3A ag category, you may certify as a commercial or noncommercial applicator:

- **Commercial applicators** may apply restricted-use and state-limited-use pesticides or regulated herbicides for hire.
- **Noncommercial applicators** making for hire applications may apply only general-use pesticides (those sold over the counter without requiring a license).

The TDA is the primary agency regulating pesticides in Texas. It licenses people who want to use restricted and state-limited-use pesticides or regulated herbicides for agricultural production commodities or for some other outdoor pur-poses.

The Texas Structural Pest Control Service (SPCS) also licenses people to apply pesticides to lawns, ornamental plants, and weeds to control landscape pests.

The TDA landscape maintenance license allows applicators to apply pesticides to control plant pests in landscapes. Because chiggers, fleas, biting flies, mosquitoes, ticks, and other nuisance insects do not attack plants, the applicators treating them must be licensed with the SPCS in the pest category.

Introduction

Most landscape managers aim to achieve and maintain attractive, healthy, vigorous landscapes with a minimum of pest problems. A pest is any organism that impairs the appearance or function of landscape plants.

Achieving this goal, whether on the home lawn, golf course, or commercial grounds, requires the long-term use of reliable control methods. Monitoring pest populations is essential to determining whether to begin control measures.

Several actions are keys to successful pest management in landscapes:

- Work to keep the turfgrass and ornamentals healthy. Healthy plants can withstand greater damage, or *pressure*, from pests than those that are weak; they can also recover more quickly when problems do arise.
- Check the landscape often for pests and their damage.
- Identify pest problems correctly.
- If you must take action, choose the appropriate control methods and use them properly.

IPM

Controlling pests in ornamental and turf landscapes involves much more than applying pesticides. You need to take a comprehensive approach that uses biological, cultural, physical, and chemical controls in a careful, environmentally sound manner. The term for this approach is *integrated pest management (IPM).*

Although IPM principles were developed for field crops, it soon became clear that they can apply to any area of pest control, including ornamental and turf.

Landscape IPM differs from crop IPM in that economic thresholds often do not apply to turf and ornamentals. A threshold is a boundary, where something begins or ends.

An economic threshold for pests is the level that a pest population must reach before it becomes cost-effective to treat them—the cost of the possible crop loss must be higher than the cost of controlling the pest, such as the cost of applying pesticide.

For landscapes, the most important factor in pest management is generally appearance.

Another difference is that pesticide applicators in urban settings must consider public concerns about pesticide use.

Landscape problems

Many factors can cause plants to appear unhealthy or damaged. To determine the problem's cause, you must be able to distinguish among living (biotic), nonliving (abiotic), cultural (such as improper mowing and weeding), and other natural factors.

Biotic factors include bacteria, fungi, insects, mites, and viruses. The most common biotic pests in landscapes are diseases, insects, and weeds.

Abiotic factors include soil compaction, construction injury, soil fertility, moisture, pH, and environmental conditions that can weaken plants.

Some abiotic factors cause symptoms like those caused by plant pests. A difference is that biotic problems usually affect only one or a few plant species; abiotic problems often affect several or many species.

For example, lack of water affects all species, but the rose mosaic virus attacks only roses and some fruit trees.

To determine how to manage the problem, you must be able to distinguish between the two.

Improper **cultural practices** can also lead to pest problems. For example, the turfgrass disease large patch (or brown patch) is more common if the grass has not been fertilized or watered prop erly.

Natural factors that influence pests include climate, natural barriers and enemies, population development and dynamics, and the availability of shelter, food, and water. These natural factors may cause pest populations to increase or decrease without influence from humans.

Applied controls

Several types of action are available to control pests, including biological, cultural, mechanical, host plant selection, and chemical methods.

Biological control involves manipulating the natural enemies of pests—those that kill and eat pests (*predators*), those that feed on but do not necessarily kill pests (*parasites*), or those that cause diseases in pests (*pathogens*). You can encourage and maintain high population levels of these natural enemies by using pesticides carefully or by releasing a pest's enemies into the target area.

Cultural control methods are the activities involved in taking care of the plants, such as site selection and watering practices. These techniques can alter the environment around the plants to affect the pests that could be attacking them.

Mechanical control involves the use of equipment or manual operations to keep out or disrupt the life cycle of pests. Barriers that exclude pests include fencing, plastic mulches, and row covers.

Host plant resistance: Some plants can tolerate damage from certain pests or are unsuitable for pest development; this trait is known as *host plant resistance.* For example, the St. Augustinegrass variety 'Floratam' is resistant to chinch bugs.

Chemical control involves the use of pesticides to destroy pests, control their activity, or prevent them from causing damage. Chemical pesticides are often the quickest way to control pests and, in some cases, the only alternative.

Plant selection

A critical step in pest control is to choose the proper plant or variety for the landscape. Choose all landscape plants according to their water requirements, shade tolerance, and susceptibility to pests.

Plants vary considerably in their requirements for growth as well as their susceptibility to plant pests:

- Choose **ornamental plants** to meet their climate, sunlight, and water needs.
- Choose **turfgrass** varieties based on those needs as well as the grass's intended use and management requirements. For example, golf courses require much more attention than do typical home lawns.

Check with a turfgrass specialist or Extension agent to find which grasses perform best in your area. The most common warm-season turfgrasses in Texas are bermudagrass, buffalograss, centipedegrass, St. Augustine, and zoysia. Common cool-season species are creeping bentgrass, fine fescue, and ryegrass.

Cultural practices

Water

Focus your irrigation practices on the plants' actual requirements, and conserve water as much as possible. Too much or too little water can damage or kill plants.

Lack of water causes leaves to wilt, droop, and drop. In landscapes, over-watering is as much a problem as under-watering. Excess water in the soil forces out the oxygen that plant roots need to survive.

Fertilization

To grow, plants need 16 elements, which in horticulture are called *plant nutrients.* The soil usually contains enough of these nutrients for normal plant growth.

However, to achieve the level of plant growth usually expected in home landscapes, some essential plant nutrients must be added. When the soil contains so little of a nutrient that the deficiency limits the plant's growth or production, that nutrient is described as *limiting.*

In landscapes, the most limiting plant nutrient is normally nitrogen; it constitutes the foundation of most common fertilizers. Other limiting nutrients that plants require, usually in smaller amounts or less often, are phosphorus and potassium. The elements needed in tiny amounts are called *micronutrients.*

The best way to determine how much and what kind of fertilizer that a landscape needs is to take a soil sample and have it tested. Soil testing can accurately measure which nutrients are lacking and which are not.

When collecting soil to send to a laboratory, gather a representative sample. Following a random pattern, collect 15 to 20 samples in the area. Take samples least 3 to 5 inches below the surface and mix them thoroughly. The total sample should be at least 1 pint of soil.

Send the samples to be analyzed by a private soil-testing lab or by the Soil, Water, and Forage Testing Laboratory of the Texas A&M AgriLife Extension Service (http://soiltesting.tamu.edu/).

Mowing

The primary cultural practice in turf management is mowing. Without regular mowing, even a fine turf quickly becomes just another weed patch.

More than any other cultural practice, good mowing practices enhance turf and can significantly help you manage pests. They can also improve turf color, density, root development, texture, and wear tolerance.

Thatch

Thatch is the layer of undecayed grass between the soil and green leaves of a turf plant. Thatch occurs because as old turf plants age and die, they decompose into finely textured humus that becomes part of the soil surface.

A major cause of thatch is the rapid, excessive growth of turfgrass, which produces plant material faster than decomposition can occur. Although good cultural practices may not prevent thatch indefinitely, they can slow its formation.

Pruning

A primary technique for producing a specimen plant is pruning. In nature, when a twig or branch has served its purpose, it dies and eventually falls to the ground. In urban settings, however, pruning prevents and treats some diseases and helps keep some ornamental plants attractive.

You must prune properly to prevent or minimize insect and disease invasion. Do not make the cuts flush with a trunk or main branch. Instead, prune the limb outside the collar, which is the section of the branch where it joins to the trunk or main stem. If you prune beyond the branch collar, the tree becomes less vulnerable to decay and invasion by pests.

Chemical control

Two approaches help control pests in landscapes: preventive and reactive pesticide applications.

Preventive applications involve applying a pesticide before the problem appears. From an IPM standpoint, this type of application is hard to justify because one of the program's goals is to minimize the use of chemicals.

However, some situations warrant the use of preventive pesticide applications, such as a recent history of pest occurrence and favorable conditions for its development. Examples are applying a herbicide before weeds sprout up or using a fungicide when the weather is warm and humid, an environmental condition that favors the development of fungal diseases.

Reactive, or curative, treatments occur after you notice the pest or its damage. Then you can apply a pesticide that targets that specific problem.

Several factors influence the decision on whether to use a preventive or reactive treatment, including treatment cost, recent pest history, and owner or manager expectations.

Health-related concerns may also come to bear. For example, some people are highly allergic to fire ants, which would necessitate preventive pesticide applications in some areas.

Pesticides and the environment

Chemical pesticides vary in how they work, how toxic they are, what their chemical structure is, and what harm they may cause to the environment. Read and follow the instructions on the label of each pesticide that you use, and understand any potential environmental effects.

Protecting water resources

Chemicals, including pesticides, can pollute surface water (such as lakes and rivers) and groundwater (water stored underground in aquifers). When used improperly, pesticides can move into these water sources and contaminate the water used for drinking, washing, and irrigation.

All applicators should follow label directions and take steps to protect our water supplies:

- Do not use more pesticide than the label directs. Applying more than the labeled rate increases the cost as well as the chances of contaminating water.
- When possible, mix and load pesticides at least 100 feet from surface water or a direct link (such as a well) to groundwater.
- Prevent pesticides from back-siphoning into your water source.
- When deciding when and how much pesticide to apply, factor in irrigation, soil type (pesticides move faster through sandy soils), and weather forecasts (delay application if heavy rain is imminent).
- Consider leaving untreated buffer strips around water sources and hard surfaces to reduce pesticide movement.

Pesticide movement

Under some conditions, pesticides can move from the intended site and cause damage to off-target areas. Take steps to reduce the likelihood of a pesticide moving away from the target pest.

Drift is the unintended movement of pesticides through the air during or after application to an area other than the intended target.

Particle drift is the movement of droplets through the air during or soon after application.

Vapor drift occurs when pesticides land on the target site but then turn into vapor (*volatilize*) and move off-target.

Runoff is the movement of pesticides across the treated surface, such as a lawn. When pesticides fall on an impervious surface such as a sidewalk or parking lot, they contaminate the runoff water.

To prevent this kind of runoff, sweep or blow the pesticide off hard surfaces such as driveways, parking lots, sidewalks, and streets.

Leaching of pesticides occurs when chemicals move downward through the soil in water. Leaching is more likely if the chemical is not strongly adsorbed to soil, if the pesticide dissolves in water easily, or if the type of soil allows water to flow through it quickly. Leaching is more likely in sandy soils than clay.

Another contributor to leaching is applying more pesticide than the label allows.

Pesticide residues

The trace amount of pesticide that remains in the environment after it is applied is known as *residue*. All pesticides break down, or *degrade*, after application.

Some pesticides degrade quickly, others slowly. The speed of degradation depends primarily on the compound's chemical structure. Other significant factors are environmental conditions—moisture, temperature, and sunlight.

Sometimes it is desirable to use a pesticide that degrades slowly (is *persistent*) because its effects will remain for a period of time, such as bare ground areas. However, use caution when applying persistent compounds because they can harm plants and animals.

For information about a pesticide's persistence, read the product label.

Resistance management

Some diseases, insects, and weeds have become less susceptible, or *resistant*, to the pesticides normally used to control them. Pests that once were controlled by a particular chemical have over time become able to survive and reproduce after being treated with it.

Resistance management is a term used for the steps that applicators take to avoid or reduce the effects of pesticide resistance.

Each pesticide has a specific method by which it kills or mitigates the target pest—this is its *mode of action* (MOA). Some insecticides kill insects by attacking their nervous system, causing tremors and other uncontrolled movements. Other chemicals disrupt photosynthesis in weeds. Still others damage the cell membranes of fungi.

Most instances of resistance have arisen because applicators have relied too much on pesticides with the same modes of action.

To prevent or at least delay resistance, rotate chemicals with different modes of action. Many pesticide products have the same mode of action. For example, all synthetic pyrethroid insecticides (Bifen, Talstar, and Tempo) have the same mode of action.

Some pesticide labels include information about MOA.

Other methods to manage resistance include using nonchemical cultural control methods, not applying pesticides until pest populations warrant their use, using label—not reduced—rates of pesticides, and using multiple modes of action.

Pesticide adjuvants

Adjuvants are products designed to make pesticides more effective:

- **Surfactants** (wetting agents) make liquid pesticides wetter by reducing surface tension and helping them cover the target better. Some surfactants dissolve the wax that limits chemical uptake by leaves.

- **Stickers** make the pesticide remain on the plant longer. They coat the plant and protect it from pests. Sometimes a surfactant is added to a sticker to improve the pesticide's coverage.
- **Colorants or dyes** mark areas that have already been sprayed. Colorants can help applicators reduce pesticide overlap and over-application.
- **Compatibility agents** enable or improve the mixing of two or more formulations, such as a herbicide with a liquid fertilizer.
- **Defoaming agents** decrease foaming when certain pesticides are mixed.
- **Drift control agents** are used in liquid sprays to help keep pesticides in the target area.
- **pH modifiers** stabilize spray solutions when a pesticide requires a specific degree of acidity or alkalinity (pH). Some pesticides perform much better under slightly alkaline, neutral, or slightly acidic conditions.

Study questions

1. **True or false:** To apply pesticide to lawns for hire in Texas, you must have a license.
   a. True
   b. False

2. What causes pest populations to rise and fall with no influence from humans?
   a. Applied controls
   b. Chemical controls
   c. Cultural practices
   d. Natural factors

3. Proper irrigation, fertilization, mowing, and pruning are all examples of good:
   a. Chemical controls
   b. Cultural practices
   c. Pest identification
   d. Plant selection

4. What should you consider before establishing a turf or ornamental landscape?
   a. Cost
   b. Water requirements
   c. Shade tolerance
   d. All of the above

5. How many elements do plants need?
   a. 3
   b. 1
   c. 16
   d. 14

6. What will you protect by mixing and loading pesticides 100 feet from water sources?
   a. Groundwater
   b. Plants
   c. Animals
   d. The atmosphere

7. What is the term for the movement of pesticides through the air during or after application?
   a. Leaching
   b. Drift
   c. Pesticide residue
   d. Injury

8. What greatly influences the amount of time required for a pesticide to degrade after application?
   a. Sunlight, temperature, and wind
   b. Moisture, residue, and sunlight
   c. Temperature, moisture, and sunlight
   d. Moisture, temperature, and odor

9. What types of compounds enable spray solutions to cover the target area better?
   a. Surfactants
   b. Stickers
   c. Pesticides
   d. Fertilizers

10. What compounds help pesticide sprays coat the plant and protect it from some plant pests?
    a. Surfactants
    b. Colorants
    c. Stickers
    d. pH modifiers

1. a
2. d
3. b
4. d
5. c
6. a
7. b
8. c
9. a
10. c

Insect Pests

Many kinds of insects and mites feed on ornamental plants, shrubs, trees, and turf. A landscape with a wide variety of plants usually attracts more types of insects and mites than do areas with only a few plant species.

However, the mere presence of an insect or mite on a plant does not mean that you have a problem requiring the application of an insecticide or miticide. Beneficial insects such as wasps and lady beetles, other biological agents, and environmental forces play an important part in keeping many insects and mites under control.

If these protective forces break down, you may need to use an insecticide and other control measures. For example, some insects and mites thrive under Texas climatic conditions, and natural forces seem to exert little pressure on them. These insects and mites may be troublesome almost every year.

Also, some plants are more susceptible to specific insects or mites. Other plants may be relatively free of insects or mites almost every year.

Insect pests of ornamentals

Sucking pests

When foliage is bleached, bronzed, stippled (flecked), or yellowed but the leaf surface looks physically sound, the injury is usually caused by insects or mites that have some form of sucking mouthparts.

These leaf symptoms often begin with stippling, which insects cause when inserting their sucking mouthparts into the leaf. The insect removes plant sap and withdraws or destroys chlorophyll at the point of penetration. Tiny discolored areas appear on affected foliage.

When many pests attack, these stippled areas merge and discolor part or all of the leaf surface. Although the damage can be difficult to spot at first, the plants will eventually take on a shiny look and sticky feel.

Sucking pests common in Texas ornamental plants include aphids, cicadas, lace bugs, mealybugs, scales, spider mites, thrips, and whiteflies.

Aphids (Fig. 2-1, page 26), sometimes called plant lice, are soft bodied, pear shaped, 1⁄16 to 1⁄8 inch long, and green, bluish green, yellow-green, reddish brown, or nearly black. Some aphids appear woolly or powdery because of the waxy covering on their bodies.

Many aphid species occur on ornamental plant foliage. They can be serious pests because they drain plant nutrients, and some species transmit plant viruses. Most species have a pair of characteristic projections (*cornicles*) that protrude from the back of the abdomen.

Aphids have one of the highest reproductive potentials of any insect. As many as 50 generations may occur annually, and each female can reproduce 50 to 100 young without mating. The average lifespan of an adult is about 1 month.

Some of the most common species in landscapes are the cotton or melon aphid, crapemyrtle aphid, green peach aphid, and oleander aphid (Fig. 2-2, page 26).

Aphids produce a colorless, sweet, sticky fluid called honeydew that attracts ants and flies. A black fungus or sooty mold (Fig. 2-3, page 26) often grows on this honeydew, hindering photosynthesis and making the plant unattractive.

Scales

Large populations of scales can cause stunted growth, yellow blotches on leaves, and dropping of some or all of the leaves.

Scales are small and covered with wax, a shell, or an armor plate. They attach themselves to the plant and can easily be misidentified for bark or buds because of their appearance. Many scale species also secrete honeydew, which can lead to sooty mold.

Common scales found in landscapes include cottonycushion scale, obscure scale, euonymous scale, wax scales (Fig. 2-4, page 26), and the crapemyrtle bark scale (Fig. 2-5, page 26).

Mealybugs are a type of scale insect that is covered with a mealy or waxy secretion. Examples are the Rhodesgrass mealybug of turfgrass and longtailed mealybug on ornamental plants.

These insects have soft bodies, grow to ¼ inch long, and rest or crawl slowly on leaves or stems. Their damage resembles that caused by aphids; use the same control methods as for scale insects.

Whiteflies (Fig. 2-6, page 26) are tiny white insects that look like miniature moths. The adults of common species are snow-white and have four wings. The nymphs are flat, oval, green or yellow, and less than 1⁄30-inch long.

Both stages can injure plants. These insects prefer the undersides of leaves and may be difficult to detect. Young nymphs feed on plant sap throughout their immature lives. Damaged plants wilt, and the tissue yellows and soon dies.

Heavily infested leaves are yellow on top. On some plants, the leaf edges (margins) appear discolored. Whiteflies excrete sticky honeydew that often glazes the upper and lower leaves, allowing black sooty mold fungus to develop.

In Texas, gardenias, hibiscus, privet, and greenhouse plants are common hosts of the whitefly.

Lace bugs (Fig. 2-7, page 26) suck sap from the leaf undersides of evergreen and deciduous trees and shrubs, such as azaleas, lantanas, mountain laurels, pyracanthas, rhododendrons, and sycamores.

Adult lace bugs are flattened, rectangular, and ⅛ to ¼ inch long. They have a lace-like covering over their bodies.

Cicadas (Fig. 2-8, page 26) are common in trees throughout Texas in late summer. Male cicadas rest on tree trunks and branches and "sing" to attract females, producing a periodic whine by means of two special vibrating membranes in the sides of the abdomen.

Cicada species found in Texas, primarily the dog-day cicada, are not considered plant pests.

The last two insect pests in this section—thrips and spider mites—do not have sucking mouthparts but are intermediates between the sucking and chewing pest groups. They scrape the leaf surface and suck plant juices.

Thrips (Fig. 2-9, page 26) are serious pests of ornamental plants because of their damage to leaves and flowers. They also transmit some plant diseases, such as tomato spotted wilt.

Thrips are slender, 1⁄10 to 1⁄40 inch long, and yellow, dark brown, or nearly black. The western flower thrips grows throughout Texas.

Thrips usually attack the tender growing tissues of plants. Their rasping mouthparts open holes that allow sap to emerge from plant tissues. The leaves curl up, wither, and die. If the buds do not open normally, the flowers may be deformed.

Biological controls and insecticides control thrips effectively. If you use insecticides, begin applying them as soon as damaged buds appear.

If the thrips populations are large, remove or burn the injured buds and flowers to control immature and adult stages. Thrips often reinfest flowering plants, particularly roses.

Spider mites (Fig. 2-10, page 26) are not insects but belong with spiders and ticks in the order Acarina. Of the general pests of ornamental plants, spider mites are among the most harmful and persistent.

Mites are usually oval and less than 1⁄50 inch long. The adults have four pairs of legs; the nymphs, only three pairs.

If you look closely, you can see spider mites without using a magnifying glass. They usually attack the leaf underside and create a characteristic web.

Damaging infestations can develop quickly, particularly in hot, dry weather. Most complete a generation in 5 to 14 days. They lay eggs near the leaf midrib or in protected places, such as buds.

Control agents for spider mites include insecticidal soaps, horticultural oils, natural enemies such as predatory mites, and miticides. Miticides can control the nymph and adult stages, but the eggs are very resistant to pesticides.

Generally, avoid chemical treatment until you see plant damage. Mites can develop resistance to miticides very rapidly.

Chewing pests

Tattered leaves or blossoms are, in most cases, caused by an insect that has chewing mouthparts. If a plant looks chewed, you can normally rule out the large group of pests that use sucking or rasping mouthparts.

The most harmful chewing pests are adult beetles and the caterpillars (larvae) of butterflies, moths, and sawflies.

Caterpillars

Cankerworms attack broadleaf trees. The two major pest species in Texas are the spring cankerworm (*Paleacrata vernata*) and fall cankerworm (*Alsophila pometaria*).

Cankerworm larvae grow to 1 inch long and are generally striped lengthwise and green, brown, or pale yellow. Like loopers, cankerworm larvae crawl with a looping movement.

Cankerworms generally feed from underneath the leaves, producing large, ragged holes and leaving dark pellets of waste.

Walnut caterpillars (Fig. 2-11, page 26) can completely strip the leaves from pecan trees. The larvae damage trees and shrubs by feeding on the leaves, needles, or stems.

These insects deposit eggs in masses of about 300 eggs on the leaf underside. The larvae feed on the leaves, with the last two larval stages consuming about 90 percent of the foliage.

Use insecticide to target the early larval stages.

Bagworms (Fig. 2-12, page 26) often attack evergreens; some species occasionally attack broadleaf plants and other ornamentals.

Bagworm larvae build tough, spindle-shaped bags of silk around themselves and cover the bags with bits of needles or leaves. The bags shield these insects from pesticides, and the plant parts camouflage the bags well.

The larvae enlarge the bags as they grow. When the larvae are fully grown, the bags may be 1½ to 2 inches long.

The male bagworm adult is a black, hairy moth with a 1-inch wingspan. Females are wingless, wormlike, and mahogany brown; they never emerge from the bag.

Their protective bags make it difficult to control this pest via spray unless you apply the insecticide early in caterpillars' development, when they are actively feeding on the foliage.

Handpicking the larvae from infested plants is effective but labor intensive.

Leaf rollers, leaf tiers, and **leaf crumplers** have similar habits and inflict similar damage. Especially subject to attack are carnations, chrysanthemums, geraniums, honeysuckles, pyracanthas, roses, verbenas, and zinnias.

The caterpillars vary from pale yellow to dark green. All are about ¾ inch long when mature. They feed on the undersurfaces of bent leaves and may even eat buds.

These pests fold, roll, or tie together groups of leaves or terminal growth, often defacing ornamental plants and interfering with normal growth (Fig. 2-13, page 26). Because they are enclosed in a flimsy structure, the larvae are often overlooked.

Tent caterpillars (Fig. 2-14, page 27) attack several kinds of broadleaf trees and shrubs, producing unsightly webs that detract from landscapes. More important, the resulting foliage loss can weaken the tree. Plants particularly susceptible to attack are chrysanthemums, verbenas, and zinnias.

Apply insecticides during the larval stages, but only if plant damage becomes severe and unsightly.

When full-grown, the larvae are colorful and over 1½ inches long. Four species are troublesome in Texas—the eastern, forest, Sonoran, and western tent caterpillars. They are closely related and have similar habits. An example species is the forest tent caterpillar (*Malacosoma disstria*).

Managing tent caterpillars may require cultural and chemical controls. Inspect the trees for egg masses during winter pruning. Insecticide application might be warranted if you notice the caterpillars early.

Apart from controlling the caterpillars, the only way to improve the tree's appearance is to physically remove the tents and webs. If needed, spot-treat trees with a registered insecticide.

The web of the **fall webworm** (*Hyphantria cunea*, Fig. 2-15, page 27) is commonly confused with the tent of the eastern tent caterpillar. Although fall webworms infest hickory, oak, persimmon, and many other trees, they prefer pecan trees.

Fall webworms build webs near the ends of branches (Fig. 2-16, page 27) and consume the leaves within the web. As the larvae grow, they enlarge the web to include more foliage. The webs usually become quite large by the fall, when the caterpillars stop feeding.

Two to four generations of this pest occur per year, depending on location in the state. The last generation is the most destructive and occurs in the fall.

Another web producer, the **genista caterpillar** (*Uresiphita reversalis)* feeds on the foliage of Texas mountain laurel. The caterpillars are about 1 inch long but less hairy than the fall webworm.

Beetles

Elm leaf beetles (*Xanthogaleruca luteola*) are probably the most common insects on elm trees.

The adult is yellowish olive green, often with an indistinct black stripe along the margin of each wing (Fig. 2-17, page 27). The eyes are black; the antennae and legs are yellow.

When newly hatched, the larva or grub is yellowish but appears nearly black because of the dark hairs and small nodules (*tubercles*) on the body. Fully grown, the larva is about ½ inch long and has two black stripes down the back.

Both stages skeletonize leaves, which dry up and shed prematurely. Heavy defoliation weakens trees and leaves them vulnerable to attack by other insects and diseases. The adults chew oval holes through leaves; the larvae eat all but the upper leaf surface (Fig. 2-18, page 27).

A tree needs no treatment until it loses more than 15 percent of its leaves. Use foliar and trunk sprays or soil-applied systemic insecticides.

Miscellaneous

Leafminers (*Liriomyza* spp.) are the immature stages of some beetles, caterpillars, and flies. The larvae hatch from eggs deposited in plant tissue and feed between the upper and lower cell layers of leaves.

They change into pupae (*pupate*) in the leaf tissue or on the ground; several generations can occur in a growing season.

Damage (Fig. 2-19, page 27) occurs when the small larvae tunnel in leaves. Chrysanthemums, zinnias, and verbenas are particularly susceptible to attack. Insecticide applications are directed at larval stages but are not needed unless plant damage has become severe and unsightly.

Wood-boring insects

Wood-boring insects are generally secondary invaders, which are pests that infect plants only when they are stressed or in poor condition. At these times, borers damage the woody stems and trunks of shrubs and shade trees.

Managing wood-boring insects can be difficult. In general, use cultural control methods—remove and destroy infested branches.

Chemical options include trunk injections and *residual insecticides,* which are pesticides that continue to be effective for a period after application.

Flat-headed borers are the larvae of metallic wood-boring beetles. These larvae tunnel under bark and create long, winding galleries just under the bark surface.

Oval in cross section, these insects pack their galleries with a mixture of waste and plant material (*frass*). At maturity, the larvae of some species reach 1½ to 1¾ inches long.

The adult beetles emerge to the surface through holes they cut in the wood. They mate and deposit eggs in cracks and crevices in the bark.

Round-headed borer (*Cerambycidae,* Fig. 2-20, page 27) larvae generally make round galleries beneath the bark and tunnel into the heartwood of trees. The emergence site is oval, clean-cut, and surrounded by sawdust-like borings. The adults are long-horned beetles.

Cottonwood borers (*Plectrodera scalator*) attack cottonwood, poplar, and willow trees. The adult (Fig. 2-21, page 27) is about 1¼ inches long and has a round head and a black and whitish yellow pattern. The 1¾- to 2-inch-long larvae tunnel at the base of the trunk.

Cottonwood borers are active from May through August.

The **red-headed ash borer** (*Neoclytus acuminates*, another round-headed borer, is one of the most common wood-boring beetles. It has a narrow body, a red middle segment (*thorax*), and light brown wing covers, each marked with four yellow lines.

This borer feeds on many plant species, including ash, elm, grapes, and oak.

Twig girdlers attack chinaberry, huisache, mimosa, and pecan trees.

Female adults appear in late summer or early fall and feed on thin tree bark before laying eggs. The pest girdles twigs and small branches of the host tree and deposits eggs in the girdled part, which soon dies and falls to the ground.

The larvae feed on the wood of these dead twigs until the middle of the next summer, when they pupate and emerge as adults.

Although small trees can become unsightly, they are not killed.

Bark beetles tunnel below the bark and into the wood of trees and shrubs (Fig. 2-22, page 27). The adults are small and reddish brown to black. Species include the Asian ambrosia beetle, European elm bark beetle, and southern pine beetle.

Carpenterworms are large larvae that tunnel through the trunks of many kinds of trees. The larvae require 2 to 3 years to develop.

Peach tree borers (*Synanthedon exitiosa*) attack peach and plum trees. The adults are clearwing moths that lay eggs in late summer and early fall. The larvae tunnel under the bark for 10 to 11 months before emerging from the trunk base, where masses of sap accumulate around the damage sites.

Gall-forming pests

Many species of fungi, insects, and mites cause abnormal growths (*galls*) on ornamental and shade trees. Each species produces a distinctive deformity on plant leaves, stems, or twigs.

The immature stages usually develop inside the developing gall. Some of the more damaging gall-forming pests are aphids, midges, mites, phylloxeras, psyllids, and cynipid wasps.

Cynipids are several species of tiny wasps that cause galls on oak leaves. They deposit eggs in the leaf tissue; in response to the attack, the plant develops galls or growths.

Different species cause the plants to form wooly-oak, gouty-oak, or horned-oak galls. The galls' shape, size, and formation may differ greatly by cynipid species.

Jumping plant lice, or psyllids, are tiny sucking insects that also cause galls. One species causes galls on hackberry. The petiole-gall aphid is responsible for galls on cottonwood stems.

Although galls usually do not harm the plant, some attract bees and wasps, which might cause concern.

Insecticidal control

Landscape managers confronted with a serious pest infestation often must apply an insecticide or miticide. Although the most common application methods are sprays, a few are liquid soil drenches or trunk injections.

Systemic insecticides are applied to the bark, leaves, or roots. Systemics are also injected into the vascular system, which transports nutrients, sugars, and water throughout the plant.

After the plant absorbs a systemic insecticide, the vascular system moves the chemical throughout the plant and kills the insects that feed primarily on the leaves.

Sprayed systemics also kill insects by contact. They are effective against many sucking pests and some chewing pests. Examples of systemic insecticides are acephate, dinotefuran, and imidacloprid.

The advantages of systemics are that they have a relatively long residual life, kill fewer beneficial insects, protect newly expanding foliage not present during application, and protect plant parts, such as growing points, that are difficult to reach with sprays.

Insect pests of turfgrass

Insect damage to turf is often mistaken for a disease, drought, or fertility problem. The symptoms are often similar: dieback, stunting, wilting, yellowing, or growth distortions. As a result, insect pests often escape notice until after they have inflicted extensive damage.

If you spot the symptoms early, you may be able to prevent the pest population from escalating. In Texas, the major turfgrass insect pests are chinch bugs, fall armyworms, mole crickets, red imported fire ants, and white grubs.

Sucking pests

Southern chinch bugs (*Blissus insularis,* Fig. 2-23, page 27) are among the most economically damaging insect pests of St. Augustinegrass in Texas during the summer. They cause minor damage to bahiagrass, bermudagrass, centipedegrass, and zoysia.

Chinch bugs prefer hot, dry weather and open, sunny areas. They damage turf by feeding on the sap of the plant's food-conducting tissue (*phloem*) and injecting a toxin that kills plant tissue.

Chinch bugs produce irregular patches of dead or dying grass surrounded by a halo of yellowing, dying grass, where the insects are most active.

The adult chinch bug is about ⅕ inch long with reddish legs, a black body, and fully developed wings. Each front wing is mostly white and marked with a triangular black patch at the middle of the outer margin.

Chinch bug nymphs are orange and smaller than the adults. When crushed, they give off a strong, pungent odor.

There are two ways to sample for chinch bugs:

- Go to the outer edge of an affected area, part the grass, and look for chinch bugs at the base of the turf.
- Remove the top and bottom lids of a coffee can, push it into the grass below the soil surface, and fill it with water. If chinch bugs are present, they will float to the top within 30 minutes.

Several insecticides can control chinch bugs. The labels of many of these products recommend that you water the turfgrass after application to move the insecticide into contact with the chinch bugs, which maximizes control.

Bermudagrass mites (*Eriophyes cynodoniensis*) are microscopic—about 1/25 inch long—and have cigar-shaped bodies and two pairs of legs.

In dry areas of Texas, these mites damage bermudagrass by sucking juices from the plants. Infested grass will appear pale and stunted.

For severe infestations, several registered miticides are available for control.

Chewing pests

White grubs

Most of the roughly 100 white grub species (Fig. 2-24, page 27) in Texas inflict little damage to turfgrass. The most harmful species in Texas turfgrass are the June beetle (Fig. 2-25, page 28) (*Phyllophaga crinita*) and the southern masked chafer (*Cyclocephala lurida*).

Both types of white grubs readily attack warm-season grasses such as bermudagrass, buffalograss, St. Augustinegrass, and zoysia. Lawn grass heavily damaged by white grubs will have only a few roots and can be rolled up like a carpet.

The adults, commonly known as May or June beetles, are about ½ inch long and gray, red, or light brown.

The adults of most species are active during the flight period, which may last for several weeks. Most areas of Texas experience major and minor flight periods, when many male adults congregate around street and porch lights.

Because lights do not attract the females much—they seldom leave the sod area—you many not find eggs in lighted areas.

Female beetles congregate to lay eggs, which leads to defined areas of infestation in yards. The egg-laying period averages 30 days; a female can lay 30 to 40 eggs and appears to avoid heavily watered sod. The eggs hatch within 3 to 4 weeks.

White grubs undergo complete metamorphosis, with egg, larva (the grub stage), pupa, and adult phases. The grub stage sheds its old exoskeleton (molts) three times; the term for each stage between molts is *instar.*

As the larva progresses through the three instars, its size and appetite grow tremendously. Because the third instar is responsible for most of the visible damage to turfgrass, it is best to take action before the insect reaches this stage.

The ideal treatment time for white grubs is about when the grubs hatch or in the first few weeks of development. In South Texas, the ideal time to treat for white grubs is June; in North Texas, early July is more appropriate (Fig. 2-26).

Later stages may be harder to control and severely damage the turf if left uncontrolled. White grubs will feed throughout the summer, thinning or killing turfgrass stands.

Not all athletic fields, golf courses, and lawns need regular treatment for white grubs. However, you may need to treat sites that are prone to white grub damage every year.

Few people sample for these insects except possibly in turf of high value or with a history of white grub damage.

To confirm that white grubs are the cause of patches of yellowing or dying turfgrass, dig up a few small sections on the edge of dying grass. Treatment may be justified if the grass pulls up readily with few roots and has five or more grubs per square foot.

White grubs can be controlled by some species of nematodes, which are microscopic worms. However, they tend to be difficult to use and more expensive than insecticides.

Although white grub insecticides can remain active in the soil for relatively long periods, the chemicals may break down too early if applied before the white grubs develop. It is usually best to wait until after mating flights to apply insecticide.

Irrigation is essential for chemical and biological treatments. Watering before treatment encourages white grubs to come closer to the surface, and it helps prepare the soil for better insecticide (or nematode) penetration.

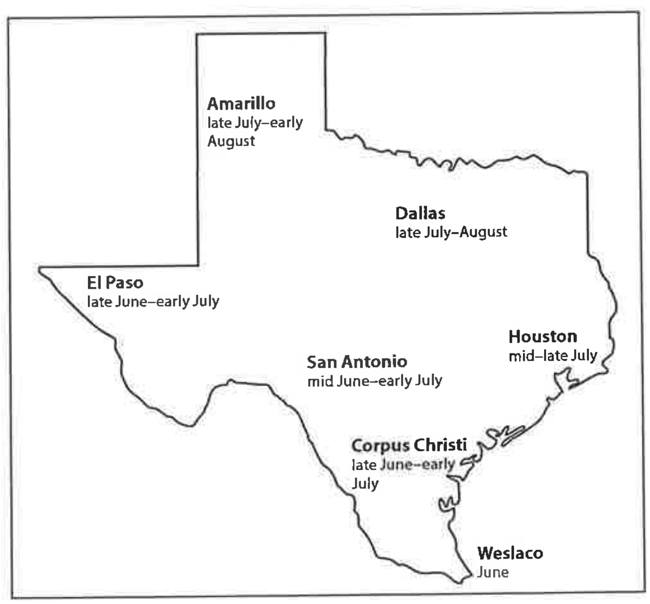


Figure 2-26. Critical treatment periods for white grubs

Insecticides need water to move them through the thatch and down into the root zone, where the grubs feed. Apply ½ to 1 inch of water immediately after (before the product has dried) applying nematodes or liquid insecticide. Granular insecticides do not provide control until they are watered into the soil.

Hunting billbugs occasionally infest Texas turfgrass, and their presence and impact appear to be increasing. Damage occurs most often in bermudagrass and zoysia, less so in centipedegrass and St. Augustinegrass.

At first, the damage appears as small pockets of yellowing and dying grass, resembling dollar spot disease. Then irregular, elongated, or round areas of grass turn brown and die. The symptoms can resemble those of disease, delayed spring green-up, or lack of water or nutrients.

Although the damage sometimes occurs in summer, it typically appears in the spring and fall, when the adults feed on turfgrass stems.

The larvae are legless, ¼ to ⅓ inch long, and white with a brown head capsule.

Armyworms

Although several species of armyworms are common in Texas, the one causing the most damage to lawns is the fall armyworm (*Spodoptera frugiperda,* Fig. 2-27, page 28).

Fall armyworms feed on a wide variety of plants but prefer small grains and grasses planted in the fall. They feed primarily on bermudagrass, bluegrass, fescue, and ryegrass.

The name *armyworm* originates from agriculture, where infestations sometimes resemble an army as they move across large agriculture fields. The same behavior occasionally occurs in turf, where they consume grass in areas as large as a football field in 2 or 3 days.

They are more likely to increase in cool, wet weather during fall and early spring, when fewer natural enemies are present and Texas lawn grasses are flourishing.

The fall armyworm has four life stages: egg, larva, pupa, and adult. The adults are generally gray moths with white underwings and a 1½-inch wingspan. The forewings are mottled with flecks of white; the males may have a triangular white spot near the wing tip and another spot in the middle of the wing.

Fall armyworms are unusually susceptible to cold, and populations are thought to die out each winter except in South Texas. Infestations often occur during "outbreak years," when exceptionally high populations of the insects survive the winter and make their way north.

Fall armyworm caterpillars are brown, gray, green, or yellow-green. Their most distinguishing characteristic is a whitish inverted **Y** between the eyes and three whitish stripes on the shield behind the head.

This species develops from eggs to full-grown larvae in 2 to 3 weeks, at which point the larvae burrow into the soil to pupate and emerge as adults 10 to 14 days later. Then the life cycle begins again.

Multiple generations occur each year, mostly in South Texas, where warm weather often enables them to develop year-round.

Because this pest destroys grasses quickly, scout for damage carefully. If the turfgrass has many armyworms, treat it as soon as possible to prevent further injury.

Several active ingredients can control fall armyworms. The products vary greatly in formulation, use site, applicator requirements, and other characteristics.

Sod webworms (Fig. 2-28, page 28) are destructive turf insects. The caterpillars feed at night on bahiagrass, bermudagrass, centipedegrass, St. Augustinegrass, and zoysia.

A sod webworm builds a small column of silk and soil at the base of a grass plant. Damaged grass blades first appear notched and ragged as the insects remove tissues from the edges. Turf damage generally appears in patches that enlarge as the caterpillars migrate in search of food.

The presence of many low-flying moths, the adult stage, is normally associated with infestations. Control options are biological insecticides, parasitic nematodes, and soil-applied insecticides.

Cutworms damage many types of plants, including turfgrass. The larvae feed on plant tissue mostly at night, usually cutting tender growing plants at the soil line.

Sample for cutworms using the method for fall armyworms. Populations of three or more worms per square foot may warrant treatment.

Control cutworms with parasitic nematodes or a registered insecticide.

Tawny mole crickets (*Scapteriscus vicinus*) and southern mole crickets (*Scapteriscus borelli*, Fig. 2-29, page 28) build extensive tunnels on top of the ground.

These mole crickets uproot turfgrass, which then dries out. They are particularly problematic on sand-based athletic fields and golf courses, where it is easy for them to tunnel. Tunneling on putting greens can affect playability and mowing quality.

The mole cricket's primary targets are bahiagrass and bermudagrass, but it can also damage creeping bentgrass, centipedegrass, and zoysia.

The southern mole cricket is more widely distributed across the state than is the tawny mole cricket:

- Southern mole crickets occur east of a line from Corpus Christi to San Antonio to Fort Worth, and south of I-20 in most of East Texas
- Tawny mole crickets occur mostly in the southeastern part of the state, from the Houston area to Louisiana.

To maximize control, scout and treat for mole crickets in May through July, while the nymphs are still small.

Flush the turf with a mixture of 1 gallon of water and 1 tablespoon of lemon-scented liquid dish detergent. This mixture irritates the nymphs and flushes them to the soil surface for counting and identification.

Several insecticides are registered for mole cricket control.

Red imported fire ants (*Solenopsis invicta*, Fig. 2-30, page 28) cost Americans $6 billion a year and are a serious pest of lawns and golf courses in Texas. Although they do minimal harm to turfgrass, other damage often warrants control:

- Fire ant stings can cause severe medical problems and even kill people and animals.
- The mounds (Fig. 2-31, page 28) created by fire ants can damage lawn care equipment and detract from the landscape's appearance.
- Fire ants infest buildings and can compromise electrical equipment by chewing on wire insulation.

Red imported fire ants look much like some native Texas species. However, they behave much differently. The imported fire ants are much more aggressive, attacking anything that disturbs their mound. Their mounds tend to be in open, sunny areas and have no visible openings.

Although eradicating these ants is unlikely, three approaches can help control or suppress them in turfgrass: contact insecticides, individual mound treatments, and broadcast applications of bait-formulated insecticide.

Individual mound treatments can require significant amounts of labor, money, and time. To be effective, the treatment must kill the queen(s). Otherwise, the colony will survive. Some nests may go undetected.

Even after every mound is treated, colonies can migrate in from untreated areas or float in on floodwater. Deep-dwelling colonies that escape mound treatment can quickly form mounds after a soaking rain.

Chemical insecticides vary widely in their effectiveness and length of control.

Biological control has shown some success in limited areas. Governmental programs have used parasitic flies from South America, which are the ants' natural enemies.

Tawny crazy ants (Fig. 2-32, page 28) were discovered in Texas in 2002. Since then, they have spread to other parts of the state, largely by humans.

Tawny crazy ants are ⅛ inch long and reddish brown; they crawl rapidly and erratically. They do not build centralized beds, mounds, or nests and do not emerge to the surface from nests through central openings.

Many of the typical control tactics for other ants do not control the tawny crazy ant adequately. There are contact insecticides that can offer some control but will not be long lasting.

Study questions

1. What type of plant damage is caused by aphids, scales, mealybugs, and whiteflies?
   a. Chewing
   b. Sucking
   c. Burrowing
   d. None of the above

2. During what kind of weather are damaging infestations of spider mites most likely to occur?
   a. Cool and wet
   b. Warm and humid
   c. Cool and dry
   d. Hot and dry

3. What insect builds webs near the ends of branches, where caterpillars consume foliage?
   a. Cynipid wasp
   b. Fall webworm
   c. Forest tent caterpillar
   d. Fall armyworm

4. The feeding of what insects causes plant galls?
   a. Aphids
   b. Mites
   c. Small wasps
   d. All of the above

5. In what kind of weather do chinch bugs damage turf?
   a. Cool and wet
   b. Warm and humid
   c. Cool and dry
   d. Hot and dry

6. What insect larva is a white grub?
   a. June beetle
   b. Moth
   c. Butterfly
   d. Elm leaf beetle

7. How many white grubs per square foot may cause economic damage?
   a. 8–10
   b. 4–5
   c. 1–3
   d. 2

8. The fall armyworm can be identified by:
   a. A white inverted Y on the head
   b. Its green color
   c. White dots on the back
   d. Number of teeth

9. Which turfgrass insect infestations are generally associated with the presence of many low-flying moths?
   a. Mole crickets
   b. Fall armyworms
   c. June beetles
   d. Sod webworms

10. Which turfgrass insect builds mounds in open, sunny areas with no visible openings?
    a. Mole cricket
    b. Chinch bug
    c. Red imported fire ant
    d. Tawny crazy ant

1. b
2. d
3. b
4. d
5. d
6. a
7. b
8. a
9. d
10. c

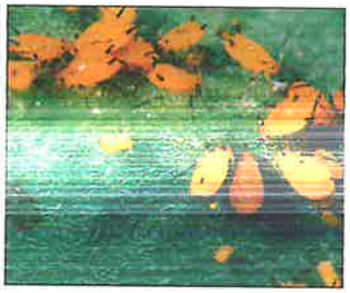


Figure 2-1. Aphids


Figure 2-2. Oleander aphids


Figure 2-3. Sooty mold on crape myrtle with cast skins (small white spots) from aphids


Figure 2-4. Wax scale


Figure 2-5. Crapemyrtle bark scale


Figure 2-6. Whitefly


Figure 2-7. Lace bug


Figure 2-8. Cicada

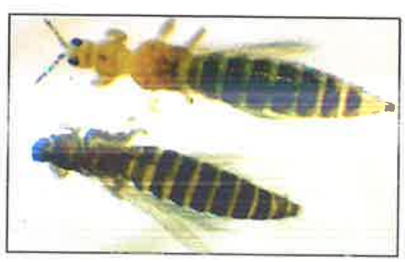


Figure 2-9. Thrips


Figure 2-10. Spider mites


Figure 2-11. Walnut caterpillars on a pecan tree


Figure 2-12. Bagworm

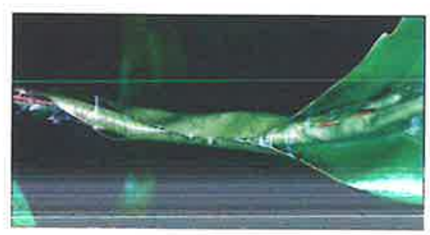


Figure 2-13. Leaf roller damage

Figure 2-14. Tent caterpillars

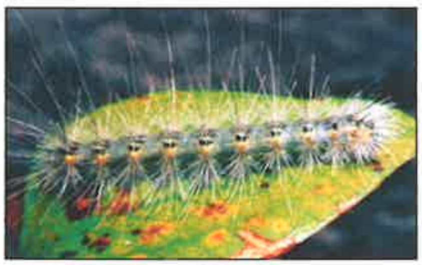


Figure 2-15. Fall webworm

Figure 2-16. Fall webworms

Figure 2-17. Elm leaf beetle larva

Figure 2-18. Elm leaf beetles and damage

Figure 2-19. Leafminer damage

Figure 2-20. Round-headed borer

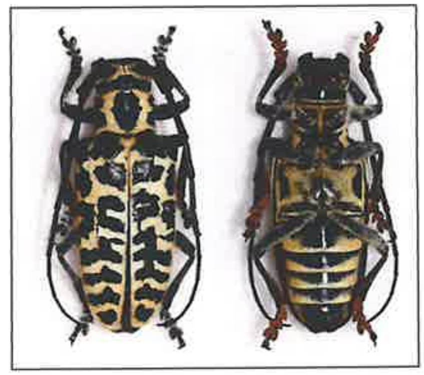


Figure 2-21. Cottonwood borers

Figure 2-22. Wood tunnels made by bark beetles

Figure 2-23. Chinch bug

Figure 2-24. White grub

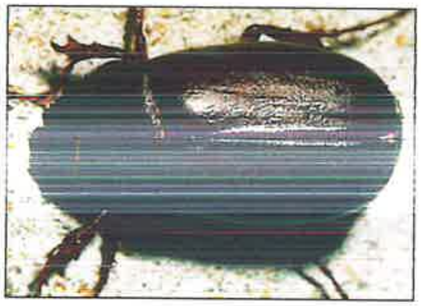


Figure 2-25. June beetle


Figure 2-27. Fall armyworm

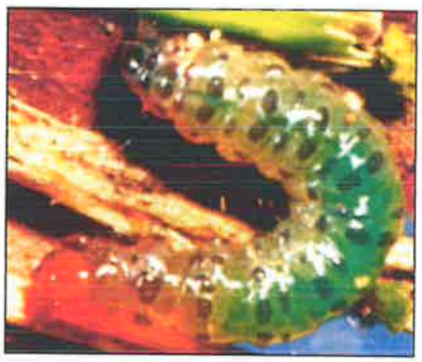


Figure 2-28. Tropical sod webworm

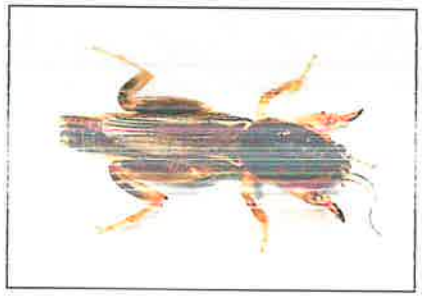


Figure 2-29. Southern mole cricket

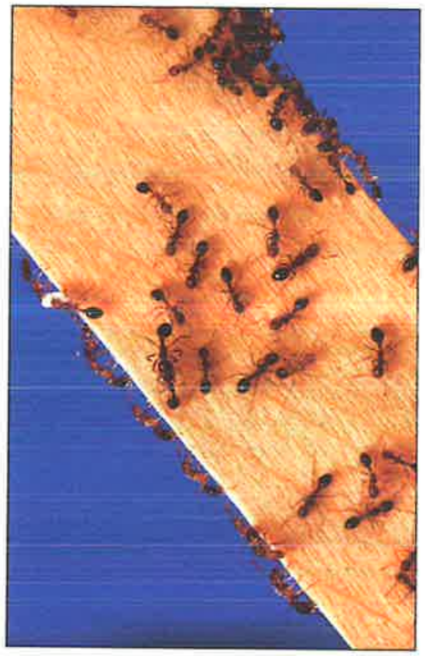


Figure 2-30. Red imported fire ants


Figure 2-31. Red imported fire ant mound

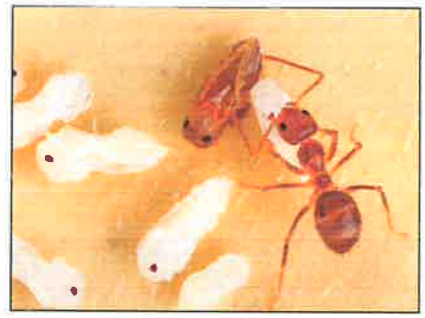


Figure 2-32. Tawny crazy ants

Diseases

A plant disease is an abnormal change in a plant's structure or function. This alteration often leads to the development of symptoms, which is the visible expression of a disease.

Disease causes

Biotic diseases are most often caused by living microscopic organisms (pathogens). The most common plant disease pathogens are bacteria, fungi, nematodes, and viruses.

Abiotic plant disease results from the presence of three factors that make up the **disease triangle** (Fig. 3-1) of a susceptible host plant, a favorable environment, and a pathogen that can infect the host plant.

These three factors are closely related. If one is missing or incompatible with the other two, no disease will develop.

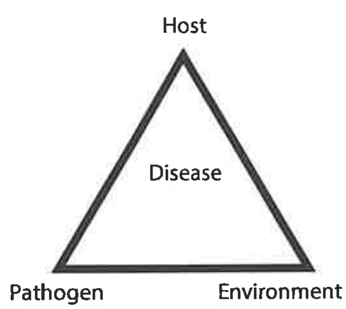


Figure 3-1. Disease triangle

Fungi cause the majority of severe plant diseases. The threadlike body (*hypha*) of a fungus usually reproduces by forming microscopic, seedlike structures called *spores*. Spores spread from one plant to another via animals, equipment, wind, splashing water, and infected plant parts.

The fungi enter the plant through wounds, direct penetration, or natural plant openings (stomata and lenticels).

Because fungi cannot manufacture their own food, they rely on host plants for nourishment. They feed on dead and living plant and animal matter.

Spores land on a leaf surface, germinate, and penetrate the leaf tissue. This chain of events is called the *infection process*, after which disease symptoms appear.

Protectant fungicides interrupt the infection process and prevent disease from developing. Fungicides must cover the leaves adequately and be sprayed at the proper intervals.

Abiotic disorders

The vast majority of problems with ornamentals in landscapes result from abiotic factors related to the environment. Common causes:

- Improper planting and maintenance
- Incorrect fertilization
- Nutrient imbalances in the soil or water
- Pesticide application issues
- Plant injury (chemical or mechanical)
- String trimmer injury
- Temperature extremes
- Unsuitable site
- Water stress

When plants are stressed, they become more vulnerable to insects and other pathogens. Although some pathogens attack healthy, vigorously growing plants, many attack and infect only stressed plants. For example, a weakened tree or shrub is much more susceptible to cankers (areas of dead tissue, usually darker and sunken, on stems and branches), decay, root rot, and some wilt diseases than is a vigorously growing ornamental.

Ornamental diseases

Black spot of rose (*Diplocarpon rosae*, Fig. 3-2, page 36) is one of the most common diseases of ornamentals. It also is the most destructive because it damages the plant's food-manufacturing organs.

Leaves produce carbohydrate materials that keep the plant healthy and productive. If the plant loses its leaves, it becomes unhealthy and dies.

A fungus with airborne spores causes black spot of rose. The disease usually occurs in spring and fall, particularly under moist or wet conditions.

Symptoms appear as black spots with fringed edges on the leaves. Pruning any damaged or infected canes can help slow this disease's development.

Rose varieties differ in their susceptibility to black spot. To prevent it, spray fungicide to susceptible roses when weather conditions are favorable for the disease's development.

Powdery mildew (*Erysiphe cichoraceaum*, Fig. 3-3, page 36) is a fungal disease of many ornamentals. It attacks crape myrtles, roses, and other plants.

Powdery mildew infects plants during cool, dry periods and can severely damage ornamentals. It is readily recognizable by the white, powdery growth that rubs off easily. The fungus penetrates the leaf's tissue and draws nutrients from the plant.

Euonymous is highly susceptible to powdery mildew. The primary symptom is white patches of fungus.

This type of powdery mildew is much more difficult to control than those infesting other plants. Although chemical control is effective, removing the plant may be advisable if it is highly susceptible but not crucial to the landscape design. Then you will not need to spray throughout the growing season.

Protectant fungicides prevent spore penetration and subsequent disease development.

Fusarium wilt (*Fusarium oxysporum*) attacks many ornamental and vegetable plants. At first, infected leaves turn yellow and the leaf stalks (*petioles*) collapse; then the plant wilts and dies. The lower leaves usually yellow first, followed by the rest of the plant. A brown-black discoloration develops inside the lower stem and upper root (Fig. 3-4, page 36).

The best control method for Fusarium wilt is to remove infected the plants. Fungicides are ineffective against this disease.

A fungal disease that affects azaleas and rhododendrons is **leaf gall** (*Exobasidium vaccinii*). The fungus penetrates the leaf, causing it to swell.

To control the disease, remove and destroy the infected leaves. Use a fungicide to prevent the fungus from developing on healthy foliage.

Crown rot and **root rot** can occur on almost all ornamental plants. Several bacteria, fungi, and nematodes living in the soil may contribute to this condition. It develops more readily when soil conditions are unfavorable for plant growth or when cultural conditions are not optimum.

Commercial growers should propagate plants in a pasteurized soil medium to keep the organisms out of the mixture. When the fungus recontaminates the medium, you may need to apply a soil fungicide to control the resulting disease.

Phytophthora aerial blight (*Phytophthora parasitica*, Fig. 3-5, page 36) can be a major problem in vincas. The fungus first infects the leaves, which quickly collapse. Next it moves to the petiole and then to the stem.

Controlling this pathogen is difficult, and fungicide is ineffective. Removing symptomatic plants suppresses the disease somewhat.

A disease that commonly infects photinia and Indian hawthorn is **Entomosporium leaf spot** (*Entomosporium mespili*, Fig. 3-6, page 36). This fungus causes problems during cool, wet weather.

Small, circular, often red spots appear on leaves and may grow together to form large maroon blotches on heavily diseased leaves.

To manage this disease, water the plants only when necessary and only in the early morning. To prevent future infection, remove diseased leaves that have fallen to the ground. You may need to spray protective fungicide when the weather is cool and wet. For best results, cover all the leaves with the fungicide.

Botrytis blight (*Botrytis cinerea*) or gray mold is a fungus that can infect any part of a plant above ground. The most susceptible plants include geranium, impatiens, and Persian violet.

The primary symptom is a fuzzy, gray-brown growth on infected plant tissue (Fig. 3-7, page 36). The disease is most common in cool, humid weather. Fungicides may control the disease if you apply them early and rotate them.

Oak wilt (*Ceratocystis fagacearum*) has become a major disease problem in black jack oaks, live oaks, and red oaks in Texas. The disease has killed more than 1 million trees in 76 Central Texas counties.

On live oaks, oak wilt (Fig. 3-8, page 36) causes the veins to turn yellow and the leaf tips brown. In all cases, the leaves on infected trees turn reddish brown, and the trees eventually die.

Because this disease spreads in tree roots, isolate infected trees to prevent further spread by digging trenches around them.

Sap-feeding beetles also transmit the disease. Prune susceptible trees only in winter and summer, when the beetles are least active. Pruning equipment should be sterilized between trees.

Systemic fungicide injections are effective when applied as preventive treatments. Once trees develop symptoms, the disease is difficult to control. Do not treat trees that have lost more than 30 percent of their leaves.

Downy mildew (*Peronospora* spp., Fig. 3-9, page 36) attacks twigs and young, tender leaves of ornamentals.

Under favorable conditions, this fungal disease can spread rapidly through the landscape. The fungus grows best in moist environments and cool or warm weather. For infection to occur, a thin film of water must be on the plant tissue.

The symptoms are small, pale yellow spots with irregular borders on the leaf tops. Directly under the spots on the leaf underside will be the downy, white-gray growth of the fungus's reproductive structures. If the disease-spreading conditions remain, you may need to apply fungicide.

Several fungi cause **leaf rust** on ornamentals. Leaf rusts appear as rust-colored spots on the leaves and stems.

To slow the spread of this disease, remove and destroy infected plant parts. However, if the infection is widespread, you may need to use a systemic fungicide.

Hypoxylon canker (*Hypoxylon* spp., Fig. 3-10, page 36) is caused by a fungus that infects primarily oak trees. On infected trees, first the leaves yellow and wilt. As the disease progresses, the tree bark will slough off to reveal a tan to gray crust of fungus underneath.

The only effective control for this disease is to keep the trees healthy.

Trees and woody shrubs can develop **fungal cankers**. Pruning and other wounds often lead to infection by canker-causing fungi. To manage cankers, prune out infected areas and promote good plant health.

Honeydew accumulates on leaves and gives rise to the fungal growth **sooty mold** (Fig. 3-11, page 36). The dark growth can be wiped off with a cloth and generally causes little harm to the plant.

The presence of sooty mold indicates the presence of large populations of honeydew-producing insects. Control the insects rather than the sooty mold.

Oak leaf blister (*Taphrina* spp., Fig. 3-12, page 36) attacks water oak, predominately in East and Southeast Texas. The disease puckers the leaves and weakens the tree.

You may need to apply a fungicide. However, use it when the tree forms buds in the spring. Once symptoms appear, fungicide will not control this condition.

Fruitless mulberry is often plagued with **leaf spot,** which causes the leaves to fall off prematurely in the summer and fall. This fungus penetrates the leaf tissue, producing a toxin that causes leaf drop.

This leaf loss weakens the tree and prevents proper growth. Fungicide application to the leaf surfaces prevents this condition.

Algal leaf spot attacks magnolias in humid areas of Texas, and chemical control may be required if it is severe. Improving air circulation by selectively pruning and removing some growth of other trees nearby area helps prevent the condition.

Lichens (Fig. 3-13, page 36) occur on the trunks of most trees in humid conditions. Lichens form when algae and fungi grow together, benefitting both organisms. A very common type of growth, lichens occur on rocks as well as tree trunks.

Modest lichen growth does not seem to harm trees.

Ball moss (Fig. 3-14, page 37) is an *epiphyte*—a plant that grows on another plant for support but not for nutrients or water. However, ball moss may become extensive enough on a live oak to damage it considerably, primarily by shading the leaves.

An effective control method is to physically remove the moss. Although chemical control is effective, use it only if the tree has an excessive amount of ball moss.

Bacteria cause some ornamental diseases. **Crown gall** (Fig. 3-15, page 37) causes a mass of plant tissue to grow at the crown. The growth can weaken or kill the plant.

Once crown gall infects trees, chemicals will not control it. To prevent this organism from entering the growing area, check plants being transplanted for signs of this disease, and destroy any that are infected.

Fire blight (*Erwinia amylovora*, Fig. 3-16, page 37) is a bacterial disease affecting many ornamental species, including roses. The bacteria causing this disease infect blossoms, young fruit, leaves, and small twigs.

After infection, the flowers and leaves wilt suddenly, turn brown or black, and die. Infected fruit appears leathery. Plants with severe infections appear to have been scorched by fire. The characteristic symptom is a stem bent at the tip (*terminal*), resembling a shepherd's crook.

In urban landscapes, chemical control is not recommended. Prune and remove infected plant parts 6 to 8 inches below the area of visible disease.

Several types of bacteria cause **bacterial leaf spots** (Fig. 3-17, page 37) on ornamental plants. Susceptible plants are begonias, geraniums, English ivy, lilacs, and several others.

The bacteria commonly infect plants after being splashed from the soil onto wet leaves. Symptoms appear as water-soaked blotches on leaves, often with large yellow areas and browning at the leaf edges (*margins*).

No safe, effective, chemical treatments control this disease. Remove the infected plant parts and avoid overhead irrigation.

Nematodes cause serious problems in ornamentals. The most common is the root-knot nematode. The typical symptoms of root-knot nematodes attacking ornamental plants are knots or galls on the roots). Plants with knotted or galled root systems cannot absorb enough water and nutrients. The tops of plants may appear wilted or inadequately fertilized.

Several chemicals kill nematodes. Because nematode-controlling agents (*nematicides*) vary substantially in toxicity and effectiveness, select control materials carefully. The number of effective nematicides available is decreasing rapidly as the U.S. Environmental Protection Agency (EPA) takes them off the market because of hazards to people, animals, or the environment.

Turfgrass diseases

Large patch (or brown patch) is a common disease of warm-season turfgrasses in the spring and fall. Caused by the fungus *Rhizoctonia solani*, large patch affects most warm-season turfgrasses in Texas.

Of the diseases affecting St. Augustinegrass and zoysia, large patch is the most chronic and economically damaging. Other host plants include bermudagrass, buffalograss, and centipedegrass.

The fungus lives in the soil and thatch year-round, but the disease develops only in wet soil and cool weather (below 70°F).

Large patch infects the grass roots, sheaths (the lower part of the grass leaf that encloses the stem), and stolons (horizontal stems that grow above ground). It is especially severe in turfgrass that is poorly drained and over-fertilized.

The first symptom of large patch is a circular, discolored patch on the turf (Fig. 3-18, page 37). The outer borders of the patches are orange or yellow; these leaves are newly infected and starting to die. Dark brown lesions (wounds or small abnormalities) appear on the stems and sheaths.

Diseased shoots pull easily from the sheaths where they attach to the stolons. Pulling up shoots is an easy way to diagnose large patch in a field.

Grass will recover from light disease symptoms as temperatures begin to rise in late spring; new growth will fill in the patches during the summer.

However, the grass may not recover if the disease damages the crown and roots extensively. In these cases, it is often necessary to re-sod the damaged area.

Once established, large patch is difficult to eliminate. Cultural practices such as proper irrigation, mowing height, and nitrogen application can greatly affect large patch.

You may need to apply a fungicide to ensure turf quality. Fungicides protect best when applied in the fall before disease symptoms appear and the soil temperatures drop below 70°F.

Fungicide becomes less effective once symptoms become evident. The damaged grass will not recover until the next spring. Fungicide applications in the spring are not cost-effective.

Take-all root rot is a fungal disease that causes weak, brown, dead patches in turfgrass (Fig. 3-19, page 37). In Texas, the disease severely affects St. Augustinegrass and bermudagrass, in which the disease is called bermudagrass decline.

The fungus (*Gaeumannomyces graminis* var. *graminis*) lives in the soil, primarily in thatch. It can produce spores but spreads mainly through the roots and stolons.

Mowers and foot traffic usually do not transfer the disease; spread is more likely when infected grass, soil, or thatch is moved elsewhere.

The symptoms of take-all root rot often appear in the spring or early summer, when the turfgrass emerges from winter dormancy. However, they may appear anytime in the growing season when the grass is stressed by drought, heat, shade, alkaline soil, or high-sodium water.

The most obvious first symptom is yellowish leaves that eventually wilt and turn brown. The turf thins, leaving brown, irregular patches about 1 foot to more than 20 feet in diameter. The roots are usually short, blackened, and rotten, making easy to lift the stolons from the soil.

On St. Augustinegrass, take-all root rot can easily be mistaken for chinch bug injury or large patch. If you suspect that the grass has take-all root rot, first eliminate the possibility of these other two common problems. The treatments for them differ greatly from those for take-all.

To control take-all root rot, reduce the soil pH to neutral to slightly acidic, if practical. Once take-all has infested a lawn, you will probably need to apply fungicide as well as adopt cultural practices such as proper mowing and watering. The best times to apply fungicides are in spring and fall.

Fairy ring (Fig. 3-20, page 37) is caused by a fungus that invades organic matter in the soil. The fungus produces mushrooms on the edge of this organic matter, forming a ring effect.

The disease becomes noticeable in spring and summer. Possible symptoms:

- Circular brown bands of dead or dying grass develop because the spreading fungi cause a water-repelling (*hydrophobic*) effect
- A ring of dark green grass appears, caused by the nitrogen released after the fungi decompose organic matter in the soil

To suppress this disease, mow the mushrooms, irrigate and fertilize the soil properly, force water into the dry areas, and apply a fungicide labeled for this disease.

St. Augustinegrass is susceptible to **gray leaf spot** (*Pyricularia grisea*, Fig. 3-21, page 37), another fungal disease. This disease can cause problems in the spring and early summer, especially in shaded areas.

Symptoms include tan lesions with purple or brown borders on the leaf blades.

To reduce the severity of gray leaf spot, stop using soluble nitrogen fertilizers on shaded lawns during the summer. To slow the disease spread, water early in the morning and remove grass clippings from infected lawns. Several fungicides are labeled for control of this disease.

Dollar spot (*Sclerotinia homeocarpa*, Fig. 3-22, page 37) is a fungal disease that attacks most turfgrasses in the South. Grasses susceptible to this disease include bentgrass, hybrid bermudagrass, and zoysia.

Generally occurring from spring through fall, this fungus prefers dry soils. The disease receives its name from the development of small, circular, brown to straw-colored spots, roughly the size of a silver dollar, sometimes larger on coarse-textured grasses.

In contrast to brown patch, which causes dark brown lesions, dollar spot creates light tan lesions with reddish borders.

Control dollar spot by removing thatch, fertilizing properly, and avoiding light, frequent watering. Several fungicides can prevent dollar spot; apply them during warm, moist periods in spring and fall.

Spring dead spot (Fig. 3-23, page 37) (SDS) is a destructive disease in bermudagrass lawns. Several fungi cause the disease in North America, and all bermudagrass varieties are susceptible.

SDS causes dead, circular areas of less than 1 foot to several feet across in the spring. Other symptoms include dark, rotted roots and slow recovery of bermudagrass in the affected areas, usually about midsummer.

Although SDS does not affect newly planted lawns, it causes problems on lawns 3 to 4 years old. It may be connected with an accumulation of thatch.

In some locations, SDS control has involved repeated applications of systemic fungicides in late summer or early fall.

Rust (Fig. 3-24, page 37) attacks many species of turfgrass, most often bluegrass, ryegrass, and zoysia.

Ryegrass can be very susceptible to rust in the spring, especially when nitrogen levels are low. Grass becomes is most susceptible when it is under stress and warm, humid conditions.

Signs of rust on grass blades are orange to reddish brown flecks that develop into pustules and eventually turn brown or black.

To help prevent rust, use cultural practices—fertilizing properly, avoiding moisture stress, and selecting resistant varieties. Failing that, several fungicides can control rust.

Bermudagrass smut is caused by a fungus that lives systemically within the plant. It is only a problem when seedheads form and cannot be controlled with fungicides.

Study questions

1. What are the microscopic organisms that most often cause biotic plant diseases?
   a. Plants
   b. Fragments
   c. Pathogens
   d. None of the above

2. What are the three factors of the plant disease triangle?
   a. Host, plant, environment
   b. Host, pathogen, environment
   c. Host, pathogen, water
   d. Three sides

3. Which pesticide should a person apply to control black spot of rose?
   a. Fungicide
   b. Insecticide
   c. Nematicide
   d. Herbicide

4. In primarily what conditions does powdery mildew become a problem?
   a. Warm and humid
   b. Warm and dry
   c. Cool and dry
   d. Cool and humid

5. What are the symptoms that oak wilt causes on live oak leaves?
   a. Chlorosis and gall formation
   b. Tip burn and black spots
   c. Vein chlorosis and tip burn
   d. Mold and tip burn

6. What disease commonly infects photinia and Indian hawthorn?
   a. Phytopthora aerial blight
   b. Botrytis gray mold
   c. Downy mildew
   d. Entomosporium leaf spot

7. What types of organisms grow together to form lichens?
   a. Nematodes and fungi
   b. Fungi and algae
   c. Cat and dog
   d. Bacteria and algae

8. **True or false:** Cultural practices such as proper irrigation, mowing height, and nitrogen application can greatly affect large patch.
   a. True
   b. False

9. Where does the fungus that causes take-all root rot live?
   a. In the air
   b. In the soil
   c. In the water
   d. On mowers

10. In addition to dark green rings, what does fairy ring often produce?
    a. Mushrooms
    b. Moss
    c. Mildew
    d. None of the above

1. c
2. b
3. a
4. c
5. c
6. d
7. b
8. a
9. b
10. a

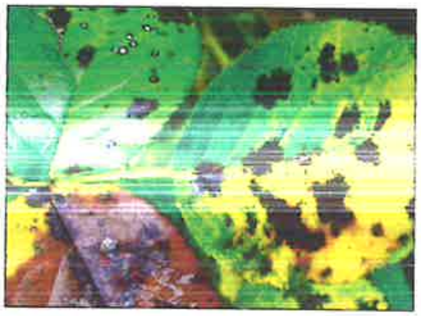


Figure 3-2. Black spot of rose

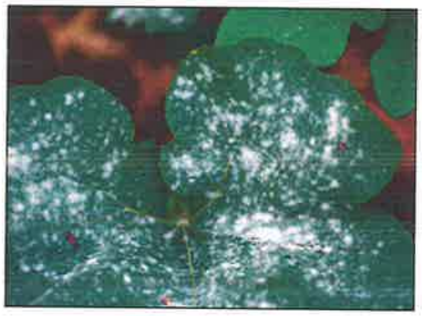


Figure 3-3. Powdery mildew

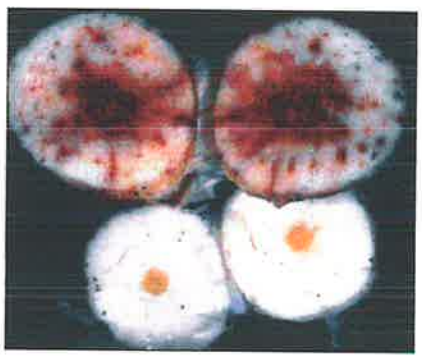


Figure 3-4. Fusarium wilt effect

Figure 3-5. Phytophthora aerial blight

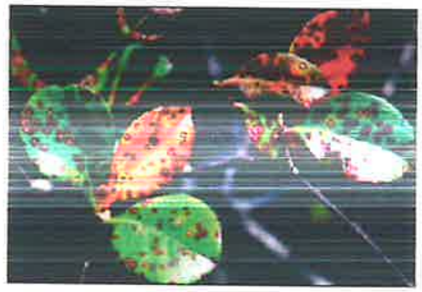


Figure 3-6. Entomosporium leaf spot

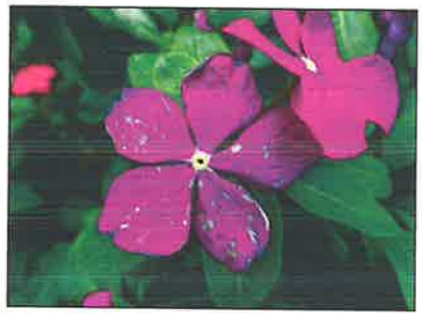


Figure 3-7. Botrytis blight of periwinkle

Figure 3-8. Oak wilt

Figure 3-9. Downy mildew

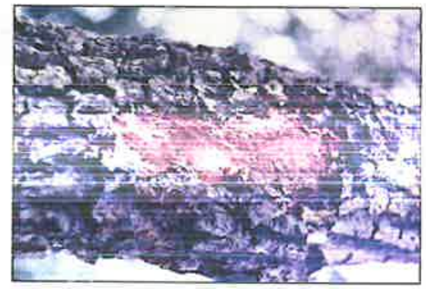


Figure 3-10. Hypoxylon canker

Figure 3-11. Sooty mold

Figure 3-12. Oak leaf blister

Figure 3-13. Lichens

Figure 3-14. Ball moss

Figure 3-15. Crown gall on rose

Figure 3-16. Fire blight

Figure 3-17. Bacterial leaf spot

Figure 3-18. Large patch (brown patch)

Figure 3-19. Take-all root rot

Figure 3-20. Fairy ring

Figure 3-21. Gray leaf spot

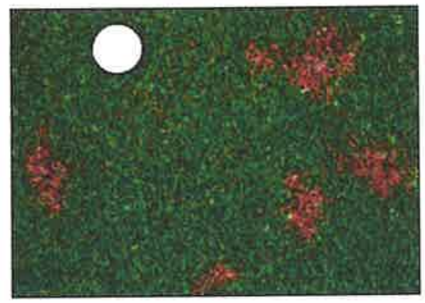


Figure 3-22. Dollar spot

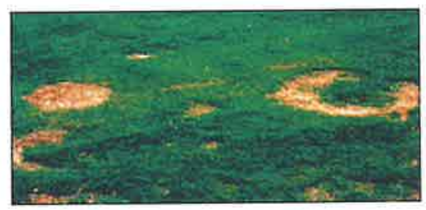


Figure 3-23. Spring dead spot

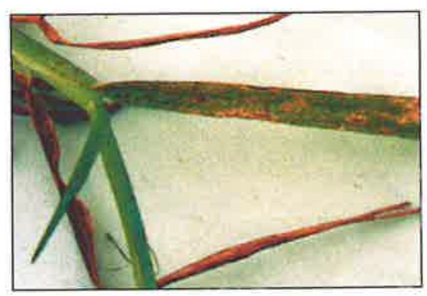


Figure 3-24. Rust

Weeds

In its simplest terms, a weed can be defined as "a plant out of place." By this definition, any plant can become a weed if it grows in an area where it is unwanted.

The first step in managing weeds is to promote a healthy, vigorous lawn. However, sometimes even a healthy lawn is unable to deter weeds. Weeds can spread via birds, water, wind, and new sod or mulch.

Weeds compete with turfgrass and ornamentals for nutrients, sunlight, and water. Weeds can be unsightly, and some contribute to allergies for people and pets.

Identification

The first step in controlling weeds is identification. Then you can determine how to manage them effectively.

Classification

Most weeds fall into one of two categories: broadleaf weeds, and grassy and grass-like weeds.

Broadleaf weeds are dicots because they produce two true seed leaves, or *cotyledons*. Dicots usually have broader leaves than do grassy and grasslike plants. Dicot leaves may take a variety of shapes with branching veins.

Most dicots produce a taproot. Examples are dandelion and Virginia buttonweed.

Grassy and grasslike weeds are monocots because when they germinate, they produce one true seed leaf, or *cotyledon*. Monocots usually have parallel veins in their leaves and fibrous root systems. Examples are crabgrass and nutsedge.

Growth habit

Weeds have two basic growth habits: upright, and prostrate or creeping. Mowing can stunt the growth of weeds that have an upright growth habit. However, mowing is generally ineffective for managing weeds that grow horizontally along the ground. Mowing turfgrass too short in an attempt to manage low-growing weeds can cause serious harm and fail to control them adequately.

Life cycle

Knowing a weed's life cycle can help you identify the species. The life cycle determines how a plant reproduces, how persistent it is, and what control strategy to use. Control strategies differ for annual, biennial, and perennial weeds.

Annuals complete their life cycle in 1 year. They grow from seed, then flower and produce new seed, and die within a year.

Winter annuals usually germinate in the fall, develop, and produce seed the following spring. The plants die after they produce seed. Examples of weeds that are winter annuals are annual bluegrass and common chickweed.

Summer annuals germinate in the spring, develop, and produce seed from early summer to early fall. The first frost kills many summer annuals. Examples of weeds that are summer annuals are crabgrass and purslane.

Biennials require 2 years to complete their life cycle. The first year, these weeds grow leaves and roots and store energy. They produce flowers and seeds in the second year, and then the plants die.

Only broadleaf weeds have biennial life cycles. Examples are cudweed and some thistles.

Perennials persist year after year. Once mature, they reproduce and spread. Although they can reproduce from seed, they primarily reproduce and spread via roots, rhizomes (horizontal stems growing underground), stolons, tubers, and other plant parts.

Perennials are difficult to control because many of their reproductive parts are in the soil, enabling the weeds to spread and take over areas. Examples of perennials are dallisgrass and dichondra.

Perennial grasses

Common bermudagrass (Fig. 4-1, page 49) is a perennial grass that can cause problems if it is not part of the intended vegetation. Bermudagrass is a warm weather grass that spreads along the ground by producing stolons. The leaves are very narrow, and the seed head consists of three to nine fingerlike spikes.

Bermudagrass thrives in full sun and is not competitive in the shade.

King Ranch bluestem (*Bothriochloa ischaemum* var. *songarica*, Fig. 4-2, page 49) is one of the most common perennial grasses in Texas. Because the Texas Highway Department seeded this grass years ago, it grows in many roadsides, pastures, and lawns.

KR bluestem, as it is commonly called, is a warm-season bunch grass with narrow leaves. Tufts of short, whitish hairs grow in the nodes (the area where the leaf attaches to the stem), and purplish seed heads emerge at the end of a slender, straw-colored stem.

Once established, this grass can be extremely difficult to remove from a landscape.

Johnsongrass (*Sorghum halapense*) commonly grows in ditches and fields and sometimes finds its way into lawns. The leaves are smooth with a thick, white midrib. The plants may reach 6 to 7 feet tall (Fig. 4-3, page 49).

This plant's thick, fleshy rhizomes sprout throughout the warmer months. Johnsongrass does not tolerate frequent mowing.

Dallisgrass (*Paspalum dilatatum*, Fig. 4-4, page 49) is a persistent perennial that spreads by seeds and by short rhizomes.

Dallisgrass is an erect plant with leaves up to ½ inch wide. The seed head has long hairs in the axils (the upper angles between leaves and stems) and three to seven unpaired branches on the stem.

Even after repeated mowing, dallisgrass shoots can emerge from the crown and outgrow the turfgrass, making the lawn look unkempt.

Field sandbur (*Cenchrus incertus*, Fig. 4-5, page 49) grows as an annual and a perennial in Texas. Its spiny bur makes this weed a major nuisance.

Field sandbur has rough, narrow leaves. The burs enable the plant to travel easily via humans and animals into warm-season turfgrasses, where it quickly becomes a problem.

Annual grasses

Annual bluegrass (*Poa annua*, Fig. 4-6, page 49) is a winter-annual grassy weed found in turfgrass across the state. Prime sites include athletic fields, flowerbeds, golf courses, and home lawns.

This grass has narrow leaves and a distinctive silvery white seed head at maturity. It produces many seeds and can survive repeated mowing.

Rescuegrass (*Bromus catharticus*, Fig. 4-7, page 49) is a winter-annual grassy weed with a drooping seed head. It invades dormant warm-season turf and grows quickly in winter and spring.

Crabgrass (*Digitaria* spp., Fig. 4-8, page 49) often invades home landscapes. Crabgrass species are warm-season grasses that can reach 3 feet tall. Some species grow along the ground, producing roots at nodes on the stem.

Crabgrass seed heads have two to nine very fine, fingerlike branches 2 to 5 inches long.

Crowfootgrass (*Dactyloctenium aegyptium*, Fig. 4-9, page 49) is a warm-season annual that grows along the ground and produces roots at the lower nodes. The plants are hairless except for fine hairs at the leaf margins.

The seed head grows at the tip of the stem of several spikes, resembling a crow's foot.

Goosegrass (*Eleusine indica*, Fig. 4-10, page 49) is a common warm-season annual grassy weed with flattened stems.

This grass grows in small clumps with white or silver centers. The leaves appear silvery green, and the seed head has 2 to 13 fingerlike spikes 1 to 3 inches long.

Goosegrass is often a problem in newly seeded turf and heavy-traffic areas during the summer.

Grasslike monocots

Wild garlic or **wild onion** (*Allium* spp.) is a bulbous perennial that produces seeds and aerial bulblets. Its slender, upright growth detracts from the beauty of well-kept turf areas in the spring.

The attractive, bright blue flowers of **dayflower** (*Commelina* spp., Fig. 4-11, page 50) are easily noticeable in landscapes. Texas has two annual and three perennial species. The flowers last only a day.

Dayflower leaves are narrow and pointed with parallel veins. The branches are fleshy and spreading, producing roots at the nodes. Stem fragments can also reproduce. Dayflower grows well in moist, shady areas.

Doveweed (*Murdannia nudiflora*) is a summer annual with parallel veins and narrow, linear leaves. It spreads by creeping fleshy stems.

Although doveweed commonly invades plant beds and mulched areas, it can also persist in mowed turf.

Sedges

Although they resemble grasses when they are small, sedges differ in that their stems are usually triangular. They tend to inhabit poorly drained soils and usually signal excess moisture.

Nutsedge (Fig. 4-12, page 50), or nutgrass, may be the most difficult weed pest to control in turf and ornamentals. Two of the most common and troublesome sedges in home landscapes are **yellow nutsedge** (*Cyperus esculentus*) and **purple nutsedge** (*Cyperus rotundus*).

Purple nutsedge forms an underground chain of tubers joined by a wiry rhizome. Several herbicides are labeled for sedge control, but you must identify the species correctly.

Nutsedge is incredibly difficult to control because it produces underground tubers that are extremely weather resistant. They can remain viable in the soil for many years. Pulling the plants out by hand does not remove the tubers.

Green kyllinga (*Kyllinga brevifolia*, Fig. 4-13, page 50) is a mat-forming perennial sedge with reddish rhizomes. It has a single, rounded seed head with up to three lobes.

Annual sedge (*Cyperus compressus*), a summer annual, grows in clusters and can persist in mowed turf.

Broadleaf weeds

Because knowing the life cycle can help you manage weeds more effectively, it is included after each broadleaf weed listed below.

Slender aster (*Aster subulatus* var. *ligulatus*, Fig. 4-14, page 50) has become more prevalent in turf in the eastern half of the state.

The leaves are simple, linear, and alternate (arranged one at a time on alternating sides of the stem). The flowers have tiny yellow disk flowers in the center and outer ray flowers that can be blue, pink, purple, violet, or white.

Asters become increasingly woody and more difficult to control as they mature late in the season and in areas where they become a perennial. *Annual* or *perennial*

Curly dock (*Rumex crispus*, Fig. 4-15, page 50) is stout and has spatula-shaped leaves. It has a fleshy taproot and a long seed head that turns reddish brown at maturity. *Perennial*

Mouseear chickweed (*Cerastium vulgatum*) is a small plant that grows close to the ground and produces roots wherever the stems touch the soil. It has hairy stems and dark green leaves that are covered with soft hair and shaped like mouse ears.

Unlike many broadleaf weeds, regular mowing does not slow the growth of mouseear chickweed. If left uncontrolled, it will cover the ground in thick, dense mats. *Perennial*

Bristly mallow (*Modiola caroliniana*, Fig. 4-16, page 50) roots at nodes along the ground. The leaves are round with many lobes, and the stems have short, bristly hairs. Although bristly mallow begins growing in the fall, it produces conspicuous pink flowers in the spring.

Mowing does not control bristly mallow. *Perennial*

Prostrate lawnflower (Fig. 4-17, page 50), or **horseherb** (*Calyptocarpus vialis*), is a low-growing weed that grows in a variety of conditions. It has small, green leaves and rough-textured stems. It produces small yellow flowers throughout the year.

Sold commercially as a native, perennial groundcover, prostrate lawnflower can be difficult to keep out of unwanted areas. *Perennial*

Common groundsel (*Senecio vulgaris*) can have wooly hairs on the leaves or no leaves at all. The leaves are opposite (arranged in opposing pairs along the stem) and deeply lobed, especially in mature plants. The yellow flowers occur in clusters. *Winter annual*

Cudweed (*Gamochaeta* sp.) species include narrowleaf, purple, shiny, and wandering cudweed. These plants have whitish to grayish hairs, particularly on the leaf underside.

Cudweeds usually overwinter in small, circular arrangements (*rosettes*) at the plant base (Fig. 4-18, page 50). *Annual* or *biennial*

Dichondra (*Dichondra repens*, Fig. 4-19, page 50) is a low-growing plant that thrives in tropical areas. It grows along the ground, forming mats not more than 2 inches tall.

Dichondra spreads by slender stolons that root at the nodes. The leaves are kidney-shaped with long stems, and the flowers are small, green, and inconspicuous.

This weed thrives in moist soils but cannot withstand freezing temperatures. *Perennial*

Dandelions (*Taraxacum officinale*) are the best-known weed in Texas. Although they spread primarily via seeds, the top growth grows back from the taproot after being mowed or chopped.

Dandelions have a thick, fleshy root and no stems. The yellow bloom is borne at the end of a long, hollow stalk and is a common sight in early spring. *Perennial*

Virginia buttonweed (*Diodia virginiana*, Fig. 4-20, page 50) is a creeping perennial with a flat growth habit. This weed has smooth, hairless stems that root at the nodes; its leaves are opposite and linear or lance-like.

The most distinctive feature is the small, white, star-shaped flowers with four petals. *Perennial*

Shepherd's purse (*Capsella bursa-pastoris*) is a common turf weed with leaves forming a rosette at the plant base. The flower stalks produce characteristic fruit that is flat, heart, or triangular-shaped pods (Fig. 4-21, page 50), which make this species easy to recognize when mature. *Winter annual*

Yellow woodsorrel (Fig. 4-22, page 50), or **oxalis** (*Oxalis stricta*), is an upright plant with three pale green, heart-shaped leaflets similar to clover. The flowers are small and have five bright yellow petals.

The fruit is a cucumber-shaped pod with a unique characteristic—when the seedpod is completely dry, the slightest touch will cause the pod to erupt and send seed flying in all directions. *Perennial*

Spotted spurge (Fig. 4-23, page 51) or **prostrate spurge** (*Euphorbia maculata*), normally grows flat on the ground in plant beds or thin turf areas.

Its leaves are small, oblong, and opposite along a purplish stem. When the stems break, a milky juice seeps out. *Summer annual*

Spiny sowthistle (*Sonchus oleraceus*, Fig. 4-25, page 51) emerges in midwinter and can be very unsightly in ornamental beds and turf.

The leaves may be relatively smooth or very spiny and notched along the margins. The flower is normally yellow; the seed head is feathery gray at maturity. *Winter annual*

Khakiweed (*Alternanthera pungens*, Fig. 4-26, page 51) and **mat chaff-flower** (*Alternanthera caracasana*) are especially problematic in Central and West Texas. Both have a prostrate growth habit and oblong, opposite leaves.

Although the fruit produced by khakiweed are soft, they have spiny heads that can be painful. *Perennial*

Common chickweed (*Stellaria media*, Fig. 4-27, page 51) is the most widespread broadleaved winter annual in Texas. The stems have many branches, opposite leaves, and many small, white flowers.

Chickweed can cover ornamental plant beds. *Winter annual*

Common purslane (*Portulaca oleracea*, Fig. 4-28, page 51) can be most troubling in newly established or thin lawns. It seems to thrive in hot, dry weather.

Purslane grows along the ground and has thick, fleshy leaves and stems. The leaves are green, the stems typically red.

The plant produces tiny yellow flowers that eventually give rise to many small black seeds. *Summer annual*

Henbit (*Lamium amplexicaule*) is another common winter weed. Its growth habit is primarily erect, although it can root at the lower nodes.

Henbit has a square stem and clasping, scalloped leaves. The flowers are pale purple and trumpet-shaped (Fig. 4-29, page 51). Once established, it is difficult to control. *Winter annual*

Carolina geranium (*Geranium carolinianum*, Fig. 4-30, page 51) grows in nearly every state of the country and in southern Canada. Its leaves are deeply cut into five lobes, and each lobe is variously divided again. It bears pink-lavender flowers with five petals at the top of the plant.

The seed capsule resembles a crane's bill, giving the plant another common name, cranesbill. *Winter annual*

Carpetweed (*Mollugo verticillata*) has the ideal growth habit for a turf weed. It grows essentially flat and horizontal along the ground and thrives in hot, dry weather.

Carpetweed has small, slender leaves that radiate from the nodes like the spokes of a wheel. It produces small, greenish white flowers in the leaf axils. *Summer annual*

Bitter sneezeweed (*Helenium amarum*, Fig. 4-31, page 51) is common in pastures and turf in many parts of Texas. In mowed turf, it remains a low-growing weed, but in unmown areas it quickly grows erect.

The bright yellow flowers and slender, green leaves of bitter sneezeweed are easily recognizable. *Summer annual*

Frogfruit or **matchweed** (*Lippia nodiflora*, Fig. 4-32, page 51) is a creeping weed that has leaves with saw-toothed margins. Small, white flowers cluster in a head at the tip of the plant's long stalk, resembling the head of a match. *Perennial*

Bur clover (*Medicago polymorpha*, Fig. 4-33, page 51) has a prostrate, spreading growth habit, and its stems can branch and spread for several feet. In closely mowed lawns, this weed can make the lawn unsightly.

The leaflets are green, the flowers yellow-orange. The seedpod forms a small bur that is not painful but has tiny barbs that can attach to almost anything, which then spreads the seed. *Winter annual*

White clover (*Trifolium repens*, Fig. 4-34, page 51) has a spreading, mat-forming growth habit that roots at the nodes. The leaves have three oval leaflets. This plant bears white flowers in headlike clusters and reproduces by seed. *Perennial*

Herbicides

Principles of herbicide use

Before selecting any herbicide, determine whether the desirable turfgrass is tolerant of the chemical under consideration. The majority of turfgrass herbicide failures result not from the weakness of the herbicide but from

- Wrong herbicide
- Adjuvant lacking or incorrect
- Agitation insufficient
- Application poorly timed or not uniform
- Environmental conditions undesirable at the time of application

- Equipment unsuitable or poorly calibrated
- Target weed at wrong growth stage
- Turfgrass species susceptible to the herbicide

Terminology

Selective herbicides harm some plant species greatly and others little or not at all. Most turfgrass herbicides are selective. For example, 2,4-D controls many broadleaf weeds without causing significant injury to most grasses.

Selective is a relative term that depends on many factors, including application timing, environmental conditions, herbicide rate, and the desirable species and variety being treated.

Nonselective herbicides control or suppress plants regardless of species. Examples are diquat (Reward), glyphosate (Roundup), and glufosinate (Finale).

Landscapers often use these products to trim along sidewalks and fences and to make preplant treatments before renovating or establishing turfgrass. **Note:** Some selective herbicides, such as atrazine, become nonselective if you apply them at high rates.

Mode of action refers to the change that a chemical causes in a plant at the tissue or cellular level. For example, some herbicides cause rapid or uncontrolled tissue growth; others destroy cell membranes; and others inhibit seedling growth.

Herbicide movement in plants

Systemic (or translocated) herbicides move throughout the plant's vascular system, which consists of two transport tissues, the xylem and phloem:

- The **xylem** transports water and nutrients in solution from the roots, where they entered the plant, through the stems, and into the leaves, flowers, and fruits.
- The **phloem** conducts food materials from the leaves, where the food is created, to other plant parts, such as fruits and developing roots, where they are used and stored.

Compared to contact herbicides, systemics act more slowly because plants need several days to a few weeks to move them throughout the plant.

Systemic herbicides may be selective or nonselective. An example of a nonselective systemic herbicide is glyphosate (Roundup). Selective systemic herbicides include 2,4-D, dicamba (Vanquish), imazaquin (Image), and sethoxydim (Vantage).

Contact herbicides affect only the green plant tissue that contacts the herbicide spray. Contact herbicides act fast—the symptoms are often visible within a few hours of application. For best control, cover the weed leaves thoroughly.

Because plants translocate these herbicides very little or not at all, they do not affect underground structures such as roots, rhizomes, and tubers. For long-term control, you must apply a contact herbicide multiple times because plants can regrow from the unaffected plant parts.

Bromoxynil (Buctril) and bentazon (Basagran T/O) are selective contact herbicides. Diquat (Reward) and glufosinate (Finale) are nonselective contact herbicides.

Timing of application

Herbicides are also classified according to the time that the chemical is applied in relation to the germination time of the turfgrass or weed seed. Most herbicides fall into one of three timing categories:

- **Preemergence:** Must be applied before weed seed germinate
- **Postemergence:** Applied to weeds that have emerged and are visible

Exceptions are atrazine (Aatrex), simazine (Princep), dithiopyr (Dimension), and pronamide (Kerb). They are both preemergence and postemergence herbicides.

Preemergence herbicides

The foundation of a turfgrass weed management program is preemergence herbicides. They are applied before the weed seeds germinate.

After rainfall or irrigation activates these herbicides, they form a herbicide barrier at or just under the soil surface. When the roots or shoots of germinating seeds come in contact with the herbicide barrier, their growth is inhibited.

Most preemergence herbicides inhibit the cell division of emerging roots and shoots, where cells usually divide rapidly. However, if the weeds have already emerged, the herbicide will not control them consistently—their growing point has escaped contact with the chemical.

Although preemergence herbicides primarily target annual weeds, they control some perennial weeds that germinate from seed.

Factors affecting the performance of preemergence herbicides include soil type, weed species, environmental conditions (primarily temperature and rainfall), and timing of application in relation to weed seed germination. The most important soil factors are texture and organic matter content.

Texture is the relative amounts of sand, silt, and clay in the soil. Herbicides move easily through sandy soil. Clay soils have finer particles and many adsorption sites to bind herbicides resulting in limited movement.

Table 4-1 lists herbicides that persist in the soil for long periods, do not dissolve in water easily, and adhere strongly to organic matter. When applied to turfgrasses and activated by water, these products form a very thin herbicide barrier.

Table 4-1 Herbicides with long soil persistence, low water solubility, and strong adsorption to organic matter

Trade name	Common name	Mode of action
Barricade	prodiamine	Inhibits cell division (mitosis)
Dimension	dithiopyr	Inhibits mitosis
Pendulum, Pre-M	pendimethalin	Inhibits mitosis
Ronstar	oxadiazon	Disrupts cell wall synthesis
Surflan	oryzalin	Inhibits mitosis
Team Pro	trufluralin + benefin	Inhibits mitosis
XL	oryzalin + benefin	Inhibits mitosis

As the weeds start to germinate, the young seedlings contact the herbicide, absorb it, and die. For best results, you must apply the herbicide and water it in before the seeds germinate.

To become active, preemergence herbicides must have ¼ to ½ inch of rainfall or irrigation, preferably within 24 hours of application to move the herbicides into the upper layer of the soil.

The critical period between application and activation by rainfall or irrigation varies with herbicide, rate, and environmental conditions.

Preemergence herbicides should ideally be applied just before the weed seeds begin to germinate. Preemergence herbicides must be in place and activated before the weed seeds germinate.

Applying the herbicide too early may reduce or prevent control because the chemical degrades or leaches through the soil. If the herbicide is applied too late, some weeds will have already germinated and will not be controlled.

Timing: The exact timing for preemergence herbicides depends on site weed type, site location, and weather conditions.

Weed type: To control winter annual weeds, apply preemergence herbicides in the fall. To control summer annual weeds, apply them in late winter or spring.

Site location: In northern parts of the state, herbicides targeting winter annual weeds should be applied earlier than in southern regions. Applications for summer annual weeds would be just the opposite: earlier in the south and later in the north.

Herbicide concentration and effectiveness begins to decrease soon after application and continues to decline over time. Factors that affect the persistence of preemergence herbicides include rainfall, application rate, soil type, and temperature.

Weather conditions: In general, cool, dry weather increases herbicide persistence; warm, wet weather reduces it. Most preemergence herbicides will degrade to the point of ineffectiveness within 6 to 16 weeks after application. Sometimes, full-season control requires repeated applications.

Follow label directions precisely at all times, particularly for preemergence herbicides. Critical restrictions involve turfgrass tolerance, soil type restrictions, and proximity to sensitive plants.

Postemergence herbicides

Postemergence herbicides are applied directly to weeds that have emerged through the soil surface. In contrast to preemergence herbicides, most postemergence herbicides have little or no soil activity.

The primary advantage of total postemergence control is that you can wait to see if weeds emerge and then decide whether you need to treat them. Disadvantages are the frequent applications needed and, in some cases, temporary turfgrass injury.

Most turfgrass managers use a combination of preemergence and postemergence herbicides. Postemergence herbicides are used to control the weeds that escape the preemergence treatments.

Established perennial weeds, both grasses and broadleaves (dallisgrass, nutsedge, Virginia buttonweed, white clover), must be controlled with postemergence herbicides. Some postemergence herbicides are effective on newly established grass.

Postemergence herbicides are most effective when they are applied at specific temperatures, weed sizes, and soil moisture levels.

Temperature: Air temperatures at application time should range from 60°F to 90°F. Although postemergence herbicides applied at below 60°F are often effective, they need more time to kill the weeds. If applied at above 90°F, herbicides such as 2,4-D, dicamba, dichlorprop, DSMA, mecoprop, and MSMA are more likely to injure turfgrass.

Weed size: Annual weeds are much easier to control if they are small (two to four-leaf stage) and actively growing. Young weeds readily absorb and translocate herbicides.

Early weed control accompanied by fertilization also allows turfgrasses that spread via stolons—bermudagrass, centipedegrass, St. Augustinegrass, and zoysia—to fill in the bare areas left by removing the weeds.

Postemergence herbicides are less effective on weeds that are stressed by heat, dry weather, or other environmental factors (such as dust covering the leaves).

Rain and irrigation can also reduce the effectiveness of a herbicide application. The extent of the drop varies among products. Typically, a rain-free period of 6 to 24 hours is enough to maintain effectiveness. However, even if rain falls soon after application, the pesticide will control the weeds to some degree.

Avoid mowing 1 to 2 days before and after application to allow more leaf area to develop and intercept the spray and to allow time for the weeds to absorb and translocate the herbicide.

Follow the label when using surfactants and crop oil concentrates with postemergence herbicides. Do not add surfactants that are not required because they increase turfgrass injury.

Under good conditions—adequate soil moisture, warm weather, and high humidity—the benefits of surfactants may not be obvious. Under marginal environmental conditions, failing to use the proper additive may reduce weed control noticeably.

Broadleaf weed control

The backbone of broadleaf weed-control programs in turfgrass has traditionally been benzoic acid (dicamba) and phenoxy (2,4-D, dichlorprop, MCPA, mecoprop). These herbicides are selective, postemergent, and applied to the leaves.

Combinations of two or three of these materials can usually broaden the spectrum of control. For acceptable weed control, perennials and tough annuals often need repeat applications of these combinations 10 to 14 days apart.

Drift management is crucial for these products because St. Augustinegrass can be very sensitive to these herbicides.

Tips for turfgrass weed control

- Avoid applying postemergence herbicides to warm-season grasses during the spring green-up or fall transition period.

Although the injury is usually temporary, it is preferable to spray while the grass is completely dormant or fully green and actively growing.

If the weed infestation is severe during the transition period, the benefits of weed control may outweigh the herbicide injury caused by treating.

- Avoid applying excess amounts of atrazine, dicamba, metribuzin, or simazine over the root zone of shallow-rooted trees, shrubs, and other ornamentals. Their roots will take up these mobile, soil-active herbicides under the right conditions (sandy soil and a heavy rainfall immediately after application).
- Beware of applying glyphosate (Roundup) to dormant turf in the winter. Only the northern and western parts of Texas have reliable dormancy periods.
- Consider conducting your own weed-control experiments. Control information is unavailable for many species that seldom occur or for particular tank-mixes that you may be considering. Always include an untreated area on the site for comparison.

Ornamental weed control

Weed control in ornamentals may be one of the most difficult challenges in pest management. Unlike turfgrasses, ornamentals are rarely planted in a single-species plot. Woody trees and shrubs often grow with annual and perennial herbaceous species in the same bed.

It is difficult to find herbicides that are compatible with the hundreds of species and varieties available. Other challenges are the scarce opportunities to use traditional weed-control approaches such as mowing, cultivating, and using selective, broad-spectrum herbicides.

Spot spraying

One of the most common ways to apply herbicides in and around ornamentals is directed spot spraying using a hand-held, pump-up sprayer or a lever-operated backpack sprayer. Limits to this approach are the lack of selective herbicides and the many obstructions that landscape plants pose.

Spot spraying solutions are typically prepared by adding a certain amount of liquid herbicide per gallon of spray mix. The labels usually list the ratio as a percentage of total volume.

For example, to make a 2 percent mixture of Roundup and water, you would add 2.56 ounces of Roundup per gallon of water. This method is best for herbicides that have little or no soil activity. Apply soil-active herbicides carefully on a per-unit-area basis (per acre or per 1,000 square feet).

When spraying, do not over-apply. Cover the plants about as much as would a light rain. Just wet the target weed's leaves and move on. Do not spray until runoff.

Use a funnel or other shield when applying nonselective herbicides such as Roundup, Reward, or Finale. You may adapt a normal plastic funnel, or cut the top of a 2-liter soda bottle. Attach it just above the nozzle with duct tape or a hose clamp. Another option is Drift Guard by Solo.

Beware of dripping or tracking in herbicide when moving from one area to another.

Tips for ornamental weed control

- Although grass-specific herbicides can help control grassy weeds in beds, these products also kill ornamental grasses.
- Preemergence herbicides that do not leach can help control weeds in landscape beds, especially if covered by mulch.
- Prevent the weeds from producing seed in landscape beds.
- Do not apply granular herbicides to ornamentals when the foliage is wet.
- Delay irrigation after applying postemergence herbicides.
- Always check the herbicide label for ornamental plant tolerance or susceptibility.
- Cut woody sprouts in landscape beds with pruning shears, and treat the cut surface immediately with triclopyr solution to avoid re-sprouting.

Study questions

1. What type of plant are broadleaf weeds?
   a. Monocots
   b. Dicots
   c. Grasses
   d. Sedges

2. What type of weed completes its life cycle in 1 year or less?
   a. Annual
   b. Perennial
   c. Biennial
   d. None of the above

3. Which weed is a winter annual that infests athletic fields, golf courses, and home lawns across Texas?
   a. Crabgrass
   b. Field sandbur
   c. Annual bluegrass
   d. Crowfootgrass

4. What type of weeds are common bermudagrass and dallisgrass?
   a. Annual grasses
   b. Annual broadleaves
   c. Sedges
   d. Perennial grasses

5. When does a winter annual germinate?
   a. Spring
   b. Summer
   c. Fall
   d. None of the above

6. Which of these plant groups produces tubers and has triangular stems?
   a. Weeds
   b. Grasses
   c. Broadleaves
   d. Nutsedge

7. What term describes herbicides that kill some plants without injuring desirable plants?
   a. Selective
   b. Nonselective
   c. Contact
   d. Systemic

8. What kind of herbicide is applied before weeds emerge and begin to grow?
   a. Post-emergence
   b. Preemergence
   c. Selective
   d. Contact

9. **True or false:** Mowing can influence the effectiveness of post-emergence herbicides.
   a. True
   b. False

10. What type of herbicide is glyphosate (Roundup)?
    a. Selective
    b. Contact
    c. Nonselective
    d. Preemergence

1. b
2. a
3. c
4. d
5. c
6. d
7. a
8. b
9. a
10. c


Figure 4-1. Bermudagrass


Figure 4-2. King Ranch bluestem


Figure 4-3. Johnsongrass


Figure 4-4. Dallisgrass


Figure 4-5. Field sandbur


Figure 4-6. Annual bluegrass


Figure 4-7. Rescuegrass


Figure 4-8. Crabgrass


Figure 4-9. Crowfootgrass


Figure 4-10. Goosegrass

Figure 4-11. Dayflower

Figure 4-12. Nutsedge

Figure 4-13. Green kyllinga

Figure 4-14. Slender aster

Figure 4-15. Curly dock

Figure 4-16. Bristly mallow

Figure 4-17. Prostrate lawnflower

Figure 4-18. Cudweed

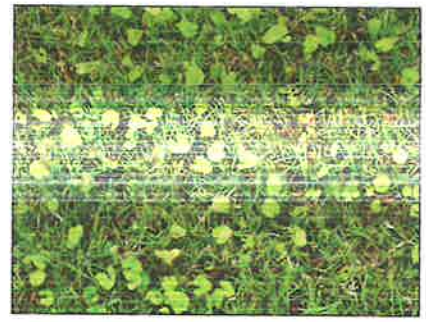


Figure 4-19. Dichondra

Figure 4-20. Virginia buttonweed

Figure 4-21. Shepherd's purse

Figure 4-22. Yellow woodsorrel

Figure 4-23. Spotted spurge

Figure 4-25. Spiny sowthistle

Figure 4-26. Khakiweed

Figure 4-27. Common chickweed

Figure 4-28. Common purslane

Figure 4-29. Henbit

Figure 4-30. Carolina geranium

Figure 4-31. Bitter sneezeweed

Figure 4-32. Frogfruit

Figure 4-33. Bur clover

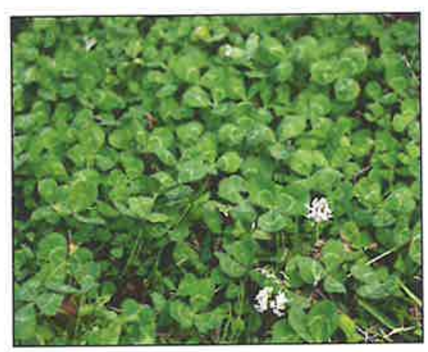


Figure 4-34. White clover

Application Equipment and Calibration

Most common pesticides and some fertilizers are applied in liquid form. Although sold as a liquid or powder, they are mixed with water, oil, or some other liquid carrier for application.

The equipment for liquid application generally consists of several types of boom and boomless (or broadcast) sprayers.

Boom sprayers

Boom sprayers use nozzles arranged along a pipe (boom) or tubing to distribute the material uniformly. Booms range from 1 to 4 feet wide for hand-held or push-type sprayer and 60 to 80 feet wide for some agricultural sprayers. Boom sprayers may be operated by hand or with a ride-on machine.

Turfgrass managers typically use boom sprayers on flat surfaces such as fairways and large lawns. Although wide booms can easily spray a large open area such as a practice field, they are difficult to maneuver in tight areas. On uneven terrain, shorter booms distribute pesticides best.

Boomless sprayers

Hose and reel skid

Hose and reel skid sprayers are useful for many landscape situations, particularly in smaller lawns where booms are impractical. Skid sprayers maneuver easily around trees and other obstacles. Products vary widely in hose length, pump type, spray gun, and tank size.

Handheld or backpack

Backpack sprayers are designed for spot treatments and areas unsuitable for larger units. These sprayers are maneuverable, relatively inexpensive, simple to operate, and easy to clean and store.

Although the units commonly use adjustable spray guns, some models use spray booms.

Granular

Drop spreaders have an adjustable sliding gate that opens holes in the bottom of the hopper, which allows the granules to flow out by gravity feed. These spreaders have uniform patterns, low drift potential, and precise control over a pattern's edge.

Rotary spreaders distribute pesticide granules to the front and sides of the spreader, usually by means of a spinning disk or fan. They are preferred for larger areas because their wide swath makes application faster.

Compared to other application equipment, rotary spreaders are easier to push, have better ground clearance, and have patterns that are more forgiving of operator error. Their rate mechanisms are less delicate and hold their calibration for longer periods.

Disadvantages of rotary spreaders include: uniform coverage is more difficult to achieve than drop spreaders; uneven distribution is a problem with combination products; and off-target placement can be a problem.

Calibration

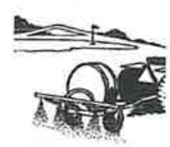
If you don't calibrate your equipment properly, you could be wasting chemicals and money as well as applying pesticide at an off label rate, which is illegal.

Landscape pesticides are not cheap, and failing to calibrate your equipment usually causes under- or over-application. Under-applying pesticides will likely reduce pest control and necessitate additional applications. Over-applying pesticides can injure plants, may be off-label, and could prompt legal claims against you.

Calibration enables you to apply a known amount of chemical uniformly over a given area. Many calibration methods are available—if you have one that works for your situation, there is no reason to change. However, if you are unfamiliar with calibration, you need to establish an accurate and consistent method for your system.

All types of pesticide application equipment must be calibrated (Table 5-1). Although the method may vary by equipment type, the general principles are the same.

Table 5-1. Checklist for improved accuracy of granular sprays

Type of equipment	Check your technique	Check your equipment
Handgun 	Gun height above ground	Pressure/delivery rate at pump
	Arm swing/ consistent pattern	Bucket check for delivery rate
	Walking speed	Check site gauges
	Proper overlap/ parallel passes	
	Trim techniques	
Rotary 	Walking speed	Spreader opening/adjust slide for correct delivery rate
	Proper overlap/ parallel passes	
	Spreader held level	Use deflector shield and adjust slide for trim
	Trim techniques	
Backpack 	Recharge by pumping to provide even output	Check nozzle for clogs
	Use a consistent walking speed	Check nozzle for wear
	Check the height of nozzle above ground	Check seals to maintain pressure
Boom 	Travel speed	Boom height
	Parallel passes	Bucket checks on nozzles
	Trim	Nozzle spacing and wear

Because walking provides the power for many types of application equipment, the person applying the pesticide is part of the equipment and can contribute to a calibration problem. Accuracy depends on the applicator's height, walking/driving speed, energy level, and body movements. As you calibrate your equipment, always consider your own physical characteristics.

Speed

The speed at which an applicator travels affects calibration greatly. In some cases, it may be useful to calculate miles per hour (MPH):

1. Measure a fixed distance.
2. Travel the distance and record the amount of time it takes to travel that distance.
3. Repeat Step 2 at least two or three times to make sure your reading is accurate.
4. Use this formula to calculate miles per hour:

$$\text{MPH} = \frac{\text{Test run distance (feet)} \times 60}{\text{Average time (seconds)} \times 88}$$

Spreader calibration

Follow these steps to calibrate a rotary spreader using the single pass method:

1. Consult the equipment manual to determine swath width and gate setting.
2. Measure and mark a convenient distance on a clean hard surface for a test strip. Suggestion: Use 100 feet or another distance

that can be divided easily into 1,000 square feet.

3. Multiply the swath width (Step 1) by the length of the test strip (Step 2) to determine the area that will be covered in the test run.
4. Weigh the amount of product that you put in the hopper. Push the spreader down the test strip while applying using a consistent walking speed.
5. Weigh the amount of product left in the hopper after treating the test area.
6. Subtract the amount left in the hopper (Step 5) from the amount put into the hopper (Step 4) to determine the amount used over the test area.
7. If the amount applied is within 10% of the recommended rate, the spreader is calibrated correctly. If the amount of product is greater or less than 10% of the recommended rate, repeat the steps above to recalibrate the spreader.

Drop spreaders can be calibrated with the pan method described above or with a catch pan attached under the drop spreader.

Sprayer calibration

Two methods for calibrating backpack or boom sprayers accurately are the 1/128th method and the 5940 calibration method.

1/128th method

The 1/128th method uses the ratio of 43,560 square feet in an acre to 128 ounces in a gallon. Instead of spraying an entire acre, you simply divide 43,560 by 128. This allows you to spray an area of 340 square feet, which is equal to 1/128th of an acre.

To calibrate a backpack sprayer:

1. Measure an area of 340 square feet. The area's shape does not matter.
2. Record the amount of time it takes to spray the area with water.
3. Using the same pressure and other settings, spray water into a catch container for the length of time recorded in Step 2.
4. Measure in ounces the amount of water caught. The number of ounces caught is the number of gallons that the backpack sprayer applies per acre (GPA).

To calibrate a boom sprayer

1. Measure the distance between the nozzles on the boom.
2. See Table 5-2 to determine the length of the calibration course, which is distance you will drive (or walk) while spraying.

Table 5-2. Length of calibration course at different nozzle spacings.

Nozzle spacing (inches)	10	15	20	30	40
Length of calibration course (feet)	408	272	204	136	102

Note: To determine a calibration course for a nozzle spacing not listed in the table, divide 340 by the nozzle spacing in feet. For example, if the nozzle spacing is 18 inches:

a. Convert 18-inch nozzle spacing into feet by dividing by 12:

$$18 \text{ inches} \div 12 = 1.5 \text{ feet}$$

b. Determine the course length by dividing 340 by 1.5 feet:

$$340 \div 1.5 \text{ feet} = 227 \text{ feet}$$

For single-nozzle backpack sprayers, the nozzle spacing is the same as the swath width.

3. Mark off the correct calibration course length.
4. Drive (or walk) the calibration course while recording the amount of time it takes.
5. To check for consistency of speed, repeat Step 4 two or three times.
6. Spray water from one nozzle into a catch container and measure in ounces. The number of ounces caught equals the number of gallons to apply per acre.

5940 method for boom sprayers

The 5940 method is more accurate than the 1/128th but requires more math. Use the following formula to calculate gallons per acre (GPA); the constant for this method is 5,940.

Gallons per acre = (5,940 × Gallons per minute) ÷ (Miles per hour × Nozzle spacing in inches)

$$GPA = \frac{5{,}940 \times \text{Gallons per minute}}{\text{Miles per hour} \times \text{Inches between nozzles}}$$

Example: A sprayer travels 3 mph; the nozzles are 20 inches apart, and the average nozzle output is 0.4 GPM.

$$GPA = \frac{5{,}940 \times 0.4 \text{ gallons per minute}}{3 \text{ miles per hour} \times 20 \text{ inches}} \Rightarrow \frac{2{,}376}{60} \Rightarrow 39.6 \text{ gallons per acre}$$

Known area method for skid sprayers

An effective way to calibrate skid or hose reel sprayers is the known area method. Because the applicator's technique is critical to a skid sprayer's ability to apply pesticide accurately, it is best to use a larger practice area than the 340 square feet mentioned above. A good, simple area to use is 1,000 square feet.

1. Measure an area of 1,000 square feet (50 feet by 20 feet works well). If you spray on asphalt or another paved area, you will be able to see the coverage more easily.
2. Using only water in the sprayer, practice your walking speed and other techniques until you become proficient and consistent.
3. Spray 1,000-square-foot area while recording the time.
4. Using the same sprayer settings, spray water into a bucket for the same amount of time that you sprayed the 1,000 square foot area.
5. Measure the amount of water caught in the bucket. This volume is the application rate per 1,000 square feet.

Any change to spray nozzle, pressure, walking speed, or other factor will change the application rate. If you need to increase the application rate, use a larger nozzle; to decrease it, use a smaller nozzle.

Do not use walking speed to adjust output because unnatural speeds are difficult to reproduce consistently.

Spot spraying

Spot spraying can help you reduce costs and the amount of chemicals applied. Because spot spraying does not involve a known area, most pesticide labels provide rate information for spot spraying in terms of percent solution. This means that you would mix the chemical based on a ratio of the chemical and water in the tank.

Example: If the label specifies a 1 percent spray solution of pesticide, you would add 1.28 ounces of pesticide per gallon of water.

1 gallon = 128 ounces

1 percent = 0.01

128 ounces × 0.01 = 1.28 ounces of pesticide per gallon of water

For granular formulations, chemical manufacturers typically provide a pre-calibrated measuring device for each product. Do not use these measuring devices for different products because they are calibrated based on the specific density of individual products.

Calculations and calibration

Once you have calibrated your equipment, determine how much herbicide to apply:

1. Measure the area to be treated. Use a tape measure to determine the length and width of the lawn, and multiply length by width to calculate the area in square feet.
   For irregularly shaped lawns, it is easier to make a drawing of the area, divide it into smaller sections, calculate the area of each section, and add them together.
2. Check the herbicide label for the recommended rate to apply.
3. Determine the amount of herbicide needed to treat the lawn.
   a. Divide the area of lawn in square feet by 1,000.

b. Multiply that number by the recommended pesticide rate.

Example: The area to be treated is 1,500 square feet and the recommended rate of herbicide is 2 ounces per 1,000 square feet.

$$(1{,}500 \text{ square feet} \div 1{,}000 \text{ square feet}) \times 2 \text{ ounces} = 3 \text{ ounces}$$

You would need to apply 3 ounces of herbicide to the lawn.

Sample calculations

1. A lawn measures 80 feet wide by 130 feet long. You will treat it with a liquid herbicide at the label-recommended rate of 4 ounces per 1,000 square feet. How much herbicide will you need to treat the lawn?
   a. Calculate the area to be sprayed.

   $$80 \text{ feet} \times 130 \text{ feet} = 10{,}400 \text{ square feet}$$

   b. Divide the area calculated by 1,000.

   $$10{,}400 \text{ square feet} \div 1{,}000 \text{ square feet} = 10.4$$

   c. Multiply that factor by the recommended rate per 1,000 square feet.

   $$10.4 \times 4 \text{ ounces} = 41.6 \text{ ounces}$$

   Answer: You will need 41.6 ounces to treat the yard.

2. You want to spray a lawn that is divided into two parts, one measuring 44 feet by 28 feet and the other 36 feet by 52 feet.
   The herbicide is a dry formulation, and the recommended rate is 4 pounds per 1,000 square feet.
   How much herbicide will you need to treat the entire lawn?

   $$(44 \text{ feet} \times 28 \text{ feet}) + (36 \text{ feet} \times 52 \text{ feet}) = 3{,}104 \text{ square feet}$$

   $$3{,}104 \text{ square feet} \div 1{,}000 \text{ square feet} = 3.104$$

   $$3.104 \times 4 \text{ pounds} = 12.42 \text{ pounds}$$

   Answer: You will need 12.42 pounds of herbicide to treat the lawn.

3. Your sprayer operates at 4 mph and has four nozzles spaced 15 inches apart. You have determined that one nozzle sprays 35 ounces in 30 seconds.
   The lawn you will treat has two parts, one measuring 60 feet by 32 feet, the other 45 feet by 65 feet.
   The herbicide rate is 3 ounces per 1,000 square feet.
   How many gallons of water do you need to spray the whole area? How many ounces of herbicide will you add to the tank?
   a. Calculate the lawn area to be sprayed:

   $$(60 \text{ feet} \times 32 \text{ feet}) + (45 \text{ feet} \times 65 \text{ feet}) = 4{,}845 \text{ square feet to be sprayed}$$

   b. Determine the number of gallons that the sprayer delivers per minute. We will need to convert the spray output (35 ounces in 30 seconds) into gallons per minute:
      i. Convert ounces per second to ounces per minute

      35 ounces per 30 seconds

      $$35 \text{ ounces} \times 2 = 70 \text{ ounces per minute}$$

      ii. Convert ounces per minute to gallons per minute by dividing the number of ounces by the number of ounces per gallon (128).

      $$70 \text{ ounces per minute} \div 128 = 0.547 \text{ gallons per minute}$$

   Answer: The sprayer delivers 0.547 gallons per minute.

   c. Determine sprayer output in number of gallons per acre.

   $$\text{GPA} = \frac{5{,}940 \times \text{GPM}}{\text{MPH} \times \text{NSI}} \Rightarrow \frac{5{,}940 \times 0.547 \text{ GPM}}{4 \text{ MPH} \times 15 \text{ NSI}} \Rightarrow \frac{3{,}249}{60} \Rightarrow 54.15 \text{ gallons per acre}$$

   Answer: The sprayer delivers 54.15 gallons per acre.

d. Now we can use either units of 1 acre or 1,000 square feet. Because the herbicide rate is in ounces per 1,000 square foot, we will use that. An acre has 43,560 square feet.

Therefore, an acre contains 43.56 sections of 1,000 feet.

$$\frac{4{,}845 \text{ square feet}}{1{,}000} = \frac{4.845 \text{ sections per}}{1{,}000 \text{ square feet}}$$

e. The area to be sprayed is 4,845 square feet.

Answer: There are 4.845 sections in every 1,000 square feet.

f. Calculate the number of gallons the sprayer will need to cover those 4.845 sections.

1.24 gallons per 1,000 square feet × 4.845 = 6 gallons

Answer: The sprayer will need 6 gallons to spray 4.845 sections.

g. Finally, calculate the amount of herbicide to add to the tank.

3 ounces of herbicide per 1,000 square feet × 4.845 = 14.5 ounces of herbicide

Answer: We need to pour 6 gallons of water into the tank and add 14.5 ounces of herbicide.

Study questions

1. An infested lawn measures 34 feet by 48 feet in the front and 52 feet by 60 feet in the back. The herbicide you have selected recommends 3.5 ounces per 1,000 square feet. How much herbicide will you need to spray the entire yard?
   a. 5.7 ounces
   b. 11.4 ounces
   c. 16.6 ounces
   d. 22.3 ounces

2. Your sprayer traveled 200 feet in an average of 36 seconds. The nozzles are spaced 20 inches apart, and the output from one nozzle was 42 ounces in 30 seconds. How many gallons per 1,000 square feet will your sprayer apply?
   a. 2.72
   b. 1.18
   c. 1.94
   d. 0.88

3. **Yes or No:** Your sprayer applies 20 gallons per acre. You need to treat an area that measures 216 feet by 112 feet. The sprayer tank holds 8 gallons. Will you be able to treat the entire area with one full tank?
   a. Yes
   b. No

1. c
2. b
3. b

Pesticide Application Considerations

Now that you have identified the pest and calibrated your equipment, you are almost ready to apply the pesticide.

Before the application

First, you need to understand several factors: tank mixing, spray water quality, pesticide label instructions, spray tank contamination, and content suspension.

Tank mixing

To save time and labor, some applicators combine chemicals in the tank. This process is called *tank mixing*. Fertilizers, herbicides, insecticides, and even fungicides are often mixed in the tank to make the application process more efficient.

Examples of pre-mixed products are weed and feed products—mixtures of fertilizer and herbicides. Unfortunately, the wrong combination of chemicals can clog nozzles, damage turf, and create precipitates and sludge in the tank.

Tank-mix incompatibility

Incompatibility occurs when one or more components of a pesticide mix react chemically, reducing the effectiveness of one or all of the pesticide components. Other effects of incompatibility include surface scum, oily drops, excessive foam, poor weed control, clumps in the tank, and clogged spray nozzles and precipitates.

When some chemicals are mixed, they interact to reduce the pesticide's effect (*antagonism*). Conversely, mixing other chemicals can result in synergism, or an increased effect beyond what would result from the chemicals being applied separately.

Incompatibility can also cause plant injury (*phytotoxicity*) to turf and ornamentals, which of course is worse than mere lack of effectiveness.

The jar test

The most practical way to determine whether a specific herbicide and fertilizer are compatible is to conduct a jar test:

1. Look on the product labels to find:
   - The spray volume per a set ground area (such as 1,000 square feet)
   - The correct rates of the fertilizer and pesticide for that area
2. Proportion each material to the volume of the jar, generally 1 quart.
3. Fill a quart jar with the correct ratio of the materials in the mix.

For example, if the spray volume is 1 gallon per 1,000 square feet and you use a pint of test solution, you would divide the product rates for 1,000 square feet by 8, as there are 8 pints in a gallon.

Spray water quality

One factor of the application process that doesn't get much attention is the quality of the water used to spray the product. Water often makes up 95 (or more) percent of the spray solution. Water quality parameters such as pH and dissolved minerals can interact with the active and/or inert ingredients of the pesticide product.

Check the pH of your water source and the tank mix. Some pesticides are very sensitive to pH levels that are highly acidic or alkaline.

Fertilizers can affect the pH of your tank mix. Phosphate fertilizers tend to be acidic; most of the commonly used nitrogen fertilizers, such as urea, are alkaline. When they dissolve, the solution can develop a pH of 8.0 to 8.5 and may become even more alkaline over time.

Avoid letting tank mixes sit overnight because the pH can change and reduce the effectiveness of the spray mixture.

It is easy to check the pH of your tank mix. Use a pocket pH meter, pH test strip, or water test kit that measures pH. A pH of 7.0 is neutral. Generally, anything close to this is acceptable.

If pH is a major issue in product performance, the label will note it. Several commercial products can raise or lower pH as necessary.

Spray water that contains high levels of suspended solids (such as silt, clay, and organic matter) can cause turbid water. The solids suspended in turbid water can bind to some pesticides and render them ineffective. Turbid water is commonly a result of using pond or river water in spray applications.

Excessive dissolved minerals (such as calcium, magnesium, and iron) in spray water can cause high levels of water hardness. Several types of pesticides can interact with these minerals and lose effectiveness. Some pesticide labels recommend specific adjuvants to compensate for this problem.

Label instructions

Chemical and fertilizer companies spend millions of dollars researching and developing their products. They list specific information, including mixing instructions, on the label. Pesticide labels usually list the following information:

- Type of formulation (such as EC, S, or WDG, which stand for emulsifiable concentrate, solution, and water dispersible granule, respectively)
- Mixing instructions, including water and agitation requirements
- A warning that the product may separate if allowed to sit for long
- A note about the use of tank additives that alter the pH
- Recommendations for a conducting a compatibility jar test
- A telephone number for technical support and safety concerns

Labels normally contain information about additives. Sometimes additives are needed to correct compatibility problems when herbicides are mixed with other products. Many herbicides already contain additives, such as surfactants. For example, if a herbicide is an emulsifiable concentrate (EC), it contains emulsifiers that keep it suspended in water.

However, using additives indiscriminately can diminish the herbicide's performance by injuring turf or reducing weed control.

Do not underestimate the importance of following the label instructions. As with any pesticide or fertilizer, it is vital that you read the entire label and follow the instructions when mixing and spraying the product.

Spray tank contamination

Start with a clean tank. Pesticide residues in the tank can damage desirable plants.

If you clean the tank properly after each spraying, contamination should not be a problem. However, if the tank is not clean, even the jar test won't help. Commercial tank-cleaning agents are available.

Content suspension

While you mix and apply the products, agitate the tank contents vigorously. Use a spray tank equipped with an agitator to keep the contents in suspension.

Sometimes paddle-type or bypass-line agitators can let suspensions settle. Jet-type or venturi agitators mounted in the bottom of the tank are better.

If you take a break, leave the agitator running.

Applying the pesticide

Even with proper agitation, never start the spray on the desired target. On golf courses, for instance, turn on your sprayer in the rough before spraying the greens. On home lawns, if you are using a hand-held spray gun, turn it on in the tank before spraying the lawn.

If you have not used a product or product mix previously, apply it to a small test area before broadcasting. Overlap the applications in some places to determine the margin of safety.

Wait a few days after spraying the test area. Signs of phytotoxicity or spray ineffectiveness should appear after a few days.

Careless applications

Every year, many complaints, investigations, and even lawsuits arise from careless chemical applications in landscapes. Under some circumstances, landscape pesticides—particularly herbicides—can damage desirable plants. Some of the common mistakes:

- Allowing drift from the target site
- Disobeying label instructions on rate, tolerance, timing, or other conditions
- Improper recordkeeping/labeling on chemicals, tanks, and/or equipment
- Misunderstanding turfgrass dormancy or tolerance to herbicides
- Spraying within the dripline of sensitive ornamental plants
- Wounding woody plants with string trimmers, which can allow the plant to take up the herbicide
- Excess spray solution, as well as rinsate, should be applied to a site and at a rate that is allowed by the label.

Study questions

1. What is the term for mixing multiple chemicals in one spray tank?
   a. Incompatible
   b. Tank-mixing
   c. Drift
   d. None of the above

2. What is the purpose of the jar test?
   a. To see what the solution looks like
   b. To allow quicker mixing
   c. To test compatibility
   d. None of the above

3. **True or false:** Pesticide residues in the tank can cause undesirable plant damage.
   a. True
   b. False

1. b
2. c
3. a

Glossary

abiotic: without life or having ever been alive

absorption: the process by which a pesticide passes from one system into another, such as from the soil solution into a plant root cell or from the leaf surface into the leaf cells

activation: the movement of a herbicide into the soil, where it can be absorbed by seeds or weed seedlings, with no chemical change in the active ingredient

active ingredient (a.i.): the chemical in a herbicide formulation that is primarily responsible for the herbicide's effect on plants

adjuvant: any substance in a pesticide formulation or added to a spray tank that improves pesticide application or activity

adsorption: the process by which a pesticide becomes attached to a surface, such as soil particles

aesthetically pleasing: having a beautiful appearance

alternate: arranged one at a time on alternating sides of the stem

annual: a plant that completes its life cycle in less than 1 year; plants can be summer annuals (warm-season) or winter annuals (cool-season)

antagonism: the interaction of two or more chemicals that when applied achieve a less predictable effect than would the activity of each chemical applied separately

apex: tip, as of a leaf or stem

aquatic: a site where water stands or flows; aquatic pesticides are designed for use in standing or flowing water

axil: the upper angle between a leaf and a stem

back-siphoning: water flowing from the spray equipment back into the water source through a connecting hose

biennial: a plant that completes its life cycle in 2 years by growing vegetatively (developing leaves, roots, stems, and other plant parts not involved in reproduction) in 1 year, producing seed the second year, then dying

biological control: the use of living organisms (insects, nematodes, other animals, or diseases) to control undesired plants

biotic: relating to living organisms

blade: the leaf of a grass plant

blight: a disease characterized by the general and rapid death of leaves, flowers, and stems

broadleaf weed: a weed with exposed buds and growing points at the top and in the leaf axils; broadleaf weeds usually have net-veined leaves. Some herbicides attack broadleaf weeds, leaving grasses unharmed.

buffer strip: an untreated strip of vegetation next to a treated site; the untreated strip catches any chemical runoff before it reaches desirable vegetation or water bodies

calibration: the adjustment of application equipment to ensure that it delivers the correct amount of pesticide uniformly over a target area

canker: a dying, often sunken lesion on a plant branch, stem, or twig

carrier: a gas, liquid, or solid substance used to dilute or suspend a herbicide during its application

chemical name: the name of a pesticide's active ingredient that describes its chemical structure according to rules prescribed by the American Chemical Society and published in the Chemical Abstracts Indexes

chlorophyll: the green pigment in plant cells that contributes to photosynthesis

chlorosis: the yellowing of normally green tissue caused by the destruction of chlorophyll or its failure to form

common name: a generic name for a chemical compound; for example, glyphosate is the common name for Roundup

compatibility: the ability of a substance, especially a pesticide, to mix in a formulation or spray tank without harming the characteristics or effects of the individual components

contact herbicide: a herbicide that injures only the plant tissue to which it is applied, it does not move appreciably in the plant

degradation: the breakdown of a herbicide by microorganisms, soil, sunlight, or chemical reactions in the soil

dicot: the abbreviated term for dicotyledon; one of two classes of angiosperms (plants that flower and bear fruit). A dicot usually has two seed leaves (cotyledons), veined leaves, and a taproot.

dripline: the area directly under the outer circle of a tree's branches; it is used as a visible guideline to help determine where roots may be growing underground

emergence: the event when a shoot becomes visible by pushing through the soil surface

eradicate: to eliminate a target organism

fibrous root system: the thin, branching roots that tend to stabilize the soil against erosion

flowable: a solid herbicide that is suspended in a liquid that can then be added to water

foliar: having to do with leaves; a foliar-applied herbicide is one applied directly to leaves

formulation: a pesticide preparation supplied by a manufacturer for practical use

fungicide: a pesticide that kills fungi

gall: an abnormal growth of plant tissue caused an insect, mite, nematode, or microorganism

germination: the breaking of seed dormancy

granular: a dry formulation of pesticide that is applied without a liquid carrier and consists of particles generally less than 10 cubic milli meters

heavy soils: soils containing enough clay or organic matter that that they tend to "tie up" (prevent the work of) a herbicide

herbaceous plant: a plant that does not develop woody tissue above ground; it is not a tree or shrub

herbicide: a chemical used to control, suppress, or kill plants or severely interrupt their normal growth processes

herbicide resistance: a trait that allows some plants to tolerate, or not be injured by, a herbicide

inhibit: to interfere with the establishment and growth of plants. For example, tall plants can shade short plants, and dense sod prevents some plants from growing in it

inorganic minerals: nonliving materials, usually those that lack the element carbon; in soils, the inorganic minerals are classified as sand, silt, or clay

insecticide: a pesticide that attacks insects

insoluble: not easily combining with water. Insoluble herbicides tend to remain at or near the soil surface and not leach through the soil

integrated pest management (IPM): a comprehensive approach to pest management that uses biological, cultural, physical, and chemical control methods in a careful and environmentally sound manner

label: the directions for using a pesticide that were approved when the pesticide was registered

larva(e): the active, immature stage of an insect with complete metamorphosis (having four life stages—egg, larva, pupa, and adult); examples are caterpillars, grubs, and maggots

leaching: movement of a pesticide with water downward through the soil. The amount of leaching that occurs depends on the pesticide, the soil, the application rate, and the amount of rainfall.

leaf margin: the edge of a leaf

life cycle: the germination and growth cycle of a plant

light soil: soil that is sandy or silty or contains little organic matter

midrib: the central vein of a leaf

mode of action: the way that a chemical attacks a pest; the action of a chemical on a pest

monocot: a plant that has one primary leaf or cotyledon; the cotyledon does not emerge above the soil surface, and the first visible leaves are actually secondary or true leaves. Most monocots have narrow leaves with parallel veins and usually a fibrous root system.

native: an organism that lives or grows naturally in a region

node: the area where a leaf attaches to the stem

nonselective herbicide: a herbicide that is generally toxic to all plants; some selective herbicides may become nonselective if used at very high rates

nontarget species: species not intentionally treated with a pesticide

organic matter: materials that were once living and contain the element carbon

opposite: arranged in opposing pairs along a stem

perennial: a plant that completes all four growth stages in the first year and then lives more than 2 years

permeability: the ability of one substance to move through another; for example, the ability of a water-soluble pesticide to move with the water through soil

persistent herbicide: a herbicide that remains in the soil and affects plant growth for a long period; also called a *residual herbicide*

petal: one of the soft, colorful parts of a plant

petiole: the stalk of a leaf

phloem: the plant part that moves food from the leaves to other parts that need it

photosynthesis: the process by which plants produce food (carbohydrates)

physiology: the chemical and physical processes that take place in an organism

phytotoxic: having the ability to injure or kill plants

plant growth regulator: a substance that controls or changes plant growth without killing the plant

pollinators: bees, flies, and other insects that carry pollen from flower to flower. Many plants need pollination to produce fruit, vegetables, nuts, and seed.

post-emergence: applied after a weed or crop is growing

pre-emergence: applied to the soil before a weed or crop breaks through the soil surface

propagate: to reproduce; plants can propagate by rhizomes, seeds, stolons, cut stumps, or cut roots

rate: the amount of product, active ingredient, or acid equivalent applied per unit of area

residue: the amount of a pesticide remaining in or on the soil, plant parts, animal tissues, whole organisms, and surfaces after application

residual herbicide: a herbicide that persists in the soil and injures or kills germinating weed seedlings over a relatively long period; also called a *persistent herbicide*

rhizome: a creeping stem below the soil surface that can produce roots and shoots at each node

selective herbicide: a chemical that is more toxic to some plant species than to others

sheath: in a grass, the base of the leaf that surrounds the stem

soil microorganisms: bacteria, fungi, and other tiny organisms that live in the soil. Many soil microorganisms break down pesticides, reducing their period of effectiveness

soil pH: a measure of the soil's acidity or alkalinity; the pH affects the speed that pesticides degrade as well as the adsorption characteristics and mobility of ionic pesticides

solution: a mixture of two or more substances

species: a particular kind of plant that reproduces its own kind. Because pesticides affect some species of plants but not others, it is important to identify the plant to be treated

spot treatment: the treatment of a small area; for example, using a herbicide to treat spots or patches of weeds within a larger area

stolon: a creeping stem above the soil surface

stomata: openings on a leaf's surface through which gases are exchanged

surfactant: a material that improves the way a pesticide disperses, spreads, or wets plant surfaces

susceptibility: the degree to which a plant is injured by a herbicide treatment (see *tolerance*)

systemic herbicide: a herbicide that moves from one part of a plant to other parts; also called a *translocated herbicide*

tank-mix combination: the mixing of two or more pesticides or chemicals in a spray tank at the time of application

taproot: a large, deeply penetrating root of a broadleaf plant, such as carrot, dandelion, and horse nettle

target area: an area to be treated with pesticide

target pest: the specific plant or organism that the pesticide is designed to attack and that has been chosen by the applicator for control

terminal bud: the bud at the top or apex of a plant

threshold: the level of infestation of a pest species at which control practices are justified

tie-up: the inability of some pesticide molecules to move downward through the soil because their positive charges are attracted and tied up by negatively charged soil particles

tolerance: 1) the ability to withstand pesticide treatment without significant effect on normal growth or function (see *susceptibility*); 2) the concentration of pesticide residue allowed in or on raw agricultural commodities

trade name: the name that a manufacturer gives to a pesticide formulation

translocated herbicide: a herbicide that is moved within the plant by the phloem or xylem; also called a systemic herbicide

transpiration: the passage of watery vapor from a plant through pores or membranes

vapor drift: the movement of chemical vapors away from an application area

vaporize: to evaporate, become a gas

vascular bundles: the grouping of xylem and phloem cells in monocot stems

vein: a vascular bundle that forms the framework of a leaf

viable: able to grow and produce a new organism, such as a plant from a viable seed

water solubility: the ability of a pesticide to dissolve in water

weed: any plant that is objectionable or interferes with the activities or welfare of people

weed control: the process of reducing weed growth and/or infestation to an acceptable level

wetting agent: 1) a substance that improves the ability of a spray solution or suspension to make contact with a treated surface (see *surfactant*); 2) a substance in a wettable powder formulation that causes it to wet readily when added to water

xylem: the nonliving tissue in plants that moves water and mineral nutrients from the roots to the shoot

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Texas Department of Agriculture: http://texasagriculture.gov

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Top, annual bluegrass. Bottom, left to right, boom, aster, and skid sprayer

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- Larry Barnes and Joseph Krausz provided photos of diseases.
- C. L. Barr, Bastian Drees, W. P. Morrison, and H. A. Turney provided photos of insects.
- Casey Reynolds provided photos of selected weeds.

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