AG1158

Ornamental, Tree and Turf Pest Control

Commercial Applicator – Classification 4
Noncommercial Applicator – Classification 9

Training Manual

DIVISION OF AGRICULTURE
RESEARCH & EXTENSION
University of Arkansas System

University of Arkansas, U.S. Department of Agriculture, and County Governments Cooperating

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Preface

This manual provides information for the Arkansas commercial pesticide applicator wishing to become certified in Classification 4 – Ornamental, Tree and Turf Pest Control – and the noncommercial pesticide applicator wishing to become certified in Classification 9 – Ornamental, Tree and Turf Pest Control. To become a certified applicator in the desired category, a candidate must pass both a general standards exam and pass an examination based primarily on the material presented in this manual and (Circular 6) Arkansas Pest Control Law (Act 488 of 1975, as amended). Information covered in the general standards examination is contained in "A Guide for Private and Commercial Applicators: Applying Pesticides Correctly." Refer to (Circular 6) Arkansas Pest Control Law (Act 488 of 1975, as amended) for specific requirements for Classification 4 and 9. The Arkansas State Plant Board administers the examinations. Up-to-date study materials can be obtained from the Arkansas State Plant Board, #1 Natural Resources Drive (P.O. Box 1069), Little Rock, AR 72203-1069, phone (501) 225-1598. Additional study information may be obtained from the University of Arkansas Cooperative Extension Service, the pesticide label, current publications on the subject, pesticide distributors and manufacturers.

Acknowledgments

Information accumulates from direct observations, scientific literature and anecdotes from others. Information from these sources blurs together quickly, and consequently, unique ideas are rare in society. Credit for sources of information on ornamental and turf pest control and management must go to Land Grant University extension and research workers in the areas of entomology, horticulture, plant pathology, and weed science who continually work to maintain and update ornamental and turf pest management information. In addition, thanks go to pest control industry workers who hold training sessions nationally, regionally, and locally where information is disseminated among the experienced and provided to the inexperienced, the Environmental Protection Agency whose personnel molded modern training and influenced the need for national uniformity in training requirements, and also to state regulatory personnel who cooperate with universities and industry and who strongly emphasized the importance of training.

This training material has been adapted from commercial applicator certification training manuals for ornamental and turf pests developed by the Oklahoma Cooperative Extension Service, Division of Agricultural Sciences and Natural Resources, Oklahoma State University; Texas Agricultural Extension Service, the Texas A&M University System; and University of Nebraska Cooperative Extension, University of Nebraska - Lincoln.

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Ornamental Pest Management

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Introduction to Ornamental Pest Management

What Is IPM?

Integrated pest management (IPM) is based on the philosophy of using various strategies to optimize the environmental, economic and sociological consequences of a management system. IPM is a systematic approach to plant protection that emphasizes increased information for improved decision-making. By understanding the ecological aspects of the system, pest populations can be minimized with less effort using various control measures. The concept of IPM is not new and is widely implemented on field crops throughout the United States and the world. Implementation in the urban environment has special challenges because of aesthetic considerations, lack of ornamental damage acceptance data, lack of demand by the public and the difficulty in dealing with a multitude of different plants with different management requirements in a small area.

These constraints have changed dramatically with an increase in the interest of people living in urban areas and those working in educational environments.

IPM, Ecology and Management

IPM incorporates ecological principles into a management program. Management strategies are integrated into an ecologically based system that includes:

- **Proper selection and placement of plant materials.** Plants that thrive in their growing environment are better able to resist insect and disease problems. This is where many management programs fail. If the wrong plant materials are selected, it will be difficult to overcome the poor initial choice – no matter how hard one tries to compensate. An example is planting cedar trees adjacent to apple trees susceptible to rust. This situation stimulates cedar-apple rust that can cause serious damage to the apple trees.
- **Host plant resistance.** Host plant resistance is a critical part of any management system. Host plant resistance is the ability of the plant to prevent pest buildup or tolerate pests without damage to the plant itself. This is a critical component and the basis of an effective IPM program. For example, selecting a Chinese elm (*Ulmus parvifolia*) will help avoid problems with the elm leaf beetle.
- **Cultural practices.** Cultural practices, or care of plants and the surrounding environment, can determine whether pests or abiotic problems, such as sunscald or drought, develop and how long plants can survive. Cultural management includes proper fertility, proper plant selection, watering, soil structure and reduced competition from adjacent plants.
- **Physical/mechanical practices.** Many times, physically reducing pests by mowing, hoeing or trimming can provide an easy, economical alternative to using pesticides. By reducing direct competition through careful tillage or mulching around the base of plants, the life and appearance of the plants can be enhanced. Also, avoiding physical or mechanical damage to plants can greatly improve a plant's survival and reduce potential pest problems. Wounds in trees caused by weedeaters or other tillage equipment can shorten the life of plants by making them susceptible to either insect or disease infestation.
- **Pesticides.** Pesticides should be viewed as a salvage treatment to prevent significant damage to plant materials. While pesticides are an important tool, they should be used only when necessary and must be used in conjunction with other management tools. In the urban environment, the tendency is to use pesticides on a preventative basis to ensure a perfect landscape. For example, the overapplication of weed-and-feed materials on lawns can have serious effects on adjacent ornamental plants. This practice must change. The development of a pest population is a sign of improper ecological management.

- **Regulatory.** The easiest way to prevent development of a pest within a landscape is simply to not allow the pest to become established. This is particularly important for some exotic pests or weeds in a landscape. It is much more difficult to eliminate exotic pest populations after they become well established. Federal and state agencies can and often do place quarantines on certain exotic pests to prevent their spread into other areas of the United States. Examples are the red imported fire ant, citrus rust and the gypsy moth.

- **Biological control.** The importance of using biological agents to control insect and disease pests is often overlooked. Biological agents include predators, parasites, nematodes and microbiological organisms, such as bacteria, viruses and fungi. Many of the aphids are controlled naturally by fungi, predators and parasites that keep the aphid numbers below damaging levels.

Why Implement IPM?

Over the past three decades, most U.S. regions have experienced rapid urbanization, with much of the population living in major urban areas. The same situation holds true for Arkansas. Like commercial agriculture, the urban environment faces many significant management obstacles. Often, ornamental trees and shrubs in a landscape have significant weed, insect, disease, fertility and cultural management problems that must be addressed for each plant's survival. Likewise, urban personnel often don't know enough about effective pest management and routinely use calendar-based applications of pesticides. With intense use of pesticides and fertilizers, there may be a significant impact on the environment and the people themselves. Without effective, economical and safe management systems, the plants may not survive. A better question may be: Why not implement ornamental IPM systems?

Ornamental IPM Programs

Ornamental IPM programs have several unique characteristics that set them apart from traditional agronomic IPM programs, including:

- Economic decision levels, called economic thresholds, often are not established or don't apply to ornamentals. The appearance of the ornamental plant is the key factor. However, most universities have developed action thresholds to give an idea of when treatments are needed to prevent extensive damage. These action thresholds are the basis for monitoring programs; however, they need to be verified and refined to improve the IPM system in ornamentals.

- In urban areas, the traditional thought has been that management strategies, such as biological control, resistant varieties, genetic manipulation and other non-pesticide control methods, are not effective or applicable because of the aesthetic concerns. These non-pesticide management tools, including sanitation, improved cultivars, habitat removal and proper plant selection, may be more readily available than in traditional agricultural situations. In an urban setting, selected replanting or pruning is economically feasible. Likewise, plant selection can be altered without significant economic hardship.

- A significant driving force in an urban setting is the public's concern about pesticide use. This concern must be addressed in any ornamental IPM program, but it is also a driving force behind these management programs. Respect for the desires of others and using caution when applying pesticides and fertilizers will prevent most problems with pesticide/fertilizer usage in urban settings.

- Agricultural crops are often in monocultures where monitoring can be simple and straightforward. This is not the case in urban settings where the landscape has been designed using a variety of plant species. Monitoring is equally important in the urban setting, but it is more difficult due to the variety of plants, pests and management requirements. This means pesticide applicators must look to sources such as the Cooperative Extension Service, nursery and landscape associations and others for assistance and employee training.

How IPM Programs Are Implemented

Developing and implementing IPM programs requires careful planning and a basic understanding of the landscape itself, management alternatives available and cost-benefit trade-offs with each alternative. Keys to an effective IPM program include:

- A long-term plan for the landscape that is being managed. This includes the careful selection of plants, fertilizer management and cultural practices.
- The development of reference materials and contacts.
- An on-going employee IPM training program.
- Periodic monitoring of the landscape to ensure plants are cared for properly.
- Monitoring and diagnosis of problems: Diagnosis of management problems often requires significant study of plants and the surrounding environment. Managers must understand the ecology of these systems to implement an effective management plan. Managers need to include:
  - A history of the landscape.
  - An examination of plants and the surrounding environment.
  - Diagnosis of problems.
  - Possible management options.
  - Long-term corrective treatments.
  - Maintenance and implementation of cultural practices that will minimize future management problems.
- A consistent schedule for maintenance, including soil testing, tillage, pruning and weed management.
- An understanding of management options to ensure efficacy with limited environmental or personal safety impact.
- The calibration of pesticide and fertilizer equipment several times per year to ensure correct applications.

The management strategy must include planning before and after implementation. IPM systems must continually be improved to maximize efficiency, minimize environmental impact and maintain a beautiful landscape.

Cultural Management for Ornamental Plants

Landscape management generally involves caring for several kinds of plants in a given area – turfgrass, flowers, ground covers, trees and shrubs. A manager must understand the ecology of the entire landscape. A management practice that favors only one kind of plant could easily damage one or more of the others. Therefore, a management plan must take into account the various species in an ornamental setting.

This chapter emphasizes management of woody plants and should be used as a source of information on landscape management. It also discusses the cultural practices needed to maintain an ecological balance within a landscape. Following sound cultural practices will result in high quality plants that are managed in a manner to minimize the need for pesticides, thus fulfilling the rationale behind integrated pest management.

Selection

Woody landscape plants should be selected for a variety of aesthetic, functional and cultural management reasons. Plants may be chosen to form borders and screens, to accent an architectural design, to modify a site's microclimate or for a large multitude of other reasons. When selecting a woody plant, consider other factors to ensure a plant will thrive and remain attractive for a long period of time. Even with all of the important factors listed below, proper plant selection is paramount, as is the selection of a diverse group of plants. Strive for diversity by having no more than 10 percent of plants of any species or cultivar in the landscape. By doing so, should a disease, insect infestation or abiotic stress arise, not all of the trees and shrubs in the planting are likely to succumb to the stress.

Table 1.2.1. Lime requirements of various soil types.

Existing pH of Soil	Pounds of Agricultural Limestone Needed Per 100 Square Feet to Raise:					
	Sandy Loam Soil		Silt Loam Soil		Silty-Clay Loam Soil	
	to pH 6.0	to pH 6.5	to pH 6.0	to pH 6.5	to pH 6.0	to pH 6.5
6.0	0.0	2.0	0.0	4.0	0.0	5.0
5.5	2.0	4.0	4.0	7.0	5.0	10.0
5.0	4.0	6.0	7.0	11.0	10.0	15.0
4.8	4.5	7.0	8.0	12.0	12.0	17.0

Source: The Fertilizer Handbook.

Table 1.2.2.Sulfur requirements of various soil types.

Existing pH of Soil	Amount of Sulfur (95% S) Needed to Lower the Soil pH to pH 6.5: (Weight is in pounds per 100 square feet)		
	Broadcast Application (then mixed in soil to a depth of 6 inches)		
	Sandy Soils	Loamy Soils	Clayey Soils
7.5	1.0-1.5	1.5-2.0	2.0-2.5
8.0	2.5-3.0	3.0-4.0	4.0-5.0
8.5	4.0-5.0	5.0-6.0	6.0-7.5
9.0	5.0-7.5	---	---

Source: The Fertilizer Handbook.

Environment

Some plants are adaptable to a wide range of growing conditions, while others can survive only in specific environments. Before selecting a landscape plant, it is important to first be familiar with the soil texture, pH, drainage, exposure and other important characteristics of the site. A plant that is not suited to an environment is much more likely to encounter serious insect and disease problems than one that is adapted.

The texture of a soil is determined by the size of its particles. Sandy soils are composed of large particles, clayey soils of small particles and silty soils of medium-sized particles. Most soils are a combination of these types. Texture determines how well a soil can retain nutrients, drain and be easily worked.

Another factor that is often overlooked is pH. All soils are measured for their pH, which ranges from 0 to 14. A pH below 7.0 is considered acidic, while those with a pH above 7.0 are alkaline. A pH reading of 7.0 is neutral. Plants such as rhododendron and azaleas usually grow best in acidic soils at a pH of 4.5 to 5.5, whereas most landscape plants are healthy in soils with a pH of 5.8 to 6.8. Plants can also usually thrive in slightly acidic soils. Therefore, the soil pH only needs to be adjusted when extremes are found after a soil test is conducted. Refer to **Table 2-1** and **Table 2-2** on the previous page for suggestions on lowering or raising soil pH. All plants have an ideal pH range in which they best grow and thrive. Although an exact pH requirement does not exist for any species, plants should be grown within an accepted standard range. Consequences that arise as a result of extremes in pH are chlorosis, stunting, overall unthriftiness and, in severe cases, necrosis (plant dieback).

All woody plants do best if planted in the kind of soil to which they are naturally suited. While some woody plants thrive in moist, undrained bottomlands, most cannot tolerate such water-soaked environments. Whenever possible, you should select a plant that grows naturally in the soil type in your area. Not only is a particular soil type important, but also plants that are indigenous to an area sometimes are much more reliable than certain exotic species. Examples would be redbud, river birch and other trees native to Arkansas. Depending on which part of the state a grower resides in, such natives could be ideally suited for a wide range of landscape types. This is one of many areas in which a nurseryperson or garden center owner can help with selection of the proper species or cultivars, regardless of whether or not the plants are native to Arkansas.

Exposure is also an important consideration. Marginally hardy plants do best on northern and northeast exposures because those sites experience the smallest fluctuations in temperature and are less exposed to the sun. To protect against desiccation by wind, plant or build windbreaks. It is not always possible to protect against the sun.

Hardiness

All landscape plants are assigned hardiness ratings that indicate the coldest zones in which they can thrive. Arkansas includes USDA hardiness zones 6a through 8a. In these zones, the lowest average temperatures range from -10°F to 10°F, respectively **(Figure 1.2.1)**. By selecting plants that are sufficiently hardy for an area, an important source of stress is eliminated that often makes a plant more susceptible to insects and diseases. Check with a knowledgeable nurseryperson to determine if hardiness-improved cultivars are available for the species of interest or if a hardier but closely related species exists. Also see UACES fact sheet FSA2097, *Arkansas and U.S. Plant Hardiness Zone Maps*.

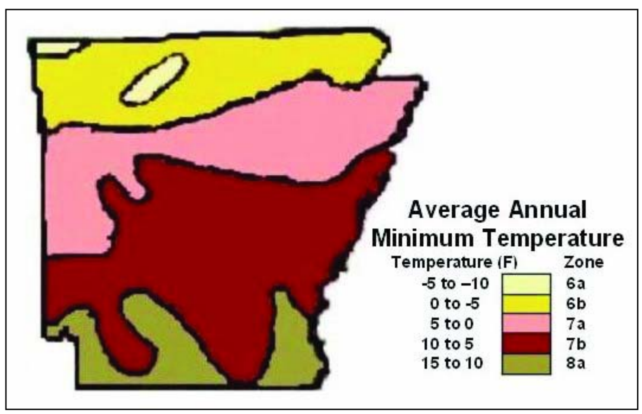


Figure 1.2.1. Arkansas plant hardiness zone map (USDA).

Each specific site has its own microclimate. For example, when a backyard is fenced, the microclimate is changed (the environment is made warmer). A zone 6 can be changed to a zone 7, and vice versa. A plant may be perfectly suited to the degree of heat in a geographical zone, but if a microclimate is rendered warmer by planting the tree beside a white brick wall, for example, the tree will still scorch. The survivability of any plant varies with the microclimate in which it is situated. The ability to change microclimates enables Arkansas growers to have trees and shrubs in their yards which otherwise would only grow in warmer climates.

Insect and Disease Resistance – Proper plant selection is important in pest management. For example, many different crabapple cultivars are commercially available in Arkansas, and all of them vary in their reactions to four common crabapple diseases – apple scab, fire blight, cedar apple rust and powdery mildew. White-barked birches are susceptible to the bronze birch borer, but the river birch (*Betula nigra*) is rarely attacked by this pest. These and other pests can be avoided by selecting resistant cultivars or species recommended by a reputable nursery or garden center worker.

Planting

Spring and fall are the best times to plant trees and shrubs; however, trees can be planted successfully any time if they are handled properly. They become more difficult to transplant after they break dormancy, primarily because during this period the new leaves and stem growth are susceptible to high transpiration (water loss). Desiccation is the most common reason newly planted trees fail to survive the first season after planting. Therefore, any cultural procedure that reduces water loss from transpiration or that increases water uptake will improve the chances of survival. Such cultural procedures include thorough mulching 3 to 4 inches at least out to the tree's perimeter (dripline) and winter irrigation when temperatures remain above freezing for prolonged periods.

Planting Hole

Dig the planting hole at least twice as wide as the root ball to be planted. This allows for easier root expansion and penetration, which ultimately leads to more rapid establishment. Not only is the width important, but also planting depth is critical. Always plant at the original grade or slightly higher than the level at which the shrub or tree was growing when it

Figure 1.2.2. Planting too deep.

was purchased. Never plant below grade because this will lead to oxygen deficiencies and waterlogging to the roots **(Figure 1.2.2)**. The exceptions to planting at grade are when the soil is a heavy clay or when overall drainage is poor. In these cases, the plant should be positioned slightly above grade (2 to 3 inches). This can be accomplished most easily by purposely digging the hole shallower than the plant's root ball. Be certain to taper soil down to the soil line; otherwise, the top few inches of the exposed root ball will act as a wick, causing the root system to dry out excessively **(Figure 1.2.3)**. Plants such as pines and other high moisture sensitive plants will benefit from this simple technique when conditions warrant it.

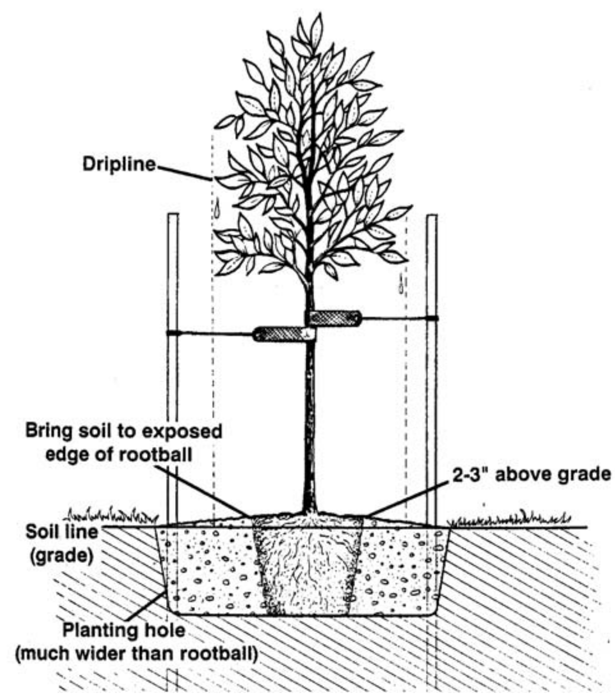


Figure 1.2.3. Guide for planting a tree in heavy clay soils.

Two other techniques used for improving survival are the split ball technique and scoring the root system. The split ball technique, also known as the butterfly technique, forces the root system to be positioned shallowly in the soil profile **(Figure 1.2.4)**. Therefore, roots are positioned in a more favorable area for growth due to better drainage and oxygen relations. Scoring the root ball is a less radical procedure, but it also stimulates new root growth **(Figure 1.2.5)**. This simple technique is particularly valuable when containerized stock is purchased. Often times, circling roots are a problem in overgrown containerized stock. This is partially corrected by scoring. If the circling roots are not corrected, they may eventually girdle the trunk as late as several years after transplant.

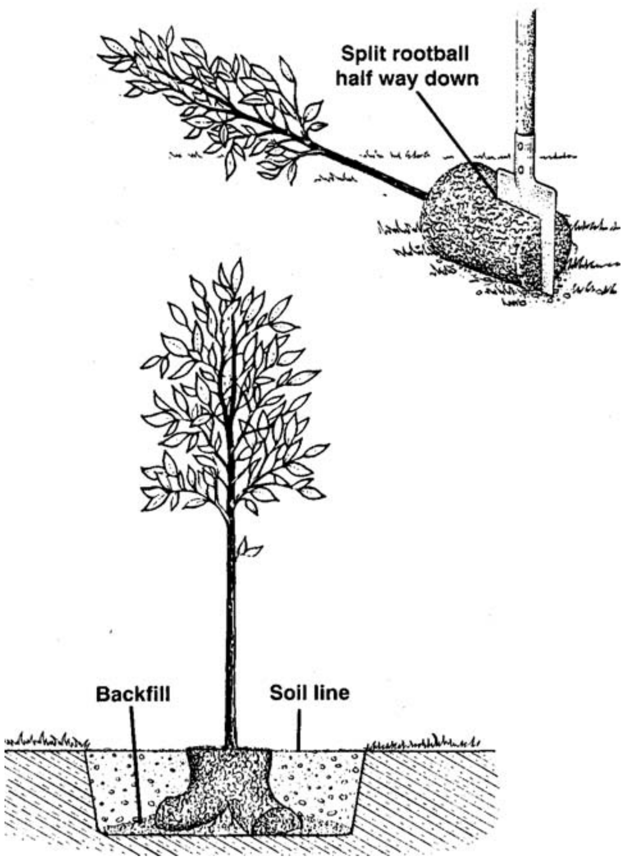


Figure 1.2.4. The split ball or butterfly technique.

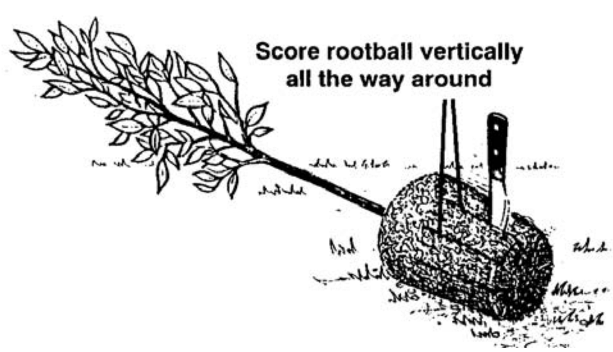


Figure 1.2.5. Scoring the rootball.

Backfilling

Soil can be backfilled around a new tree in either of two ways. Soil may be added dry or as a "slurry" by simultaneously adding soil and water, thus forming a thick "soup" in the planting hole. Both methods have advantages. The dry soil method is fast and clean. Even though the slurry method is messier, it is better at removing air pockets around and under the root ball. Do not stomp in air pockets because this could result in serious root damage and compaction. Use the end of the shovel handle to lightly tamp the soil and always backfill with native soil present at the planting site.

Watering

Before watering a plant, form a basin around its base so that water will soak in rather than run off. Make sure new plantings never dry out. Keep the soil moist but not waterlogged at any time during the first season. It is imperative that water does not stand in the basin for more than 20 minutes after watering. If it does, drainage is poor and should have been corrected beforehand or the planting area avoided altogether. Simply putting gravel or crushed stone in the bottom of the hole will not solve the problem. In fact, an artificially raised water table may result (perched water table), which will essentially "drown" the roots. Constant moisture invariably leads to root rots and other diseases.

Mulching

It is always a good idea to mulch newly planted trees or shrubs. Shredded hardwood bark, well-rotted manure, coarse peat moss, compost and grass clippings are good mulch materials that conserve moisture, retard weed growth and help maintain a more even soil temperature. Never apply mulches such as grass clippings or other plant materials if they have been recently exposed to herbicides, because the herbicides may damage or kill the plant. A 2- to 3-inch mulch layer is usually sufficient for one season. However, for fall transplants, mulch can be increased to 4 to 5 inches. The deeper mulch will delay deep frost penetration, thus allowing more time for root growth and establishment. Be sure the crowns of the plants are not buried with mulch material. Keep a weed-free mulched area well out from the tree's trunk. Mulch reduces competition for water and nutrients. Also, landscape caretakers are less likely to girdle tender trunks with string trimmers or bruise them with lawn mowers.

Synthetic mulches are suitable, but plastic can cause several problems, especially when applied around plants such as yew, azalea, rhododendrons, hollies and pines. Plastic prevents air and moisture exchange in the soil and thus stresses the plants. Also, plants grown with plastic mulch may develop very shallow root systems that suffer during temperature extremes common to Arkansas. Newly developed fabric barriers have shown promise in the landscape. Although more expensive than clear or black plastic, they allow gaseous and water exchange to occur more freely. This improvement in the rhizosphere (root growing area) can make the difference between success and failure with plants that are sensitive to lowered oxygen and moisture extremes.

Pruning

It is usually not necessary to prune aboveground parts at planting time. It was once thought pruning helped equalize the top growth with the amount of remaining roots, thus reducing the amount of water that was lost through transpiration. However, recent research shows this pruning is unnecessary. Injured or diseased branches, however, should be removed.

Pruning too early or excessive pruning also leads to sunscald and overall depressed growth. Since the lower limbs have leaves that directly contribute to photosynthate production, their removal should be avoided. The more limbs that are removed, the lower the production of photosynthate for the young plant. This in turn leads to depressed growth rates. Also, the lower limbs help shade the young, susceptible trunk from summer or winter sunscald. Pruning is discussed in greater detail later in the chapter.

Wrapping

Newly planted trees should have their trunks wrapped, while shrubs often do not need wraps. Wrapping protects trunks from sunscald and rodent attack. Paper, burlap, hardware cloth and plastic tree wrap may be used for this purpose. The polyurethane wraps are permanent and quite resistant to rodent damage.

Before wrapping, inspect the tree trunk for mechanical damage and the presence of insects. If the tree is being planted during the time(s) when borers may be laying their eggs, consider spraying the trunk with a suitable insecticide to prevent borer infestation. Begin wrapping from the base of the trunk and work up to the first main branch. Overlap the wrapping material to create a shingling effect. Then, anchor it by tying it in several places with two-ply jute twine or water- proof tape. Do not use plastic twine because plastic will not degrade naturally and may eventually girdle the trunk. Avoid wrapping trees during the summer months. The warmer, moist environment encourages insects and diseases to develop. However, some thin barked trees may need summer protection. This is why a young tree should not be limbed up (pruned) too soon. Lower limbs help shade the sunscald-susceptible trunk. Check with a nursery or garden center person for advice on which trees need summer wraps. Ginkgos and Japanese pagoda trees, for example, may benefit from summer wraps while the trees are young (during the first two or three growing seasons).

Not only will tree wraps prevent rodent damage in the winter, they also help keep the bark at an evenly cool temperature to reduce exposure during periods of winter warm-up. Sometimes, the bark's cells start to grow, only to be damaged by the eventual plummeting temperatures. This phenomenon has been called "Southwest injury."

Staking

Most studies have shared common conclusions that trees must sway in the wind somewhat to grow normally. Therefore, overstaking or making the tree too rigid should be avoided. When the tree can sway, it develops a stronger root and shoot system and quicker caliper (trunk diameter) development. Trees will benefit from stakes being removed as soon as possible, perhaps after the first growing season. This is a judgment call, of course, and is contingent upon such factors as the size of tree, establishment rate and average wind velocity in the area. After the first year, gently tug at the tree. If the root ball easily moves away from the surrounding soil, the root system is not established. Leave the tree staked and repeat this procedure the next growing season. In most cases, if root systems do not establish after the second growing season, something is preventing the tree from adapting to the site.

Regardless of the number of stakes and their duration, always check them regularly. Girdling, essentially strangulation of the trunk, can occur rapidly in fast-growing trees **(Figure 1.2.6)**. The traditional hose and wire is particularly likely to damage young, tender trunks. Be prepared to periodically check the trees throughout the growing season. The strap and grommet method is an alternative staking system that allows for lessened and slower girdling and thus is more "forgiving" **(Figure 1.2.3)**.

Figure 1.2.6. Stake left on too long.

Watering

There are no exact rules for watering plants. Water newly planted trees and shrubs well at the time of planting, and adjust all later waterings to the plants' needs. Since different plants have different moisture requirements, soil and plant conditions should be used as primary guides. Many woody ornamentals in Arkansas reach maximum growth when they receive an equivalent of at least 1 inch of water from rainfall or irrigation each week during the growing season. Newly planted trees and shrubs will probably have to be watered two or three times a week in extremely hot, dry, windy weather because their root system cannot take up the needed amount of water to replenish the water transpired by the growing leaves. Wilted leaves are normally a reliable sign that the tree needs moisture. If the soil seems to be moist and the tree is still wilting, it may be necessary to intermittently moisten the canopy. However, chronic wilting can also be a sign of an oxygen deficiency due to overwatering or disease.

Follow these general rules when watering established plants:

- Do not water until plants show signs of light wilting.
- Apply water slowly to allow it to soak into the soil.
- Wet the soil thoroughly to a depth of 8 to 12 inches. Thorough wetting encourages a uniform root system, which is better able to withstand stress.
- If possible, water the soil only, rather than the entire plant. If the entire plant is to be watered, water early in the day so that the foliage will dry before late afternoon. This practice helps prevent certain foliar diseases.
- Do not overwater, since overwatering can leach nutrients from the soil or deplete oxygen availability to the roots. Some plants, such as yews, are sensitive to too much water. Do not plant high-moisture sensitive plants next to gutter downspouts or other areas where excessively wet soils develop.
- Give special attention to plants set close to a wall where an overhanging roof blocks rainfall.
- Check the soil for moisture near the root zone, not just at the surface, before deciding whether or not to irrigate. Quick summer showers may not supply enough moisture to wet the entire root ball area.
- Lastly, mulch plants whenever possible to reduce supplemental irrigation. Even if a plant is touted as being drought resistant, it still needs to be mulched and irrigated at least the first growing season after it is transplanted.

Winter Irrigation

Experienced landscapers know that plants benefit from winter irrigation when temperatures are above freezing, which could be a significant period during average Arkansas winters. This is particularly true for all broad-leaved evergreens and many deciduous species. When plants are properly mulched, however, the need for winter irrigation is greatly reduced.

Fertilizing

Fertilization is a necessary part of woody plant care. Vigorously growing plants are more attractive and recover more easily from insect and disease infestations than plants with insufficient amounts of nutrients. Poorly nourished plants have reduced or abnormal growth; small, discolored leaves that may drop prematurely; fruits that abort or fail to form; and reduced vegetative and root growth. However, plants have limits on how much of any nutrient they can tolerate. Thus, excessive fertilizer amounts can be toxic.

Elements that are essential for plant growth and reproduction include hydrogen, carbon, oxygen, nitrogen, phosphorus, potassium, calcium, sulfur, magnesium, copper, manganese, iron, boron, chlorine, zinc, nickel and molybdenum. Hydrogen and oxygen are supplied by water, and carbon and oxygen by the air. All of the other elements needed for growth are absorbed from the soil by the plant's roots. Nitrogen, phosphorus, potassium, calcium, sulfur and magnesium are needed by the plant in relatively large amounts and are called macronutrients, or major elements. Copper, manganese, nickel, boron, chlorine, zinc and molybdenum are needed in relatively small amounts and thus are called micronutrients, trace elements, or minor elements.

Nutrients are derived from organic, synthetic organic or inorganic sources. Organic sources come from plant or animal material, such as manure, bone meal, dried blood, cottonseed meal, composted plant material or inorganic material that has not been "processed." Synthetic organic fertilizers are manmade fertilizers with a carbon skeleton. Complex synthetic organic fertilizers have been developed to give controlled release of nutrients. Inorganic fertilizers are minerals that are usually mined or manufactured by man.

Since nutrients are absorbed by plants as inorganic ions, organic fertilizers must be decomposed before the ions are available for plant uptake. The principal advantage of organic fertilizers is that they improve the tilth and water-holding capacities of the soil. Inorganic fertilizers are generally more apt to burn or injure plant roots and should be used with additional care. However, they are usually needed in smaller amounts and are much easier to handle. Nutrient application is like any other input into a landscape – care must be used to maximize inputs without creating potential damage to the environment or applicator.

Timing

Trees and shrubs should be fertilized in the spring, early summer or late fall. Spring applications will provide nutrients for the initial flush of growth, when nutrients are most often needed. Plants can absorb nutrients as long as soil temperatures are above 40°F. Nutrients from fall applications are absorbed by plants and stored until they are needed for growth. Root growth will occur even though the top of the plant appears dormant. Avoid fertilizing in late summer because extra nourishment at that time can result in a flush of fall succulent growth that may not have sufficient time to harden off before the first frost. Fertilize after leaf drop or after the first hard freeze.

Fertilizer Rates

Determine the need for fertilizer by observing deficiency symptoms on plants and by taking soil tests. Deficiency symptoms only indicate that fertilizer is needed; soil tests determine how much fertilizer to apply. Soil tests are the primary measures used. When taking a sample for a soil test, remove a core of soil about 1 inch in diameter and 12 to 18 inches deep. Always take a composite sample of at least 10 to 20 cores to obtain a true "picture" of the area's fertility. In other words, take 10 to 20 small samples throughout the growing site and blend them into one composite sample to be tested. Such a sample will yield more accurate information.

Fertilizer application rates are determined by the area to be fertilized **(Table 1.2.3)**. Six pounds of actual nitrogen per 1,000 square feet per year is recommended to encourage optimum tree growth. Woody plants should receive 3.6 pounds of phosphorus (P_2O5) per 1,000 square feet and 6 pounds of potash (K_2O) per 1,000 square feet every three years.

Remember that a sick or weakened plant will only respond to fertilizer when a true nutrient deficiency exists. Often times, the stress is some other culprit. In such a case, no amount of fertilizer will improve the health of the afflicted plant. Only an actively growing plant or one suffering from a nutrient deficiency can benefit from fertilizers. Fertilizers used in excess of label rates may exacerbate any problems existing prior to the fertilizer application.

Always be wary of high-priced fertilizers with exaggerated claims for luxurious growth or improved flowering. This also holds true for vitamin and hormone formulations. Check with a reputable nursery or garden center person for further advice on products available and amounts needed.

Table 1.2.3. Fertilizer application rates.

Type of Fertilizer	Approx. Amount of Fertilizer (lbs./1,000 sq. ft.)
Ammonium nitrate (33-0-0)	18
Ammonium sulfate (21-0-0)	30
Urea (45-0-0)	12
10-10-10	60
12-12-12	48

Note: Many other types and formulations of fertilizers are acceptable.

Pruning

Pruning is one of the principal techniques by which a specimen plant is produced. In nature, when a twig or branch has served its purpose, it dies and eventually falls to the ground. In urban settings, however, deliberate pruning is needed for aesthetic and functional purposes. Pruning is also important in the prevention and treatment of certain diseases.

The plant and its environment must be considered together. Often a plant is selected without thinking about how large it will grow. In a foundation planting, a shrub may be planted that in a few years will grow up and screen a window. It would be hopeless to try to prune the shrub for best effect and also keep it at the desired height. It would be much better to replace it with one that would grow no higher than the height desired. Foresight in plant selection will often save much labor and will provide a plant that looks better and more natural for a longer period of time. Ask a nursery or garden center worker if a dwarf cultivar is available for a prized species. Also, check for cultivars that grow more upright than the species. This growth habit could also reduce the need for pruning in close growing quarters. The upright cultivars will often have the name 'Fastigiata' or 'Columnaris,' for example.

Pruning must be done to produce a good appearance and to ensure the health of the plant. This is why pruning is considered both an art and a science. It is important to know how plants grow and develop, what effect pruning will have on a plant's health, how much growth one should remove and at what points one should prune.

The obvious effects of pruning are the changes that occur in a plant's size and shape. But, physiological changes also occur that are not immediately visible. For example, pruning during the dormant season (fall or winter) reduces the number of growing points on the tree. Therefore, the food (carbohydrates) that is stored in the roots and main stems during the winter is concentrated in fewer branches in the spring. The result is more vigorous vegetative growth. By contrast, pruning during the summer growing season has a tendency to check or retard growth. If the most active growing points are removed, the plant stops growing until new buds are activated.

All pruning has the general effect of making the plant fuller. Topping or heading back is a method by which the terminal buds are removed. These buds usually inhibit the growth of the lateral buds below them – a phenomenon known as apical dominance. If the terminal buds are removed, the lateral buds will show more growth, thus creating a fuller and denser plant.

Pruning can also be used to control the direction of growth. If you want a plant to grow toward a certain point, cut back to a bud which points in the desired direction. This kind of pruning is used in heavy traffic areas in landscapes where a definite shape is desired.

Proper pruning cuts are essential in preventing or minimizing insect and disease invasion. Flush cuts are no longer recommended. Instead, limbs should be pruned outside of the branch collar **(Figure 1.2.7)**. By pruning beyond the branch collar, the tree is able to defend itself from decay by imposing physical and chemical barriers.

Prune older trees to maintain their appearance and vigor. Always remove dead,

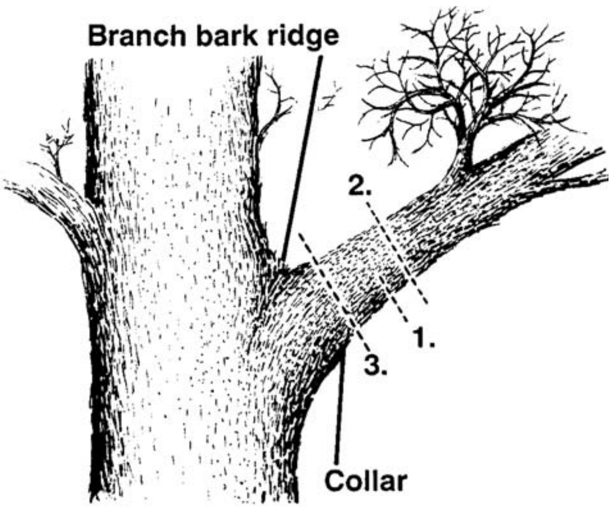


Figure 1.2.7. The three-cut method for removing heavy limbs.

dying and broken branches as soon as possible, both to improve the appearance of the plant and to reduce the danger of falling branches. Branches that grow back into the center of the canopy should also be removed, so they will not rub against healthy branches as they develop, and remove all crossing or rubbing branches. Rubbing branches can develop bark wounds that can serve as entry sites for insects and disease-causing organisms.

Pruning Flowering Shrubs

It is important to understand when flower buds are formed on ornamental shrubs. Some flower buds are formed on old wood during the summer, then overwinter and bloom the next spring. However, others form buds on new wood or form buds after new growth begins in the spring that bloom that same year. Pruning a plant at the "wrong" time of the year could cause the plant not to flower properly. Consult a nursery or garden center worker for the optimum time to prune any given tree or shrub.

Pruning Paints

Whether or not to use pruning paints is a chronically debated issue. Recent research has suggested that paints may actually delay the healing process. Even if they do not delay it, they probably do not aid in wound closure. Therefore, most researchers have labeled pruning paints as cosmetic. However, some researchers have concluded the paints may offer defense against woodborer invasion and other pests. If pruning paints are desired, they probably should only be applied as a thin coat or only when requested by the client.

Winter Protection

Many of the important winter protection practices have already been mentioned. The first step in avoiding winter damage is to select plants that are winter-hardy in the area. In addition, avoid late-summer fertilization and pruning, both of which may force soft, succulent growth that will not have time to harden off before winter. Remember to apply tree wraps to all young trees during the fall and winter months.

Another large part of winter protection is proper watering. It is essential for plants to enter the winter months with a good supply of moisture. This is especially true for evergreens, such as hollies, boxwoods, rhododendrons, junipers and yews. Water plants well before the soil freezes and then mulch.

Mulching plants is an excellent practice in winter. Mulch helps keep the soil moisture and temperature levels even, thus preventing rapid and damaging changes. Avoid burying the crowns of the plants too deeply. This practice can lead to crown rot in some plants and may also create a harboring place for insects and rodents. The main purpose of mulch is to protect the root systems, not the crowns. Roses and other budded or grafted plants, however, are often exceptions to this rule.

During the winter, extra time is often afforded the landscape attendant to review maintenance records for the year. During this time, cultural management decisions made can be reviewed and evaluated and modified if necessary for the next growing season.

Remember: Despite everything that is mentioned in the literature, proper plant selection is critical, and thus the most important factor that can be controlled in achieving success with ornamentals.

Diseases of Landscape Ornamentals

Plant Diseases – An Introduction

A plant disease can be defined as an abnormal alteration in the structure and/or physiological function of a plant. This alteration often leads to the development of symptoms, which is the visible expression of a disease. Some diseases produce specific symptoms that are used in diagnosing the disease. The causes of plant diseases may be broadly divided into two basic groups, those that are abiotic (nonliving agent) and those that are biotic (living agent). Abiotic diseases are those that are caused by an unfavorable growing environment. Examples of environmental stress include water stress, temperature extremes, nutrient imbalances and plant injury (chemical or mechanical). Biotic plant diseases are most commonly caused by living microscopic organisms called pathogens. These diseases are often referred to as parasitic diseases. A parasitic disease is the end result of three very important factors that make up the "Disease Triangle" (Figure 1.3.1). This triangle consists of a susceptible host plant, a favorable environment and a pathogen (causal agent) capable of infecting the host plant. There is a very close relationship between these three factors. If one of these factors is incompatible with the other two at a specific time, there will be no disease development. The most common plant disease pathogens consist of fungi, bacteria, viruses and nematodes. Biotic diseases usually develop over an extended period of time, whereas abiotic diseases are usually over a short time period.

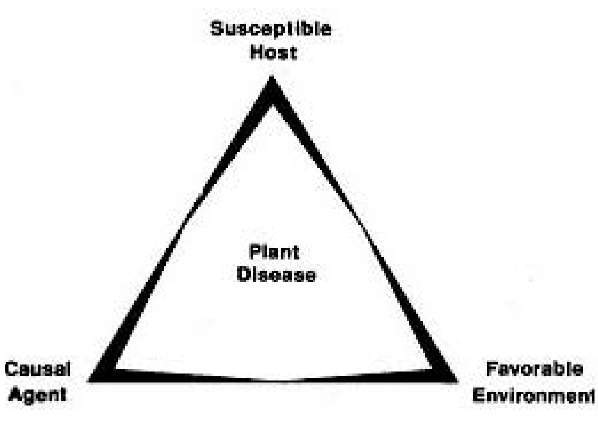


Figure 1.3.1. Disease Triangle.

Fungi cause the majority of severe diseases on plants. The threadlike body (hyphae) of a fungus usually reproduces by forming microscopic seedlike structures called spores that are commonly spread from one plant to another by wind, splashing water, equipment, animals and infected plant parts. The fungi may enter the plant by natural openings (stomata, lenticels and nectarines), wounds and direct penetration. Fungi cannot manufacture their own food, thus they rely on a host plant for nourishment. They can live off of dead or living plant or animal matter. Spores land on a leaf surface, germinate and penetrate the leaf tissue. This is called the infection process, after which disease symptoms appear. Use of protectant fungicides interrupts this process and prevents disease from developing. Understanding the preventive nature of this process helps an applicator understand the importance of proper spray intervals and adequate coverage of foliage. Not all fungi are detrimental to plants. Some fungi are beneficial because they break down organic matter and are extremely important in the food-making process and the production of some antibiotics. Significant plant diseases caused by fungi include late blight of potato, downy mildew on grapes, powdery mildew on many field-grown ornamentals, cereal rusts and smuts, chestnut blight, daylily rust, Dutch elm disease, brown patch of turf, brown spot of rice and soybean rust.

Bacteria are single-celled microorganisms that reproduce by dividing themselves. Most plant pathogenic bacteria are rod-shaped microorganisms that divide rapidly. Under optimum conditions, bacteria may divide every 20-50 minutes, one bacterial cell becoming two, two becoming four, four becoming eight and so on. Bacteria enter plants through wounds created on the plant or through natural openings such as the stomata on the leaf, nectarines of the flower and lenticels on the stems. Bacteria are spread by splashing water, wind, equipment, animals and soil. Some insects are important vectors of bacterial diseases. Most bacterial diseases are related to moist environments where plants are grown. The bacteria commonly infect plants by being splashed onto wet plant foliage from the soil. Water-soaked or greasy areas are common symptoms on plants. Important diseases caused by bacteria include fire blight on apples and pears, bacterial leaf spots and wilt on many ornamental foliage plants, crown gall on a variety of field-grown ornamentals, bacterial leaf scorch on shade trees and citrus canker on citrus.

Viruses are much smaller than bacteria and can exist and multiply only inside living cells. Viruses enter the plant only by wounds made mechanically or by vectors or occasionally by infected pollen grains. These agents do not divide and do not produce any kind of a reproductive structure like spores of a fungus. They multiply by inducing the cells of the living host plant to form more virus particles. They are spread mainly by contact between plants, sucking insects (leafhoppers, whiteflies and aphids), propagation of infected plants, and contaminated equipment. Mosaic (a mixture of dark and light green areas), flecking and ringspotting are foliar symptoms typical of viruses. Viruses can also cause stunting and other growth disorders. The disease symptoms of some virus infections often resemble other plant problems such as herbicide injury and nutritional imbalances. Viruses may remain from season to season in perennial weeds, insects, nematodes and seeds. Once a plant is infected with a virus, no practical treatment for complete removal of the pathogen exists. Plant removal is often recommended to prevent spread of the virus to healthy plants. Infected plants may serve as a reservoir for additional infections when there is an insect or other vector present that can transmit viruses. Chemical control for virus diseases is not effective. Diseases caused by viruses include rose mosaic, tobacco mosaic, tomato spotted wilt, impatiens necrotic spot, barley yellow dwarf of wheat and plum pox of stone fruits.

Mycoplasmas are ultramicroscopic organisms that lack a true cell wall but are bounded by a “unit” membrane. They grow to various shapes and sizes. These organisms reproduce by budding and binary fission. They do not produce spores like the fungi often do. Spiroplasmas and phytoplasmas are related organisms and cause diseases including corn stunt, aster yellows and elm yellows. These organisms may be found in the food-conducting tissues of the plant.

Nematodes constitute a serious problem with many plants. Nematodes are microscopic round worms approximately 1/50-inch long. If they have a satisfactory food source, they reproduce rapidly. A single female nematode may lay up to 500 eggs at a time. Once the egg hatches, the immature nematode will undergo several morphological changes as it matures into an adult. Nematodes can be found in all types of soil, but tend to be most numerous in sandy or light-textured soils. Nematodes are usually spread from one locale to another by soil movement or irrigation water. Many types of plant parasitic nematodes exist, but the most common one is the root-knot nematode. This nematode may attack many species of economically important plants. Most of the damage inflicted by nematodes is a result of direct feeding on the roots. The nematode inserts a sophisticated feeding tube (stylet) into the cells of the root. Although the majority of plant parasitic nematodes feed on the roots of plants, some feed on the leaves. Plants with knotted or galled root systems cannot absorb enough water and nutrients to adequately supply the plant. The tops of plants may appear wilted or inadequately fertilized. Once the soil becomes infested with nematodes, it is difficult to eradicate them completely from the soil by conventional means. Damage to the plant may not become apparent until the nematode population increases beyond an economic threshold for the host plant. Chemical treatment is often used to reduce the population so that a reasonable crop can be grown. Important nematode problems include root knot on many ornamentals and vegetables, lesion nematode, cyst nematode on soybean, reniform nematode on cotton, foliar nematode on ornamental foliage plants and pinewood nematode.

Parasitic higher plants such as dodder, mistletoe and witchweed obtain all or part of their nutrition from a host plant. The dodder produces a yellow, small-diameter vine that attacks plants intertwining around the host plant. With the aid of a specialized absorbing organ (haustoria), it drains nutrients and water from its host. The mistletoes can be found on a number of woody plants. These parasitic plants have chlorophyll and produce sticky seed that are often dispersed by birds that eat them. Control is difficult to achieve. Witchweed, another parasite, is not common in North America. It is a parasite on corn, rice, sugarcane and a few small grain crops. Heavily infected plants will die as a result of the roots being parasitized by witchweed.

Abiotic plant disorders constitute a vast majority of problems with ornamentals in the landscape. Among the most common problems are moisture and temperature stress, improper planting and maintenance, improper site, improper fertilization and pesticide application, and string trimmer injury. When plants are stressed, they are more vulnerable to the effects of attack by disease-causing pathogens and insects. Although some pathogens will attack vigorously growing and healthy plants, many attack and infect only plants that are stressed. A weakened tree or shrub, for example, is much more susceptible to cankers, wood decay, root rot and certain wilt diseases than a vigorously growing ornamental.

Accurate disease identification is the first important step in planning an effective and efficient disease control program. An understanding of the pathogen's life cycle and mode of action is crucial in developing control strategies. Literally thousands of specific diseases exist. As growers, we may encounter only a few during a particular season, but we must be able to distinguish significant and potentially serious diseases from those of lesser importance.

Ornamental Diseases

Black spot of rose (Diplocarpon rosae) is one of the most common and destructive fungal diseases of rose. It is most destructive because it damages the plant's food manufacturing organs (leaves). Leaves are necessary to produce carbohydrate materials that keep the plant healthy and productive. If the leaves are not retained on the plant throughout the season, the plant becomes unhealthy and dies. This disease is caused by a fungus that produces airborne spores. Spores formed on infected or fallen dead leaves are typically splashed onto the new lower leaves in the spring of the year. An additional crop of new spores may form on infected leaves in as few as 10 days after infection. The fungal spores readily attack newly expanding foliage and canes. Black spot of rose is usually a problem in the spring and fall, particularly under moist or wet conditions. Wet leaves can lead to an increase

Figure 1.3.2. Black spot of rose.

in disease activity at any time of the year. Varieties of roses differ in their susceptibility to this disease. Symptoms appear as black spots with fringed edges on the leaves (Figure 1.3.2). Pruning any dead/damaged or infected canes can help to slow disease development if done prior to the spring. Roses that are susceptible will need regular fungicide applications during times of favorable development to prevent this condition. Reducing overhead irrigation water can also reduce severity levels of this disease.

Mosaic virus of rose often produces a line pattern of light and dark green areas that give a mosaic effect on infected leaves (Figure 1.3.3). The infection reduces the overall quality. Infected plants may remain symptomless. Generally speaking, symptoms are most apparent in the spring. This virus disease is actually caused by two viral pathogens, apple mosaic virus and prunus necrotic ringspot virus.

Figure 1.3.3. Mosaic virus on rose.

As with other virus diseases of ornamentals, no chemical control is available. Growing and propagating disease-free material is the best control. Diseased plants should be removed and destroyed.

Powdery mildew (Erysiphe spp.) is a common fungal disease of many ornamentals. It is a common disease on roses, euonymus and crapemyrtle. Powdery mildew causes infection during cool, dry periods and is capable of severely damaging ornamentals. It is easily recognizable by the patchy white powdery growth usually present on the leaves (Figure 1.3.4). The fungus penetrates leaf tissue and draws nutrients from the plant. Euonymus is highly susceptible to powdery mildew. The primary symptom is white patches of the fungus.

Figure 1.3.4. Powdery mildew of crapemyrtle.

While chemical control is feasible, it may be advisable to remove a highly susceptible plant that is not crucial to a landscape design to prevent periodic spraying throughout the growing season. Protectant fungicides prevent spore penetration and subsequent disease development. For these materials to be effective, they need to be applied just prior to or at the first evidence of disease activity.

Fusarium wilt (Fusarium oxysporum) causes a vascular wilt of many ornamental and vegetable plants. The first signs of infection are chlorosis (yellowing) of the leaf tissue and collapse of the leaf petiole, followed by plant wilt and death. Typically the lower leaves or an isolated branch or section of branches of infected plants will yellow and wilt first, followed by the remainder of the plant. Any plant infected by this disease will show an internal red-brown discoloration of the lower stem and upper root when the plant stem is split lengthwise. The best control method for Fusarium wilt is to remove infected plants from the landscape. Fungicide application is not an effective control measure for this disease.

Azalea leaf gall (Exobasidium vaccinii) causes a peculiar leaf swelling on this common ornamental shrub. The fungus that causes this disease penetrates the leaf tissue and causes leaf swelling. The galls appear thick and fleshy. (Figure 1.3.5). This disease may also affect rhododendrons and camellias. The disease is best controlled by hand pulling the infected leaves with galls from the plant and destroying them before the swellings become white. When the galls become white, the fungus is producing spores that serve to initiate new infections the following spring. Use a fungicide to prevent development of the fungus on healthy foliage. Most protectant fungicides protect only the newly developing foliage. Little to no control will be achieved on already infected leaves. Minimizing leaf wetness is very important in helping control this disease.

Figure 1.3.5. Azalea leaf gall.

Crown and root rot can occur on virtually all ornamental plants. A number of fungi, bacteria and nematodes that live in the soil may contribute to this condition. Phytophthora spp., Pythium spp. and Rhizoctonia spp. are among the most common root rot fungi. Root and crown rots develop more readily when soil conditions are unfavorable for plant growth or cultural conditions are not optimum. Root and crown rots often develop in poorly drained soils that remain wet for extended periods. Good drainage is essential in disease control for these types of diseases. Commercial growers should always propagate plants in a pasteurized soil medium to exclude organisms from the mixture. Careful attention should also be given to irrigation amount and frequency.

Phytophthora aerial blight (Phytophthora parasitica), sometimes called Phytophthora branch and stem rot can be a major problem in vinca landscapes. This pathogen typically infects the aerial portion of plants, hence the name. Infection first occurs on the leaves and is marked by a rapid collapse and water-soaked appearance of the leaf. From the leaf, the fungus moves to the petiole and then to the stem where it moves down the stem, killing tissue as it goes (Figure 1.3.6). The fungus can spread from plant to plant just by leaf contact. Control of this disease is very difficult, and fungicides have not proven to be very effective. Removing symptomatic plants provides some suppression. Since wet conditions favor disease, spacing plants and minimizing overhead irrigation can reduce severity.

Fire blight (Erwinia amylovora) is a bacterial disease affecting many ornamental species in the Rose family. Fire blight occurs on apple, cotoneaster, crabapple, hawthorn, pear, quince, pyracantha and serviceberry. The most common host plants in Arkansas are the apple and ornamental pear. The bacteria causing this disease infect blossoms, young fruit, small twigs and leaves. Some insects bring the bacteria to the blossoms during pollination. After infection, blossoms and leaves wilt suddenly, turn brown or black and die. Infected fruit appears leathery. Young twigs and branches die from terminals and appear burned or scorched by fire. The characteristic symptom of this disease is the bending of the blighted terminal, resembling a shepherd's crook (Figure 1.3.7). Dead leaves usually remain on the twigs. In urban landscapes, no chemical control of this disease is recommended. Prune and remove infected plant parts 6 to 8 inches below the area of visible disease. Pruned twigs should be destroyed.

Figure 1.3.6. Phytophthora branch rot on vinca.

Figure 1.3.7. Fire blight on pear.

A disease that commonly infects red tip photinia and Indian hawthorn is Entomosporium leaf spot (Entomosporium mespili). The photinia is the most significant host in Arkansas. This fungal pathogen causes the most 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 (Figure 1.3.8). To manage this disease, water plants only when

Figure 1.3.8. Entomosporium leaf spot on photinia.

necessary. If plants must be watered, do so in the early morning. Diseased leaves that have fallen to the ground must be removed to minimize future infections. Protective fungicide sprays may be needed to control Entomosporium leaf spot during periods of cool, wet weather. For optimum effectiveness, it is important to cover all the foliage with the fungicide. Regular fungicide applications may be necessary beginning in the spring and continuing into the summer. Avoid summer pruning. This will encourage a rapid flush of susceptible foliage. Since this foliar disease is common and widespread in Arkansas, growers should consider selecting a suitable substitute in the landscape.

Botrytis blight (Botrytis cinerea) is a gray mold fungus that can infect any aboveground portion of a plant. Gray mold is most commonly a greenhouse disease where moisture condensation on plant surfaces may be an issue. Virtually all herbaceous ornamentals are susceptible to this fungus. The most susceptible plants include poinsettia, exacum, geranium and impatiens (Figure 1.3.9). The fungus may produce a variety of symptoms on the plant. It is usually seen first on the flowers or leaves, causing a rapid collapse of these tissues. Stem or branch lesions may also result from infection. As tissues become infected, the fungus produces a gray fuzzy growth on them. Spores of this fungus are ubiquitous in the greenhouse. This disease is most common in the winter, when temperatures are cool and the humidity is high. Fungicides may control the disease if applied early. Rotating effective fungicides is important in disease management to avoid the development of resistance in the fungus population. Good sanitation must be an essential component in management practices since the fungus readily attacks stressed or weak plants.

Leaf rust on ornamentals may be caused by several fungal pathogens. Leaf rusts appear as rust-colored spots on leaves and stems. These fungi produce pustules that contain golden yellow or orange colored spores that may serve to initiate new infections in the growing areas (Figure 1.3.10). Removing and destroying infected plant parts can slow the spread of this disease. However, if infection is considerable, the use of a systemic fungicide may be necessary. The use of resistant varieties is often quite effective in control.

Leaf blister (Taphrina spp.) is a common disease that may occur on many red and white oaks in Arkansas. This disease causes "puckering" or small circular depressions in the leaf surface. It may resemble insect activity at first glance. It is considered more of a "cosmetic" disease that may result in some premature defoliation. Fungicide applications may be required for specimen trees. To be effective, fungicides must be applied before bud break since the fungus may over-winter on the bud scales and infect the leaf at it emerges from the bud. They must be applied, however, when the tree is forming its buds in the spring. Application after leaf emergence is not effective in controlling this disease.

Figure 1.3.9. Gray mold on poinsettia.

Figure 1.3.10. Leaf rust on daylily.

Trees and woody shrubs can develop a variety of fungal cankers that maybe fungal or bacterial in origin. Cankers are areas of dead tissue, usually darker in color and sunken beneath the surface of stems and branches. The causal fungus may produce fruiting bodies that resemble small "pimples" within this area. Wounds that occur to the stems or branches often lead to infection by canker-causing fungi. To manage cankers, prune out infected areas and promote good plant health, as most of these fungal or bacterial organisms do not become systemic within the plant. By pruning the affected twigs, spread of the fungus or bacteria into other portions of the plant is retarded.

Lichens occur on the trunks of many trees and on the lower branches of woody shrubs if the humidity is sufficient. Lichens form when algae and fungi grow together (Figure 1.3.11). The relationship is beneficial to both organisms and is a very common type of growth. They may be seen on rocks and wooden fence posts as well as on the trunks of trees. They are not considered plant pathogens, but often occur on stressed plants.

Figure 1.3.11. Lichens on branch.

Figure 1.3.12. Sooty mold on crapemyrtle.

Ball moss is an epiphytic plant that grows on other plants as well. It may become heavy enough on some trees to cause considerable damage to the tree, primarily by shading the foliage. Physical removal or handpicking can be an effective control method. Chemical control is effective but should be used only if the ball moss growth is excessively thick.

Sooty mold results from insect activity on ornamentals. Sucking insects such as aphids and whiteflies produce a sticky substance, honeydew, that accumulates on leaves and gives rise to this fungal growth called sooty mold (Figure 1.3.12). The dark-colored fungal growth can be wiped off with a cloth and generally causes little harm to the plant. Crapemyrtle and holly are commonly affected by this black fungal growth on plant surfaces. The presence of sooty mold is an indicator of significant populations of honeydew-producing insects. Any control measures should be directed toward the insect populations rather than the sooty mold growth on plant tissue.

Several ornamentals are susceptible to bacterial leaf spot. These spots may appear similar to fungal leaf spots, making it difficult to distinguish between the two. Bacterial diseases on ornamentals are commonly found in wet environments. Most bacterial spots are caused by either Xanthomonas or Pseudomonas species of bacteria. Bacterial spots are initially light green in color and look water-soaked or greasy. These spots often turn brown or black in color. English ivy, peach, ornamental pears and syngonium are common plants affected by bacterial leaf spots. Bacteria are often splashed from the soil onto wet foliage, where they enter through stomates or wounds. Bacteria are usually spread from leaf to leaf by splashing water when plants are watered or during rain periods. Many bacterial pathogens found on plants have the ability to invade plant vascular tissues and spread systemically throughout all parts of the plant. Under certain conditions, these pathogens may begin to multiply in localized areas of the infected plant and cause stem rots, leaf blights, wilts and root rots (Figure 1.3.13). Some fungicides that contain copper are helpful, but the use of overhead irrigation must be avoided in order to control this pathogen. In most cases removing infected foliage is also helpful. For systemic bacterial infections, utilizing good sanitation practices and disease free plants are the best methods of control.

Figure 1.3.13. Bacterial blight on syngonium.

Figure 1.3.14. Crown gall of euonymus.

Crown gall (Agrobacterium tumefaciens) is a soil-inhabiting bacterium. It has the broadest host range of any bacterial plant pathogen. This bacterium causes a mass of plant tissue at the crown that can weaken or kill the plant. These galls or "swellings" may occur on the roots and stems, especially at the root collar, or root crown as a result of growth stimulation from the bacterium (Figure 1.3.14). Aerial galls are common on highly susceptible plants as rose, willow and euonymus. The crown gall bacterium is disseminated by soil or irrigation water. It can remain in the soil for extended time periods. If there are a few stem galls present, stems can be removed and destroyed. Bare-rooted nursery stock can be treated with an antagonistic strain of Agrobacterium prior to transplanting.

Anthracnose diseases of ornamentals are caused by a number of fungi, including Apiognomonia, Discula, Gloeosporium, Gnomonia, Monostichella and Kabatiella spp. The symptoms vary greatly with the host plant. Symptoms are leaf spots, blighting of leaves and shoots, cankers and dieback of twigs and branches (Figure 1.3.15). Several tree species, including ash, birch, dogwood, elm, maple, oak, sycamore and walnut, are susceptible to anthracnose. The anthracnose diseases develop under conditions of wet weather at moderate temperatures; fungi may cause several cycles of infection annually. Spores dispersed by splashing and running water start each cycle, infecting succulent plant tissue that is susceptible. The pathogenic fungi overwinter in the vegetative and/or reproductive state in lesions on leaves or twigs remaining on or under the tree. Spores of the anthracnose fungi are all dispersed by splashing water. Outbreaks of anthracnose often occur following cool and wet springs. Although this disease alone seldom kills the tree, it can make the tree more susceptible to other "less virulent" diseases or stresses. For valuable specimen plants, multiple sprays of the foliage may be required with a registered fungicide. Spray applications should start as soon as the leaves began to form and continue into the summer. All fallen leaves and twigs should be gathered and destroyed in the fall to remove the overwintering fungi, which produce spores for the following spring's infections. Infected dead twigs should be pruned whenever feasible and destroyed.

Figure 1.3.15. Anthracnose of maple.

Summary

Diseases, whether abiotic or biotic, can be destructive to all plants. It is very helpful to become familiar with the way healthy plants look in the landscape. Proper placement and maintenance are of the utmost importance in overall plant health. We have discussed the interactions of the "disease triangle" and its role in disease development. Infectious disease development is an ever-changing and dynamic process in which a series of events occurring in succession leads to the development and perpetuation of the disease and a pathogen.

In order to diagnose a plant disease, it is important to determine if the disease is caused by a pathogen (fungus, bacteria, virus, etc.) or if the problem is a result of an unfavorable growing environment. Accurate identification is the first and most important step in designing an effective disease control program. Details of the symptom expression on individual plants are very important in the diagnosis of plant disease. Each causal agent, biotic or abiotic, will produce some specific symptoms. These symptoms may vary, depending on the plant, growth stage, exposure time, etc. The ability to anticipate and react appropriately to common problems and implement preventive solutions can be quite valuable in maintaining a healthy lawn grass and landscape planting.

The aim of this information is to help with the diagnosis and understanding of disease mechanisms of ornamentals and turfgrasses. It describes many common diseases that have distinctive symptoms. This information offers comments on controlling these various diseases.

For further information and assistance with plant disease identification and control, consult you local Extension office.

Insects and Mites Affecting Ornamentals

Many different kinds of insects and mites feed on trees and shrubs. Generally, the greater the variety of plants in the landscape, the more insect and mite species will be encountered. However, the mere presence of an insect or mite on a tree or shrub does not mean there is a problem that has to be controlled with insecticides or miticides.

Wasps, lady beetles and other biological and environmental forces play an important part in keeping many insects and mites under control. These protective forces break down during some seasons, and insecticide and other control measures may then be needed. Some insects and mites thrive under Arkansas climatic conditions, and natural forces seem to exert little pressure on them. These insects and mites may be troublesome almost every year. Some plants are more susceptible to specific insects or mites, and they require constant attention, while others are relatively insect- or mite-free almost every year.

The following is a discussion of insect and mite management of ornamental shrubs and trees in Arkansas. The insects and mites are grouped according to the kind of injury they cause.

General Considerations

Dealing with insect pests on plants involves a procedure similar to dealing with human ills. You should have some knowledge about the situation and then use this knowledge in the proper sequence to achieve the best results. In general, the procedure for dealing with insect and mite problems is as follows:

1. **Examination of the situation.** Know what the normal or healthy condition of the plant looks like. If the plant deviates too far from this condition, look for possible causes. (See the Key to Common Tree and Shrub Pests located at the end of this chapter.)

2. **Identification and assessment.** If insects, mites or damage apparently caused by them are found, determine what the pest is and the severity of the problem. Not all insects are pests. Some may be incidental visitors, and some may be beneficial. On the other hand, some pests may be causing little damage at the moment, but the problem may become serious in a short time. Even if the plant is healthy, it may be vulnerable to attack from pests, and thus it is important to know what insects or mites are likely to be pests on a given host plant.

3. **Management options.** This may involve preventive action, curative action or no action at all, depending on the identification and assessment of the situation.

   Preventive action often involves maintaining plant vigor by proper site selection and good cultural practices. The sanitary practices of pruning out dead or unhealthy plant parts and cleaning up ground litter that may harbor pest insects are also helpful. In some cases, insecticides are used to protect plants from becoming infested.

   Sometimes natural controls are sufficient to give the plant an advantage to overcome the pest attack. At other times, an insecticide may be needed. The most common of the points to consider when selecting and using an insecticide or miticide are:

   - Is the insecticide/miticide registered with the EPA for this site/plant, and is the product labeled for the intended use?
   - Is the use of this insecticide/miticide safe to you and others in the situation in which you want to use it?
   - Is the insecticide/miticide likely to harm the plant you want to protect? If so, under what conditions?
   - Will the insecticide/miticide also kill beneficial insects or other beneficial animals in this situation?
   - Will the insecticide/miticide kill the pest?
   - What is the proper time to use this insecticide/miticide for this particular pest?
   - How and to what parts of the plant is the insecticide/ miticide applied?

   No action is suggested when the pest is not a serious one or when the curative action probably would give rise to problems more serious than the one at hand. Sometimes a pest may be causing extensive damage, but there are no practical methods of control during this particular stage of the insect's development.

4. **Insecticide/Miticide Application.** Knowing what the problem is and what to do about it does not solve the problem. Some of the common problems associated with insecticide application are:

   - Errors in mixing insecticides in the right proportion.
   - Inadequate coverage of the plant with the spray. Plants usually should be thoroughly wetted with spray.
   - Tendency of the spray to separate or settle out unless the spray solution is kept agitated. If the spray solution is allowed to settle during spraying, some plants will be overdosed and others underdosed.
   - Improper timing of sprays. If applied too early, the insecticide may have disappeared by the time the insect population is present. If the spray is delayed, the insects may have developed to a more resistant stage or may have bored in where the spray cannot reach them.
   - Adverse effects due to weather conditions. Rains following spraying may wash off the insecticide before it has accomplished its full effect. Temperature extremes combined with application of an insecticide may injure the plant, reduce toxicity of the insecticide, increase pest resistance or volatilize the insecticide.

5. **Evaluation.** Did the control work? Also, keeping records on the extent of infestations and the control actions taken will provide valuable historical reference for measuring success and failure of control efforts.

Diagnosing Plant Problems Caused by Insects/Mites

Most individuals recognize when a plant is unsightly, growing poorly or having some type of problem; however, determining the cause of poor plant performance can be difficult.

Insects and their relatives (arthropods) must feed to survive and reproduce. Most feeding pests cause visible and predictable changes in the plant's appearance that narrow the possibilities when trying to identify the offending pest. Plant identification and the recognition of damage symptoms are the important first steps in the diagnostic process. For convenience, symptoms of insect damage can be grouped into five categories:

- Chewed or tattered foliage or blossoms.
- Stippled (flecked), yellowed, bleached or bronzed foliage.
- Distortion of plant parts.
- Dieback of plant parts.
- Presence of insect products.

Chewed or Tattered Foliage or Blossoms

The symptoms of chewed or tattered foliage or blossoms are, in most cases, caused by an insect that has chewing mouthparts. Thus, with these symptoms, one can normally dismiss from consideration the large group of pests with sucking or rasping mouthparts (where, except in unusual situations, the feeding of such insects does not result in tattered plant parts). The most important pests causing chewed or tattered foliage and blossoms are larvae (caterpillars) of moths, butterflies and sawflies; adult beetles; and grasshoppers.

Stippled (Flecked), Yellowed, Bleached or Bronzed Foliage

When a plant's foliage has this type of damage and no loss in the physical integrity of foliage surface is seen, the injury is caused by insects or mites with some form of sucking mouthparts. These symptoms often begin with stippling, or flecking, of leaves, resulting from the insertion of sucking mouthparts into the leaf. Plant sap is removed and chlorophyll is withdrawn or destroyed at the point of penetration. Tiny discolored (stippled) areas appear on affected foliage. With large numbers of attacking pests, these stippled areas coalesce, resulting in leaves that appear partly or mostly bleached, yellowed, bronzed or silvered. Pests that typically cause these symptoms are leafhoppers, plant bugs, lace bugs, aphids, mealybugs, psyllids and spider mites. Thrips have rasping mouthparts that the pest uses to rupture plant cells and then suck up released fluids. The resulting damage is similar to that caused by pests with true piercing-sucking mouthparts.

Distortion of Plant Parts

Plant distortion may appear as curled or cupped leaves, twisted growing points or galls (swellings or abnormal growths) of various types on leaves, flowers, twigs or stems. In many cases, the arthropod responsible may not be readily visible on the surface of the affected plant part. Pests associated with this type of damage/symptom are aphids, thrips, cynipid (gall) wasps, larvae of certain types of moths, and eriophyid mites (cause galls, blisters, bud distortion, etc.). Also, extensive feeding by thrips can cause distortion of leaves, buds and flowers.

Dieback of Plant Parts

Leaf, twig or branch dieback characterizes this category of symptoms. In a few cases, death of the entire plant may occur. Twigs and branches of deciduous plants that die during the growing season often retain dead leaves well into the subsequent dormant season, because the leaf abscission layer will not have been formed before the plant part died. Parts of non-deciduous plants that die at any time will retain dead leaves for long periods. When these symptoms are seen, the following pests are suspect: scale insects, larvae of boring beetles or moths, and cynipid (gall) wasps.

Presence of Insect Products

Some insects' products are evidence of their presence beyond that of plant injury. Many of these products remain intact for weeks (or months) after the pest has completed its activities. The most commonly seen products and the pests responsible for them are:

- Honeydew (and often black, sooty mold growing on the sugary material) – aphids, soft scales, mealybugs, psyllids and whiteflies.
- Dark fecal specks (droppings) – thrips, lace bugs or larger pieces of fecal matter (frass) left by larvae (caterpillars) of moths.
- Tents, webs, silken material – tent caterpillars, webworms, leafrollers/tiers and spider mites.
- Spittle (spit-like material) – spittlebugs.
- Cast skins (from molts or shedding of the exoskeleton during growth) – aphids, leafhoppers, lace bugs and spider mites.
- Cottony, waxy material (flocculence) – mealybugs, certain scale insects and certain aphids.
- Sawdust, wood chips and pitch balls or tubes (usually found on or below the host plant) – wood borers, shoot borers, bark beetles and larvae of certain moths (e.g., pitch masses at the entrance of pine tips/shoots from Nantucket pine tip moth larvae).

Sampling and Monitoring for Pests and Their Natural Enemies

Various methods have been devised to sample, or estimate the numbers of, arthropods on trees and shrubs. Many of these procedures were first developed for use in agricultural crops, but several have resulted from investigations on landscape ornamental pests. The objectives of sampling or monitoring are to detect the presence or absence of pests, quantify abundance of pests and their natural enemies and follow the progress of an arthropod population through time by regular, periodic sampling. The goal of monitoring is to reach a decision as to whether, or when, a pest population requires control action. All sampling procedures share certain characteristics:

- They use a common sampling unit, such as leaves, terminals, beats or minutes.
- The unit chosen must be consistent with the feeding habits of the pest population under observation. Do not select leaves as the sampling unit for scale insects that occur predominantly on twigs. Similarly, do not count aphids on the younger leaves if they occur mostly on the older leaves.
- The number of samples taken must be adequate. What is "adequate" must be determined on a case-by-case basis and by time and equipment constraints. Pests are seldom distributed uniformly over a tree or shrub. Similarly, every tree in a group of trees of that species will not be infested to the same degree. Generally, the number of samples

taken from each plant at each interval is held constant over the entire sampling period and over the entire group of plant samples.

- The sampling procedure must be standardized. It helps if the same person does all the samplings. If two or more persons are involved, they should check one another in a preliminary sampling exercise to determine that their sampling methods and results are the same.
- Written records of arthropod counts are kept by date, location and person sampling, with a brief description of procedures used.

Because some insects and mites are quite small, the person sampling or monitoring pests and their natural enemies should carry and use a 10X hand lens.

Methods of Sampling

Counting Insects on Plant Parts

Each sample is pruned or pinched from the plant and the number of arthropods present is counted immediately without magnification or under magnification using a hand lens. The number of samples taken from each plant usually ranges from five to 25.

Variations include estimating pest numbers in 10s or 100s, when counts are high, or taking more samples (around 100) and recording only whether pests are present or absent on each unit.

Counting insects on plant parts is effective for sampling aphids, spider mites and other arthropods that do not readily fly or drop from the plant when the sampling unit is removed. Sometimes only the immature insect stages are counted, if the adults fly readily when the sample is taken.

Time Counts

The person responsible for sampling counts the number of insects seen during a one- or two-minute visual search of the plant. Several such aimed searches are made in different parts of the same plant (if large). This procedure is useful for large insects, such as caterpillars, or for egg masses of insects on tree trunks or limbs. The plant is not damaged, and the insects counted are available for re-counting at the next scheduled sampling. Because it is difficult to count insects and keep track of time simultaneously, two persons are required for best results, unless an electronic alarm watch can replace the second person. The time-count is not a useful sampling method if the insect population is high because the insects can't be counted fast enough.

Beating Samples

A sampling tray is held horizontally just beneath plant foliage, and the foliage above is struck sharply a standard number of times (two to five) with a short stick or the other hand. Arthropods falling to the tray are immediately counted and then shaken off. This process is repeated several times around the periphery of the plant. An attempt is made to standardize the density of foliage beaten. The tray may be 1 square foot in surface area or as small as a 5- or 6-inch circle (pads of paper or plastic disposable pie plates have often been used).

The trap surface is usually white to contrast with the insects being counted. This procedure has been used to sample such pests as psyllids, certain aphids, plant bugs and spider mites.

Fecal Pellet Collections

Lepidopterous larvae, like catalpa caterpillars, oakworms and datanas, produce relatively large, solid, dark fecal pellets, most of which fall to the ground beneath the plant. Using three to five shallow pans, paper cups or sticky cards deployed beneath the foliage of infested trees, counts of pellets give an estimate of the larval population in the tree. The size of the individual pellets indicates whether the caterpillars are young or more mature. Collection traps are usually deployed for a 24-hour period each week. Traps are put out at times when no rain or sprinkler irrigation is expected within the 24-hour period.

Some tent-making and leaf-rolling caterpillars tend to deposit their fecal pellets such that few fall to the ground. The fecal trap method is not useful for estimating the number of these pests.

Attractant Traps

Devices containing synthetic or natural attractants and that physically trap the insects attracted to the device are useful for sampling several moth and beetle pests of ornamentals. They will trap only the mobile adult stage and, in the case of most sex pheromone traps, only the male of the species.

Sampling and Monitoring Natural Enemies

When sampling for pests, the person sampling should also look for:

- Predators, such as ladybird beetle adults and larvae, syrphid fly larvae, lacewing larvae and spiders.
- Evidence of parasitism, such as aphid "mummies," darkened greenhouse whitefly pupae and scale insects with exit holes of the parasites.
- Signs of insect diseases, such as blackened, dead caterpillars and dead, discolored aphids infected with fungi.

The impact of biological control can be estimated by counting the number of natural enemies per sampling unit, then calculating the ratio of affected pests to healthy ones. If signs of biological control are apparent, delay any insecticide treatment and sample again in a week for pests and natural enemies. If the natural enemy population is increasing faster than the pest population, consider no insecticide treatment. If natural enemies are still active but the ratio has increased in favor of the pest, and pest numbers or plant unsightliness are approaching unacceptable levels, then consider the following measures when an insecticide is applied:

- If possible, use a material that is selective to preserve natural enemies (e.g., *Bacillus thuringiensis* for caterpillars) or a material that is minimally disruptive to natural enemies (e.g., insecticidal soap, horticultural oil or systemic insecticides).
- If the use of selective or minimally disruptive materials is not possible, treat only the plants that are in immediate need of an application, leaving the untreated plants to serve as a reservoir for natural enemies.
- Various honeydew-producing insects, especially soft scales and aphids, are protected or guarded by ants, whose only interest is the honeydew food source. Ants interfere with parasite and predator activity. Therefore, the presence of ants on plants infested by honeydew-producing insects should suggest control of the ants by insecticidal treatment of the base of the plant only. This is another kind of selective use of an insecticide. Sticky bands may be used instead of insecticide treatment, e.g., for walnut datana and spring cankerworm adults.

Methods of Managing Pests

Management options for existent or threatening pests of ornamental plants are biological control, cultural control, physical (or mechanical) control and insecticidal control.

Biological Control

Every insect and mite pest has its complement of natural enemies (parasites and predators) that serve to reduce populations of the pest. Most natural enemies of landscape pests are native species, but others have been deliberately introduced, usually from foreign countries, and then released into the environment for biological control purposes. Biological control, then, is the use of parasites and predators to suppress pest species.

Except in a few situations, the arborist or other landscape manager is seldom in a position to introduce new parasites and predators into the environment in which he or she works. The greatest opportunity is to preserve those organisms that are already there. This is best accomplished by:

- Learning to recognize important natural enemies of pests commonly encountered.
- Avoiding the use of insecticides when a cultural or physical control measure would reduce pest numbers to an acceptable level.
- Using an insecticide that has a minimal effect on parasites or predators.

Cultural Control

Plant growth-related practices useful in preventing or mitigating pest damage include thinning rank vegetation, maintaining high plant vigor, judicious pruning and planting resistant species or cultivars.

Thin Rank Vegetation

Remove dead or dying vegetation to create a physical environment less favorable to certain soft scale insects. For example, observations indicate that populations of black scale will decline if greater air circulation and more sunlight are allowed to enter the interior parts of dense plantings of oleander. Part of the scale decline may be due to improved accessibility of natural enemies to the scales. It is likely that other soft scales are similarly affected and that vegetation control applies also to plants other than oleander.

Maintain High Plant Vigor

Bark beetles (family Scolytidae) of coniferous trees often attack trees in stress or in a reduced state of vigor caused by drought, root disease, root compaction, root damage done during construction, air pollution, a poor growing site or even old age. Several bark beetles of nonconiferous trees, such as the smaller European elm bark beetle in elm and the shothole borer in plants of the genus *Prunus* spp., similarly appear to preferentially attack weakened trees. Many flatheaded borers (family Buprestidae) and roundheaded borers (family Cerambycidae) prefer to attack weakened trees, as compared to apparently vigorous ones. Because control of most boring insects after they have infested plants is essentially impossible, preventing their attacks by using cultural practices that contribute to high plant vigor makes good sense.

In a few documented instances, high plant vigor actually has contributed to high pest levels. Most of these instances involve sap-sucking pests. For example, high populations of the oleander aphid can be prevented by reduced watering and pruning of plants. These practices discourage rank flushes of new growth preferred by the aphids. Yet, control of sucking pests is infinitely easier than control of established borers, and a strong case remains for the general principle of maintaining plants in good vigor.

Judicious Pruning

Prune trees judiciously at the proper time of the year to reduce attacks by certain boring insects. Conifers, in particular, are susceptible to attack by several species of borers after tree trunks have been injured.

To prune judiciously, avoid excess pruning, including topping, which results in poor balance between root and top growth, and avoid making flush pruning cuts. Conifers have often died from bark beetle attack soon after being excessively pruned.

For several boring insects, pruning (or otherwise opening wounds in tree trunks) during the late winter through spring and summer period has resulted in far more severe borer infestations than when pruning was done during the fall or early winter months. Adult borers are inactive in the fall and winter, and pruning at that time allows the tree to begin the wound closure process before adult activity resumes the following spring or summer. The application of wound dressing compounds is not a good alternative to judicious pruning at the proper time and in the proper manner.

Plant Resistant Trees and Shrubs

Pests do not attack equally every species and cultivar of all plants. Therefore, selecting and planting those least susceptible to pests, so long as they meet basic requirements of size, color and form, greatly reduces or negates the need for insecticide control of insect pests. The term resistant does not necessarily mean immune. Low numbers of pests often occur on resistant plants, but these levels would be considered insignificant under most circumstances.

Despite the huge benefits from using pest-resistant plants, this cultural practice has the following shortcomings and limitations:

- A plant resistant to an important arthropod pest may be susceptible to serious plant diseases or have other problems.
- If the landscape is already established, pest-resistant plants are of no use until new trees or shrubs are required.
- A plant that is resistant to an important pest today probably would not be resistant to a new pest entering the area at some later time.
- Eventually, some insect pests have shown an ability to adapt to resistant plants. These new strains or "races" of pests are called biotypes.
- If a little-used plant should become widely used because it has been found resistant to an important pest or for any reason, the chances are great that an increasing number of insects would become pests of that plant. The thornless honeylocust cultivars, when first developed, were advertised as pest-resistant. If they ever were, they are no longer.

You should become informed about pest-resistant and other low-maintenance plants by consulting with university researchers, attending seminars and workshops and reading various periodicals and other literature, looking specifically for information on resistant varieties that are adapted to Arkansas.

Physical (or Mechanical) Control

In some cases, a pest infestation may be controlled or averted by physical means. Examples follow:

Pruning

Prune off the tips of branches harboring colonies of caterpillars. Pruning branch tips when the larvae are young produces the best results. In the case of some tent-making caterpillars, the insects forage for foliage away from the tent on clear, warm days, but tend to return to the silken web before nightfall and remain there during cool, rainy weather. Therefore, the branch tip containing the caterpillar colony is best pruned off during inclement weather.

Larvae of the fall webworm feed from within the protection of their tent and build an increasingly larger tent, as more food is required for the colony. Their tents and colonies can be pruned from trees during any kind of weather, but results are best when the tents are small.

Some species of caterpillars that do not form tents tend to feed gregariously, especially when young. If caterpillars are found feeding together, the entire colony can be removed by pruning off the branch terminal on which it is feeding.

Control by pruning, however, is of limited use on tall trees or when infestations are large.

Reduce Infestations of Certain Boring Insects

Various scolytid bark beetles breed in stressed, dying or recently dead wood of conifers. Removing such wood from the vicinity of living conifers reduces the likelihood of living trees becoming infested. This action should be taken as soon as a potential breeding wood is detected, whether it is infested or not. The smaller European elm bark beetle (SEEBB), vector of the Dutch elm disease fungus, and the shothole borer similarly breed in declining or recently dead wood of elm and *Prunus* spp., respectively. Getting rid of such wood is recommended as a physical means of protecting nearby susceptible living trees. Burning, chipping or burying dead trees to a depth of 18 inches or more, or physically removing the tree to a distance of at least one-fourth mile are effective means of disposal.

Prompt removal of the bark of freshly cut wood, a difficult task, will effectively negate its use as a breeding place for just about all insects and will safely allow the wood to be kept as firewood. The bark that is removed need not be destroyed, because boring insects will not breed in it. Covering freshly cut wood (without first de-barking it) completely with a sheet of clear ultraviolet ray-resistant plastic negates the wood being used as a breeding place for boring insects. Spraying freshly cut wood with an insecticide, if such wood will later be used as firewood, is not recommended. More detailed information on the SEEBB and its association with Dutch elm disease is provided later with the discussion of bark beetles.

Insecticidal Control

When confronted with a serious pest infestation, the landscape manager often has no choice but to apply an insecticide. Most are applied as sprays, but a few are used as liquid soil drenches or trunk injections.

Spray Application Methods

Sprays may be applied either by hydraulic or mist blower machinery. With the hydraulic sprayer, the insecticide is diluted in water and delivered to the target tree or shrub by high pressure and volume through a hose and gun. Mist blowers deliver a more highly concentrated insecticide by means of a high volume, high velocity air stream. The insecticide is diluted largely in the air rather than in water. Mist blowing is most effective when there is no wind. Large mist blowers can treat tall trees rapidly and thoroughly, with practically no runoff and little drift, if there is no wind. Backpack models are often used on smaller trees and shrubs. Generally, emulsifiable concentrate formulations, if available, should be chosen for use in mist blowers because the abrasive characteristics of wettable powders eventually cause mechanical problems.

Systemic Insecticides

When systemic insecticides are applied to the roots, leaves or bark or injected into the vascular system, they are absorbed and translocated upward to kill insects feeding primarily on the foliage. When applied as sprays, they also kill insects by contact action. Acephate (Orthene), dimethoate (Cygon/Defend), and imidacloprid (Merit/Marathon) are examples of systemics. Advantages of systemics are relatively long residual life; protection of newly expanding foliage not present at the time of application; protection of plant parts such as growing points, which are difficult to physically penetrate with sprays; and reduced kill of beneficial insects.

Systemics will not kill all insects living in or on plants, however. Regardless of how the insecticide is applied, it moves rather quickly to, or remains in, the foliage. Many sucking pests, such as aphids and thrips, and certain insects that chew foliage can be easily controlled with the proper systemics. Systemics are not effective against most woodborers or bark-feeding scale insects, unless the proper material is applied as a spray that results in kill by contact action.

Trunk Injection of Systemic Insecticides

The Mauget and Acecap systems are sold commercially for injection and implantation, respectively, of systemics into the trunks of specific ornamental trees for insect control. Treatments are normally made in the growing season. In the Mauget system, feeder tubes are inserted into each hole. Then, a plastic unit containing a prefilled small amount of insecticide is tapped onto the free end of each feeder tube, breaking a seal that allows the liquid to enter the feeder tube and then the tree's vascular system. After the plastic units have emptied, they and the feeder tubes are removed. In the Acecap system, the entire small plastic unit containing a dry insecticide product is placed into each hole, seated just beneath the inner surface of the bark, and left there. Sap within the tree dissolves the insecticide and translocates it upward in the tree.

Insecticide injection has much to recommend it, if trees accept the systemic quickly and if the insecticide is effective against pests for which it was intended. This type treatment can be beneficial for control of pests on trees in difficult to treat locations, e.g., long, busy streets and in or around malls. The equipment required is simple and inexpensive, trees can be injected during weather unsuitable for spraying, insecticidal drift is avoided, and negative impact on beneficial insects is believed minimal. Yet, the possible chronic effects resulting from holes made in trees, which are required during the injection process, is not completely resolved, particularly for trees repeatedly treated.

Oils as Insecticides

Most oils available today as insecticides are termed superior-type horticultural oils, and are considered appropriate for use in the dormant season and in the growing (or verdant) season.

Oils are contact materials that kill certain insects and mites by intervening physically, rather than chemically, with respiratory processes. Research has shown that oils have essentially no residual life; that is, oils affect pests present at the time of application, but do not kill pests arriving after the application. Yet, there is some evidence that certain insects arriving soon after treatment may be repelled by the oil residue.

Depending on the pest involved, oils may kill the egg, larval, or adult stage. In the dormant season, oils have been useful against scale insects, mites, plant bugs, psyllids, and certain moths. Whether oils are used in the dormant or growing season, they should never be applied to trees or shrubs stressed by a soil moisture deficit. If used in the growing season, do not make application to plants pushing out the spring flush of growth, because tender foliage may be injured.

Some plants reportedly sensitive to oils include maple, hickory, walnut, and azalea. Those having a tendency toward sensitivity to oils include beech, Japanese holly, redbud, photinia, spruce, and Douglas fir. Oils will temporarily remove the glaucous bloom from such conifers as Colorado blue spruce.

Soaps as Insecticides

Several insecticidal soap products (such as Safer AgroChem's Insecticidal Soap and Acco Highway Spray) are available for landscape pest control during the growing season. They have some of the same characteristics as horticultural oils in that they kill principally by physical rather than chemical action. They also have essentially no residual life, meaning the application will have to be repeated if the target pest has a long period of activity during the growing season. Soaps have given good control of certain exposed pests, such as aphids, greenhouse thrips, spider mites, psyllids, and whiteflies.

Microbial Insecticides

Microbial insecticides are composed of microscopic living organisms (viruses, bacteria, fungi, protozoa or nematodes) or the toxins produced by these organisms. They are formulated to be applied as conventional insecticidal sprays, dusts or granules.

Microbial insecticides are an effective alternative for the control of many insect pests. Their greatest strength is their specificity, because most are essentially nontoxic and nonpathogenic to animals and humans. Although not every pest problem can be controlled by the use of a microbial insecticide, these products can be used successfully in place of more toxic insecticides to control some ornamental insects. Because most microbial insecticides are effective against only a narrow range of pests, and because these insecticides are vulnerable to rapid inactivation in the environment, users must properly identify target pests and plan the most effective application.

Insects and Mites That Are Damaging to Ornamentals

There are several kinds of insects and mites that you should recognize. They can be grouped as outlined previously in the section on diagnosing plant problems or as follows, according to the part of the plant on which they feed (leaves or shoots, twigs, trunks and roots) and the kind of injury they cause (chewing, rasping or sucking).

Note: See the seasonal appearance calendar at the end of this chapter. It lists ornamental and shade tree pest activity by month of average first occurrence.

Leaf Feeders – Chewing Injury

Deciduous trees and shrubs usually can tolerate considerable defoliation without affecting tree vigor. Generally, late season defoliation of deciduous trees and shrubs is less important than early season defoliation, because food necessary for growth has been produced and stored. However, late season defoliation of evergreens can be important. Evergreens can be seriously affected by heavy defoliation. This is because evergreens replace only a portion of their total complement of foliage each year. (Pines, for example, replace about one-third, and if the new needles are eaten, the tree will be missing about one-third of its needles for three consecutive years.) Also, evergreens usually use their leaves or needles to produce growth regulators (hormones) and to store food reserves for the next year. If these leaves or needles are destroyed, so are sites for growth regulator production and food storage. New foliage is the most efficient producer of photosynthate (plant food). If this foliage is lost to defoliators, the current year's food production can be reduced considerably.

The two most common types of leaf-chewing insects are caterpillars and leaf beetles.

Caterpillars

Caterpillars feed on the foliage of trees. Some form webs or tents on branches and some have more than one generation per year. Several important caterpillars in Arkansas are bagworm, mimosa webworm, fall webworm and cankerworm. **Note:** These pests can be controlled with bacterial products (*Bacillus thuringiensis*). Where environmental and personal safety are critical considerations, you might wish to consider B.t. products in lieu of "classical" synthetic insecticides in your control program.

Bagworms

Bagworms will attack and defoliate most evergreen and deciduous trees and shrubs, but prefer arborvitae, red cedar, juniper, bald cypress, several species of pine, and boxelder. Bagworms live inside a spindle-shaped bag which they construct while they are in the larval or caterpillar stage. The bags are dragged with the caterpillars wherever they go and are made of silk and bits of foliage. The front part of the larvae protrude from the bag for feeding movement. Full-grown larvae are three-fourths to one inch long, dark brown with white to yellowish heads and a black spotted thorax **(Figure 1.4.1)**.

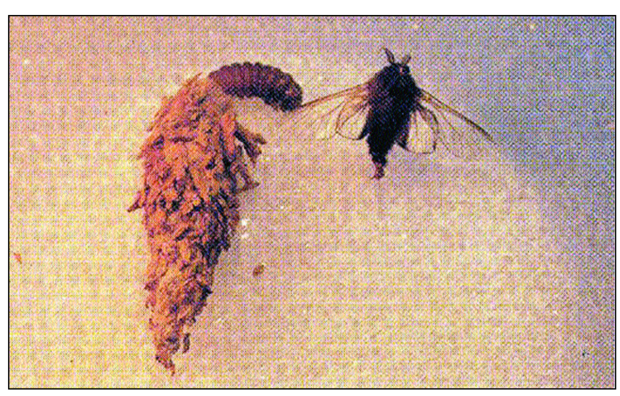


Figure 1.4.1. Bagworm larva and adult male.

Figure 1.4.2. Bagworm eggs.

Life History. Bagworms overwinter as eggs inside the bags of the females **(Figure 1.4.2)**. The eggs hatch in late spring (May to early June) and the larvae begin feeding and constructing their protective case. As the caterpillars grow in size, the bag is constantly enlarged. The larvae pupate in late summer and the males emerge from their bags as black moths with furry bodies, feathered antennae and clear wings with a wingspan of almost one inch. The female is a wingless moth that remains in a wormlike form and never leaves the bag. She is fertilized by the male, lays 500 to 1,000 eggs inside the bag and then dies. There is one generation per year.

Management. Light infestations, particularly on small shrubs and trees, can be effectively controlled by hand-picking all the bags from the infested plants and destroying the bags before the eggs hatch .

Half grown to nearly full-grown bagworm caterpillars can be difficult to kill with insecticide. The key to successful control with insecticide sprays is to spray when the bagworms are small (late May to mid-June, when their cases are a half inch or less in length). To be able to time sprays exactly so they will do the most good, collect a few bags before the eggs hatch in late May and place them outdoors in a fine-screen cage. When the newly hatched larvae are seen leaving the caged bags, it is time to spray. When collecting bags for this purpose, keep in mind that male bags will not have any eggs, so collect enough bags to ensure that at least some of them have eggs.

Mimosa Webworm

Mimosa webworm attacks honey locust and mimosa **(Figure 1.4.3)**. The many varieties of thornless and seedless honeylocust are subject to attack. Larvae are ravenous feeders, and they feed mainly on the upper surface of the leaflets but may feed on both leaf surfaces. The leaflets soon turn brown and die, leaving unsightly nests due to dead leaves and webbing scattered over the tree. Damage to the foliage develops rapidly. By mid-July and August, much of the foliage may be destroyed. Small trees may be completely defoliated. Mimosa webworms live inside irregularly shaped webs made of silk and webbed-together foliage. While in the larval stage, the webworms do not leave the webbing, unless disturbed or to draw more foliage into the web. The adult moth is silver-gray with black specks or dots on the wings. The wingspan is about one-half inch. Larvae are dark brown to green with five longitudinal white stripes. Full-grown larvae reach about one-half inch in length.

Figure 1.4.3. Mimosa webworm.

Life History. Mimosa webworm overwinters in the pupal stage inside a cocoon in the soil or other protected area. The moths emerge in May, mate and lay pearly gray eggs on leaves by late May or early June.

If feeding larvae are disturbed, they generally twist violently and frequently drop from the feeding site on a silken thread. The larvae reach maturity in early July, with a new generation occurring in July and August. There are three generations per year – the third occurring in September and October.

Management. The webbing of the larvae makes it difficult to get adequate penetration of the webs with insecticidal sprays. As a consequence, many control failures are reported. To be successful, insecticides must be thoroughly applied over the entire tree shortly after the eggs hatch and before the leaves are webbed together. Close examination of the trees is necessary to detect newly hatched larvae.

Insecticide control may be needed for each of the three generations of larvae. However, exact timing of sprays will depend on the locale within the state and the growing season.

Fall Webworm

The fall webworm is the larval stage of a moth that is responsible for unsightly webbing seen on shade and nut trees from mid-summer to fall **(Figure 1.4.4)**. These webs should not be confused with tent caterpillars, which appear on fruit trees in the spring. The larvae feed on the leaves of more than a hundred kinds of fruit, ornamental and woodland trees **(Figure 1.4.5)**. Favored trees in Arkansas include persimmon, pecan, English walnut, black walnut and hickory. Larvae confine their feeding to leaves they have covered with webbing. Larvae characteristically web only the outer ends of branches. One or more branches may be defoliated, often with no damage to the tree other than appearance.

Life History. The moth is satiny white and may have black or brown spots on the forewings. They have a wingspan measuring slightly over one inch. Moths emerge from overwintering pupae in late spring (late April to May) and lay clusters of up to 500 greenish eggs on leaf surfaces of host trees. The eggs are partly covered with white hairs or scales and usually occur on leaves near the ends of branches.

Figure 1.4.4. Fall webworm webs.

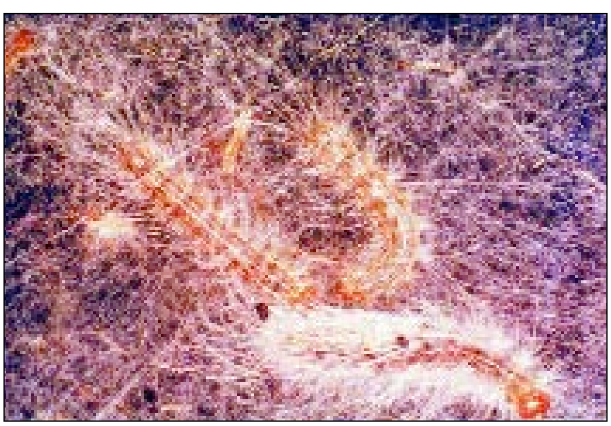


Figure 1.4.5. Fall webworm larva.

Depending on the weather, tiny larvae hatch from eggs in early June. Larvae immediately begin weaving their webbing over the leaves at the end of branches. The web is small at first but soon becomes large as the larvae extend the web to cover more leaves. Feeding is done entirely in the protection of the web. Only the tender portions of leaves are eaten, leaving the veins intact. As the larvae grow, the web becomes filled with dead leaves, cast skins and feces. The larvae are about one inch long when full-grown and are pale yellow with dark spots down the back. The body is covered with long, silky, gray-white hairs. When full grown, they crawl down the tree to spin a cocoon and pupate in the ground litter in July. There are two generations a year – the first in early June (into July) and the second and normally the largest and most damaging generation of larvae present in August and September (sometimes into early October), Larvae from the second generation remain in the pupal stage until the next spring, when the moths emerge to begin the cycle again.

Management. When pruning out webs is not practical, insecticidal sprays, including bacterial sprays, will give excellent control if sufficient pressure is used to penetrate webbing. Control will be most effective if treatment is made while the webs are still small.

Cankerworms

Cankerworms are known also as measuring worms, inchworms or loopers **(Figure 1.4.6)**. They attack early in the spring just as the leaves are beginning to appear, or they sometimes attack the buds before the leaves open.

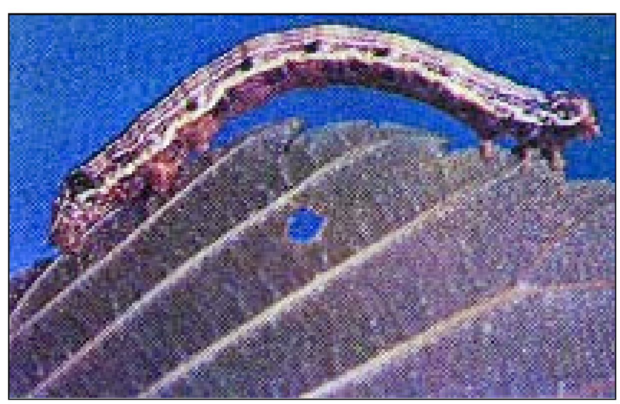


Figure 1.4.6. Cankerworm.

Life History. The spring cankerworm adult emerges in late February and March as winged male and wingless female moths.

The females crawl up the trunk of the tree to deposit eggs. Eggs hatch in April or early May and the larvae devour developing leaves for three to five weeks. Dispersal is accomplished when small caterpillars are blown from one tree to another. There is one generation per year. Defoliation is often not readily apparent, although trees may appear dead because they are late in leafing out. **Note:** Even if this pest causes virtual defoliation of new spring foliage, trees normally recover and "re-leaf."

Caterpillars first chew holes in leaves, then progress to eating the whole leaf as the larvae get bigger. Elms, hackberry, oaks and apple are favorite hosts. These caterpillars are often seen dangling from the foliage of infested trees on fine strands of silk (as from being dislodged by wind or disturbed foliage); however, the worms quickly climb the silk strands back up into the foliage.

Management. Applying bands of sticky material to the trunks of individual trees to catch the wingless females as they crawl upwards to lay their eggs is an old technique that can work. However, because large numbers of the small caterpillars are dispersed to other trees by the wind, the use of sticky bands works best when done on a community-wide basis.

Insecticides including bacterial (B.t.) products are effective in reducing damage to trees from this pest, if applied in April or early May to kill the newly hatched caterpillars.

Leaf Beetles

The most damaging leaf beetle in Arkansas is the elm leaf beetle **(Figure 1.4.7)**. The elm leaf beetle is an introduced pest from Europe that feeds only on elm. Although most elm species are subject to attack, the beetles usually prefer Siberian elm, *Ulmus pumila* (commonly called Chinese elm) and hybrid elms. The true Chinese elm, *U. parvifolia*, is seldom attacked, and the American elm, *U. americans*, seldom suffers any significant damage from this pest.

Elm leaf beetle feeding damage may result in partial or complete defoliation of the tree. Severely damaged/eaten leaves will turn brown and often drop prematurely. Sometimes the entire tree may be defoliated by mid-summer. Most of the damage is caused by the larvae as they feed on the lower side of the leaves. Trees

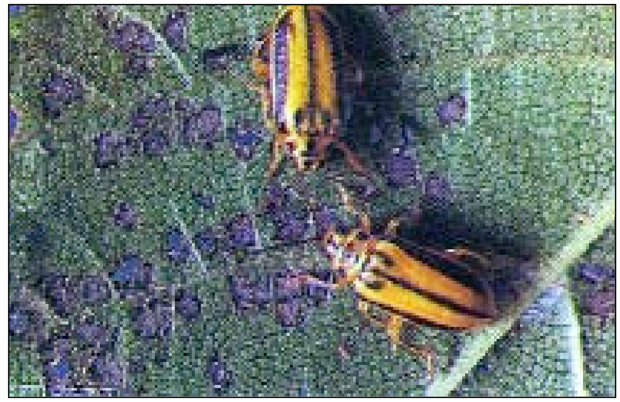


Figure 1.4.7. Elm leaf beetle adults.

that lose their leaves as a result of elm leaf beetle damage commonly put out a new flush of growth that may also be consumed by the insects on the tree or later generations of larvae.

Feeding damage by elm leaf beetles seldom kills an elm tree. However, severe feeding will weaken a tree, making it more susceptible to attack by other pests.

Life History. Elm leaf beetles overwinter as adult beetles in houses (where they are a nuisance), sheds and protected places out-of-doors (under loose bark or house shingles). Adults are about one-fourth inch long, yellow to olive green, with dark stripes along the outer edge of each wing cover. Adults emerge from their overwintering quarters during late April to early May, fly to nearby elms, mate and lay eggs. The adults eat small, circular holes in the expanding leaves. The orange-yellow, spindle-shaped eggs are laid on end in groups of five to 25, always in parallel rows on the underside of

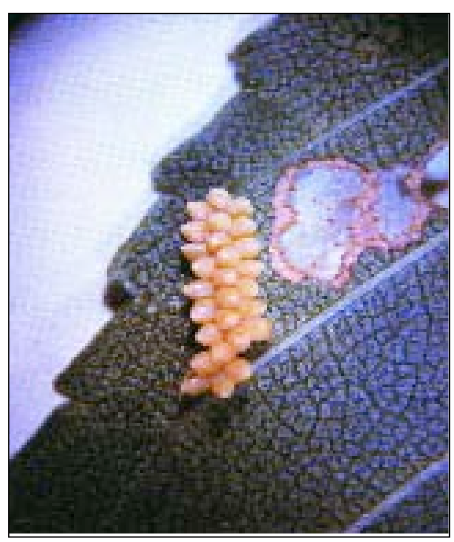


Figure 1.4.8. Elm leaf beetle eggs.

leaves **(Figure 1.4.8)**. A female will lay 600 to 800 eggs in her lifetime. Small black larvae feed on the undersurface of the leaves for about three weeks. Mature larvae are about one-half inch in length, dull yellow, with two black stripes down the back.

Larvae feed in groups, eating the undersides of the leaves, leaving only the upper leaf surface intact, resulting in a skeletonized appearance **(Figure 1.4.9)**. At the end of the feeding period (larval stage), the larvae move to the lower parts of the tree to pupate in cracks, crevices or crotches on the trunk or larger limbs. Adults emerge in about eight days and lay second-generation eggs. In Arkansas, there are three full generations and sometimes a partial or complete fourth generation of elm leaf beetles.

Figure 1.4.9. Elm leaf beetle larva.

Management. Spraying infested trees should be timed to kill the young first brood larvae in May. Other treatments will likely be needed as later generations of larvae appear. Rain within 24 hours of treatment may result in having to retreat the tree to ensure sufficient insecticide residue to kill larvae. Also, properly labeled systemic insecticides can be applied to the soil to control elm leaf beetles. (Check product labels for specific application procedures.) **Note:** New varieties/strains of *Bacillus thuringiensis* (var. *tenebrionsis*) are available for control of this pest.

Leaf Miners

Leaf miners are larvae of certain species of small flies, wasps, moths or beetles. They feed inside the leaf between the upper and lower surface. Damage appears as brown or discolored blotches or winding trails in leaves **(Figure 1.4.10)**. There may be more than one generation per year, depending on the species of mining insect. Leaf miners are difficult to control after they have entered leaves. A systemic insecticide will best reduce leaf miner numbers in hawthorn, birch, oak, holly and other infested plants. Treatment should be made when miners first appear in new foliage (in late spring or early summer).

Figure 1.4.10. Leaf miner damage.

Leaf Feeders – Sucking Injury

Aphids

Few plants exist, cultivated or wild, that are not hosts to one or more aphid species. Aphids, scale insects and the true plant bugs obtain their food by sucking the sap from plant tissue. Some species feed only on foliage, others on twigs, branches, flowers or fruit and still others on roots. Many live on several distinct hosts, spending part of their seasonal development on one host and the remainder on another.

Appearance and Damage – Aphids are small (seldom over 1/8 inch in length), soft-bodied, pear-shaped insects of many colors, such as green, black, gray or red. They usually can be distinguished from other insects by the presence of cornicles– a pair of “tail pipe” or tubelike structures projecting upward and backward from the upper surface of the abdomen. (One group of aphids, the most common member of which is the wooly apple aphid, does not have these structures). Cornicles may be long and narrow, short and broad or somewhere in between, depending upon the species.

Most aphids attack en masse, preferring young shoots or leaves. The feeding of large numbers of aphids can cause serious damage to plants by 1) robbing plants of sap, 2) the toxic action of their salivary secretions injected during feeding, and 3) serving as vectors of viruses which cause plant diseases. Aphid damage stunts growth, deforms leaves and fruit or causes galls on leaves, stems and roots.

Figure 1.4.11. Aphids.

Besides this damage, many aphid species excrete a sticky substance known as "honeydew." This material falls onto the leaves, twigs and fruit, and a black, sooty mold soon begins to grow in it. This mold not only mars the appearance of the plant, but also restricts certain physiological functions, such as photosynthesis. Honeydew attracts ants and flies and is a nuisance on cars, chairs, tables or other objects that happen to be under infested plants.

Biology of Aphids – Much variation is found in the biology of aphids; however, there are certain general biological facts that may be applied to the group as a whole. Aphids usually reproduce without mating and give birth to living young. Species of aphids are usually rather restricted to specific host plants, feeding on a group of more or less related plants. Some species have alternate hosts on which they are found at different seasons.

Aphids are frequently held in check by natural forces, primarily adverse weather conditions such as beating rains and high and low temperatures, fungus diseases, and naturally occurring insect predators and parasites.

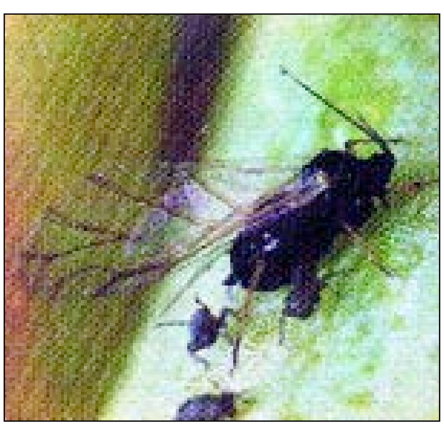


Figure 1.4.12. Winged Aphid.

The natural insect enemies of aphids are lady beetles, syrphid fly larvae, lacewing larvae and small wasp parasites known as Braconids.

Foliage-feeding Aphids – These aphids constitute a large group of small, soft-bodied insects frequently found in large numbers sucking sap from stems or leaves of plants. Such aphid groups often include individuals in all stages of development. This group contains a number of serious pests of cultivated plants. Many species affect particular plants (host specific), but a few can be found on many different types of plants. These aphids cause a curling or wilting of plant foliage, and they serve as vectors of a number of important plant diseases.

Wooly Aphids – Aphids in this group vary in color from shades of brown to purple. However, they all have in common a white, wooly, waxlike covering. Generally, the cornicles are reduced or absent, the sexual forms lack mouthparts and the fertile female produces only one egg.

Nearly all members of this group of aphids alternate between host plants, with the primary host (on which the overwintering eggs are laid) usually being a tree or shrub and the secondary host an herbaceous plant. These aphids may feed either on the roots of the host plant or on the part of the plant above ground.

Damage resulting from their feeding is characterized by prematurely opened leaf buds, distorted leaf edges curled or rolled in a gall-like manner, "clustered" leaves or enlarged or knotty growth on twigs and branches.

Managing Aphid – Beneficial insects play an extremely important role in natural aphid control. Frequent inspections will acquaint the observer with the presence of beneficial insects, their relative population level, efficiency in reducing aphid numbers and degree of parasitization. Insecticide applications for aphid control destroy beneficial insects as well as pests, leaving trees or shrubs unprotected if aphid resurgence occurs. Where practical, try washing aphids off with a forcible stream of water rather than using insecticidal sprays. (Apply water or insecticides during early morning or late afternoon to avoid sunscald of foliage or other tender plant parts.) When aphid populations are large and causing damage as previously noted, insecticides may be needed.

Spider Mites

Several species of mites attack trees and shrubs and cause the plants to become an off-green color as a result of these sap-sucking pests. Severely infested plants lose their vigor, become unsightly, and may even be killed. Mites are close relatives of insects, but mites differ in that they only have two body regions, no antennae and the adults have eight legs.

Two-spotted Spider Mites – This mite is perhaps the best known of the mite species and is often called the common red spider mite. It feeds on the lower surface of leaves on deciduous trees and shrubs. The mites suck sap from the foliage. Infested leaves become stippled with gray and may be covered with strands of silken webs.

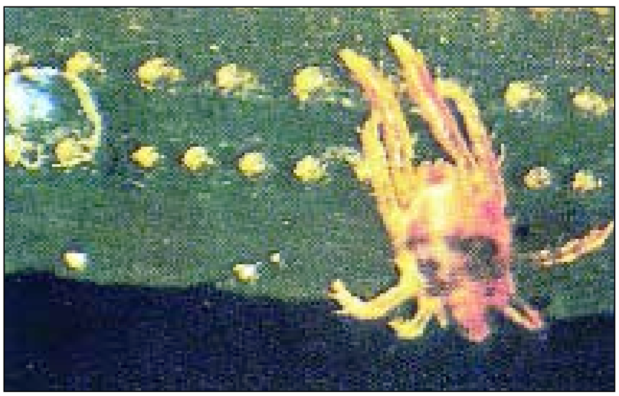


Figure 1.4.13. Spider mites.

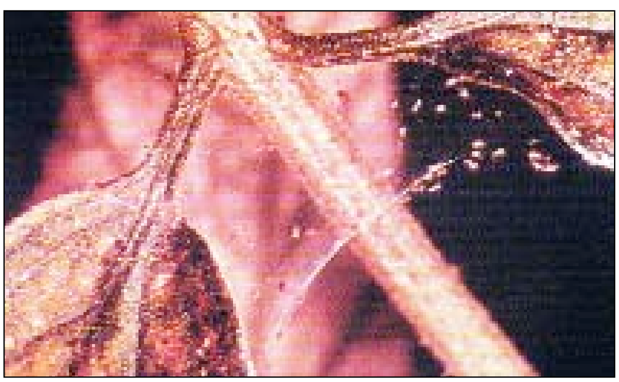


Figure 1.4.14. Spider mite webbing.

Two-spotted spider mites overwinter as adults in protected places (soil, debris, etc.). The overwintering mites are bright orange, whereas the summer forms are usually cream to green color with two dark spots on their backs. Females deposit eggs on the lower surface of the leaves. The length of the spider mite life cycle varies greatly, but in warm weather it may require only two weeks from egg to adult. This is why a mite population may build up rapidly.

Checking for Mites – If plant foliage begins to become an off-green color and mites are suspected, one way to determine if mites are present is to make a foliage check. This is done by holding a piece of white paper under a branch suspected to have mites and striking the branch hard against the paper. The mites are only about 1/50 of an inch in diameter. That's why they may not be seen on the plant foliage. If 10 mites or more are seen at each site, management procedures need to be considered.

Management – In general, cool, humid and rainy weather will hold mite development and numbers down to nondamaging levels so that no control measures are needed. Hot, dry weather is ideal for development. Certain mite predators feed on the destructive mites and, when abundant, they keep the population in check.

If natural controls fail to reduce mite populations below damaging levels, miticide (acaricide) sprays will likely be needed. One should consider rotation of products (pesticide classes) to reduce the chance of pesticide resistance developing in the mite population.

Lace Bugs

Lace bugs are small, broad, flat insects with clear, lacelike wings **(Figure 1.4.15).** Eggs, nymphs and adults all may be on a plant at the same time. Both adults and nymphs suck sap and cause leaves to be off-colored, speckled and yellowed and to drop. Many small, black, varnish-like spots of excrement on the underside of leaves are evidence of lace bug infestation. Lace bugs are common on pyracantha, hawthorn, quince, sycamore, oak and American elm. Control should be considered when infestations are causing obvious damage.

Figure 1.4.15. Lace bugs.

Plant Galls

Plant galls, abnormal tumorlike plant growths, are quite abundant in both rural and urban areas. They attract attention because of their unusual shapes and colors and because many homeowners prefer damage-free ornamentals in their yards.

Large numbers of galls can appear one year and few the next, or galls may be abundant year after year on the same plant. The abundance of galls is related to the abundance of the insect or mite causing the gall. Unfortunately, there is not enough knowledge about most gall-forming organisms to predict their abundance.

How Galls Are Formed – The young of insects or mites initiate the formation of most galls through their feeding activity. Certain chemicals produced by these young cause the living plant cells to increase rapidly in size or numbers. The exact mechanism for gall formation is not fully understood, but it is most remarkable that galls produced on specific plants by a given insect or mite are similar in shape and size year after year.

Species of aphids, midges, wasps and psyllids are the main insects that form galls. Eriophyid mites are also prominent gall formers. In addition, some galls are produced on plants by nematodes, fungi, bacteria and viruses. With most insect-caused galls, you should be able to see the insect(s) inside galls that are cut open.

Leaf galls can appear as curling of leaf margins, shriveling of the leaf or wartlike growths on leaf blades or petioles. These wartlike growths may be smooth, spiny or velvety.

Bud galls deform buds in various ways. Flower structures may be altered to look like spines, leaves or shapeless masses. Such growths can be numerous enough to destroy the aesthetic value of a tree.

How Injurious Are Galls? Galls are rarely abundant enough to seriously affect the normal growth of most plants. However, bud galls on conifers can lead to deformed growth of the tree, and occasionally twig galls can kill affected twigs.

In young trees, large numbers of galls can reduce growth. Control of the causal organism may then be necessary. On mature trees, however, leaf gall control is rarely justified.

Management – For plants such as roses, galls can be pruned out when they are discovered. Gall material should be removed from the premises so that reinfestation is less likely to occur. The same is also true for leaf galls. Removing the leaves in the fall also can help reduce the numbers of gall-forming organisms. However, by the time many galls are seen, the insect or mite has left the gall and will not be back until next year.

Some simple procedures are necessary when considering using pesticide controls (including oils). The insect or mite causing the gall must be vulnerable. Once the gall is formed, insecticides will not control the pest. Insects or mites which affect new plant growth require treatment just before bud development begins. Late applications have minimal value, although they may slow the development of additional galls. Some reduction in gall formations can normally be achieved if treatments are applied in the spring (e.g., at bud swell, a second application when leaves are one-fourth grown and a third treatment when leaves are one-half to three-quarters grown).

Common Galls

Hackberry Nipple Gall – A small, mottled, jumping plant louse (or psyllid) is responsible for this gall. The adult lays its eggs on the developing leaf buds or the undersides of the leaves. As soon as the egg hatches, the resulting nymph begins to feed, thus initiating the development of this gall. Mature psyllids emerge from the various galls at about the same time. These are sometimes enormous in number. Their small size permits them to go through 14-mesh window screen where, because of their abundance, they cause concern to homeowners. The galls do not harm the tree. Fine mesh screens will keep them from entering houses.

Petiole Gall of Poplar – Aphids feeding at the base of the newly developing leaf cause the leaf stem to fold back on itself, forming a closed cup. If the cup is opened during the summer, a large number of aphids are usually observed. A poplar or cottonwood tree may lose a few leaves from this gall but is not otherwise affected. No control is suggested.

Oak Galls – A variety of oak galls on the leaf blade, petiole and twigs are formed by flies, mites and tiny wasps. They vary in size, shape and color. Most are harmless, but they can occasionally make a tree unsightly. A few, such as the fly-caused veinpocket gall, may distort the foliage to such an extent that, from a distance, the tree appears to be suffering from herbicide injury. Two other common galls caused by flies are the midrib and marginal fold galls. The succulent oak gall, one of the most common galls on pin oak in Arkansas, is caused by a tiny wasp and appears as green, grapelike galls. The previous comments on galls can be applied to oak galls **(Figures 1.4.16 and 1.4.17)**.

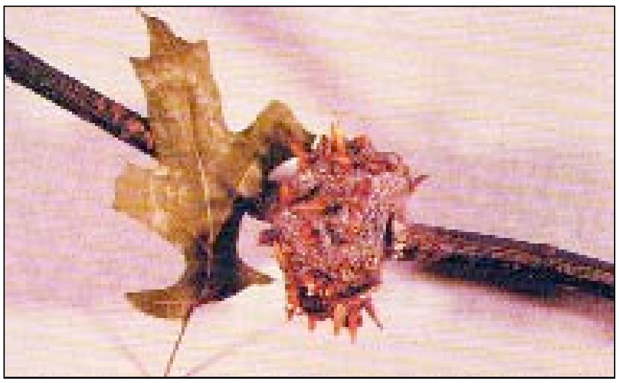


Figure 1.4.16. Horned oak gall.

Figure 1.4.17. Oak gall.

Shoot, Twig, Trunk and Root Feeders – Chewing Injury

Many kinds of insects attack ornamental plants and shade trees, but the woodborers are among the most injurious. Damage by these insects is often overlooked during summer months because the immature borers (larvae) feed in tunnels constructed in twigs, shoots, branches or trunks. Generally, plants lacking vigor are more susceptible to borer attack than are vigorous, healthy trees and shrubs. **Note:** Pheromone traps (male attractants) are available for monitoring the activity of some borer species. You may wish to consider integrating trapping into your IPM programs as a predictive "tool" to assist with proper timing of control efforts.

Borers can be classified in several ways; however, it is more convenient to list them by family groups, rather than by parts of the host plant attacked or by emergence periods. There are two groups of boring insects: beetles and moths.

Wood Borers – Beetles

The true beetles that attack woody tissues can be extremely injurious. Members are easily recognized because the adult insect body is hard and the wing covers meet in a straight line down the middle of the back. Two families of woodborers will be discussed: flatheaded woodborers and roundheaded woodborers.

Flatheaded Wood Borers

Adults of the flatheaded woodborers generally are brightly metallic colored, boat shaped and one-third to one inch long. Adults are commonly called metallic wood-boring beetles because of their color **(Figure 1.4.18).** These borers are destructive to newly transplanted trees.

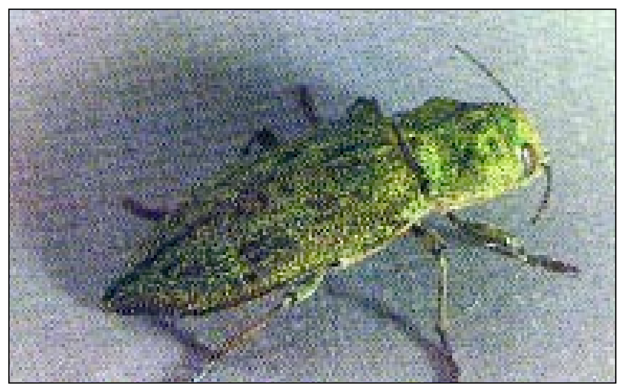


Figure 1.4.18. Metallic wood-boring beetle.

The larvae or grubs are one-half to two inches long, yellowish white, legless and have a pronounced flattened enlargement just behind the head. This enlargement bears a hard plate on both the upper and lower sides.

Adult beetles emerge from host trees in the early spring and summer months and lay eggs near cracks and wounds in the tree bark. The larvae hatch from the eggs and bore first beneath the bark and then enter the sapwood. Their tunnels are packed with borings arranged in concentric layers, so that arclike bands appear when the galleries are exposed. Most species complete their life cycle in one year, while others may require two to three years. The flatheaded appletree borer is a common flatheaded woodborer in Arkansas.

Flatheaded Appletree Borer. This flatheaded woodborer attacks newly transplanted trees. Hard and soft maple, apple, sycamore, oak, hickory, pecan, linden, poplar and willow are preferred hosts, but several other species may be attacked. Newly planted trees, those that have been pruned to expose the trunk to sun, and weakened trees are the most susceptible to borer infestations. A single larva may girdle a small tree. Larvae are about one inch long at maturity. They overwinter as mature larvae, and adults emerge in May, June and July. Eggs are deposited in crevices of the bark during June and July. Hatching extends over several months so that all stages of larval development may be observed on a single tree. There is one generation per year. An effective method of protection is to wrap the trunks of newly planted or pruned trees with a good grade of wrapping paper or newspaper. Apply the paper to give continuous coverage from the ground to the first branches.

Insecticides can be applied on the trunks in May, June and July to kill newly hatched larvae.

Roundheaded Wood Borers

Adult beetles are cylindrical, hard-shelled and sometimes colored in contrasting bands, spots or stripes. Adult beetles are commonly referred to as longhorned beetles because their antennae are usually at least half as long as the body **(Figure 1.4.19)**. In some species, it is nearly one and a half times as long. The larval stages of the beetle have no legs, are white to yellowish in color and are fleshy and rather round-bodied.

Figure 1.4.19. Longhorned beetle.

Adult beetles emerge from infested trees from late spring to early fall. Mated females then seek egg-laying sites, often under bark scales, in crevices or in tree wounds. Some of the longhorned beetles cut elliptical niches in the inner bark to lay eggs. After hatching, the larvae of some species may feed beneath the bark prior to entering the wood. Other species remain under the bark. Life cycles of the different species vary from one to four years. An example is the cottonwood borer.

Cottonwood Borer. This longhorned woodborer will attack cottonwood and other poplars. The adult is large, about one and a half inches long, with a black and white patch and cross stripe design. Eggs are laid in the tree trunk at the soil surface in July to August. Larvae live for two years in the trees. They bore both beneath the bark and into the wood and exude considerable frass. Larvae may completely girdle the bases of trees, cutting off sap movement and killing the trees. Lombardy poplars may be damaged so severely that they break off near the soil surface. Barriers constructed of wrapping paper or burlap and placed around the bases of young trees will help prevent oviposition. Such barriers are needed for several years. All factors that promote good growing conditions will help in reducing losses from borers. Borers can often be cut out of their tunnels with a pocketknife if done in early September of the first season of attack.

Insecticidal control is based on preventing attacks. Spray the lower trunk and saturate the soil around the tree base with insecticides in July and/or early August.

Borers Associated With the Pinewood Nematode

There are several species of longhorned woodborers in the genus *Monochamus* which attack and breed in various conifers. The larvae (roundheaded woodborers) are commonly known as sawyers or pine sawyers. The name sawyer has been used to describe the larvae because they frequently make loud noises while they are feeding.

The adults and larvae are most commonly associated with or infest freshly cut, felled, stressed, dying or recently dead trees. Young larvae feed on the inner bark, cambium and outer sapwood, forming shallow excavations (surface galleries). These galleries are filled with coarse fibrous borings (saw dust) and frass. As they grow older, growing larger with each larval molt, they start to bore back toward the surface, thus forming a U-shaped tunnel. After the last stage of larval development, they form a pupal cell at the outer end of the tunnel near the surface of the wood. After pupation, the adult emerges by chewing a hole through the remaining wood and bark.

Pine sawyers (*Monochamus* spp.) are secondary invaders that lay eggs in conifers that are declining as a result of any kind of stress. The pine sawyers are nondiapausing insects and do not have a synchronized emergence. Thus, there can be larval feeding and adult emergence during warm periods year-round. Research in Missouri indicates that the beetles average two and a half generations per year. Thus, during any warm period, some of the population that is in the pupal stage (or ready to pupate) can emerge as adults. During midsummer, it is estimated that the beetles complete a life cycle (egg to adult beetle) in 50 to 60 days. The majority of the adults emerge and are active from May through late September, However, since there is staggered emergence during this period (nonsynchronized emergence), all life stages can be present over the summer, and during warm periods in the winter some adults may emerge. For this reason, it is virtually impossible to ensure control or limit spread of these beetles by pesticidal means.

The emerging adults exhibit two behaviors: visiting healthy pines and feeding on the bark and/or visiting stressed/dying trees and feeding, mating and laying eggs in small cavities the females chew in the bark.

Association with Pine Wilt Disease

Pinewood nematodes (pine wilt disease) have caused the decline and death of numerous pines in Arkansas and throughout much of the rest of the U.S. The disease is unique in its complexity, since it involves a plant-parasitic nematode, one or more insect vectors (primarily pine sawyers), wood-staining fungi and possible other organisms. The most serious problems are occurring in introduced species of pine (nonindigenous species, e.g., Scotch, mugho and Virginia). It is believed that native species of pines have defense mechanisms that provide them protection from the pinewood nematodes, such that even if they become infected, they are not as seriously affected.

The adult beetles that emerge from pinewood nematode-infected pines usually pick up some of the nematodes on their bodies (body hairs, legs and antennae), and many of the nematodes enter the beetles' respiratory openings (or enter the spiracles and are thus carried in the tracheal system). The infested pine sawyers that visit healthy trees to feed on bark can introduce nematodes into the feeding wounds, thus infecting the pine (and introducing pine wilt disease). In this type of introduction, it usually takes one month or longer for the nematode population to feed and reproduce such that the tree expresses symptoms or shows signs of decline.

Pine sawyers that are attracted to stressed or dying pines both feed and lay eggs in the bark. This provides two entry paths for nematodes that may be on or in the beetles' bodies. Experience has shown that these pines usually have already been infested by other woodborers or bark beetles that have introduced fungal diseases (such as blue stain), and this provides an excellent early food source for newly introduced pinewood nematodes.

Observations in Missouri have been that trees 12 feet or more in height (or 12 to 15 years old) are most commonly infected with pinewood nematodes or show signs of pine wilt disease. Indications are that the disease is far more common or readily expressed in the fall following a drier than normal summer.

Most of the pine wilt disease problems are reported in landscape pines rather than in plantation or nursery plantings. It is likely the large pine plantings are subjected to less stress by extensive cultural/pesticide maintenance, and they are normally younger than those pines in landscapes that are typically infected with the nematodes.

Positive identification of pine wilt disease can be made by submitting large sections from recently killed pines suspected of being infected. Sections placed in plastic bags can be submitted to the Arkansas Plant Disease Diagnostic Clinic for pinewood nematode extraction and identification. Most of the diseased trees have been Scotch, Japanese red, Japanese black and Austrian pines.

Unfortunately, there is no effective control for the nematodes that are in infected pines. As previously noted, insecticide control of the vectors (the pine sawyers) is not very feasible because of the possibility for almost year-round emergence of adults during warm periods. Products labeled for "borer" control can provide some protection to landscape pines. The sprays would have to be applied preventatively to otherwise healthy pines from May through late September at about 30-day intervals. These applications can be of some help in killing the pine sawyers that occasionally visit healthy trees to feed on the bark. The only suggestion for pines showing rapid decline and for dead trees is to remove and destroy them by burning. This will kill beetle larvae and pupae in the infected trees before they can emerge and spread the nematodes to other pines.

Wood Borers That as Adults Are Moths

Moths are most readily recognized by the powdery scales on the wings and by their long, coiled mouthparts. This order of insects contains a number of injurious borers which are not as easily recognized as the beetles. Only the caterpillar stage is destructive. One family of this order will be discussed – clearwinged moths. These insects are more likely to attack healthy trees and shrubs.

Clearwinged Moths – Members of this family are known as clearwinged moths because the greater parts of one or both pairs of wings are without scales, thus leaving them clear or transparent. Many species bear a striking resemblance to bees or wasps. (However, the moths do not have pinched/constricted waists like most wasps.) Also, unlike most moths, they are active during daylight hours. The larvae are ivory white and usually have a light brown head. They bore into roots, trunks or branches of trees and shrubs, vines or the stems and roots of herbaceous plants. One member of this group is the lilac borer/ash borer.

Lilac Borer – This is a very destructive borer on ash. Look for boreholes in rough canker-like areas on stems. Moist sawdust oozing from these holes indicates active feeding. Eggs are laid on rough bark near scars or wounds in May or early June. Larvae bore into the stems during the summer and overwinter there. Insecticides applied on tree trunks in May and June help control adult lilac borers and newly hatched larvae.

Signs of Borer Activity. Look for sawdust-like material at the base of the plant. This material comes from the tunnel made by the borer. If sawdust is present, look for small punctures in the branches and trunk. Generally, there is a discharge of sap from the tunnel opening which wets and discolors the bark below it.

Borer damage should not be confused with woodpecker damage. Woodpeckers make small V-shaped impact holes. There is no tunnel and the holes do not bend, turn or "go anywhere." The yellowbellied sapsucker, a type of woodpecker, makes a series of such horizontal marks and, upon superficial examination, may give the "shot hole" appearance of some borer damage.

Borer holes are round or oval and generally turn and go through the inner bark and cambium area beneath the outer bark. Some borers tunnel into sapwood or heartwood. Probing the hole helps to determine if there is a tunnel.

Reducing Borer Attack. Because borers are not usually recognized until extensive damage is complete, it is necessary to implement tree management practices that aid in reducing borer attack. These practices include:

- *Water and Fertilizer.* Be sure trees have plenty of water throughout the season, especially during drought periods. Also, have the soil analyzed and apply the correct kind and amount of fertilizer.
- *Pruning.* With established or newly transplanted trees, remove and destroy only dead and dying wood.
- *Mowing.* When mowing lawns, do not injure roots or other parts of the plant at ground level.
- *Plant Selection.* Select trees and shrubs that are suited to the local climate and not as susceptible to borer attack. Ash, cottonwood, poplar, linden and soft maple are especially susceptible to borer attack.
- *Wrapping.* Wrap trunks of young or transplanted trees with wrapping material to prevent egg laying by adult borers. Wrapping may also aid in preventing sunscald and mechanical damage.
- *Management in Infested Trees.* Once borers have entered the wood of a tree, control is extremely difficult. There is no quick or easy way of controlling established infestations; however, the following methods can be helpful:
  - Where only a few trees are involved, borers often can be controlled by hand worming. Locate and clean out borer tunnels with a sharp knife or wire probe. Remember, when borers are deeply established, even the wire probe is

ineffective because deep tunnels often are plugged with wood shavings.
– In situations where oviposition and hatch can be accurately determined, conventional sprays with insecticides may be of value. **Note:** Systemic insecticides (soil or foliar applied) have not been very successful in controlling borers already active in woody tissue.

Shoot Borers

Insects in this category feed on the surface or inside of shoots, causing shoot malformations and death. Moths and beetles cause most of the damage. The pine tip moth is the most serious borer in Arkansas.

Pine Tip Moths

The Nantucket is the primary damaging species in Arkansas **(Figure 1.4.20)**. Pine tip moths destroy new growth of pines. The damage often deforms small, young trees up to 15 feet tall, slowing their growth and detracting from their normal symmetrical form. In some cases, repeated attacks can cause trees to die. Most species of two- and three-needle pines are subject to attack, except slash, Austrian and long leaf pines, which generally suffer no significant damage. Young pines growing in full sunlight have a tendency to be most heavily infested.

Life History. The moth overwinters as a pupa in terminal buds or just under the bark near the tips of other infested shoots. Emergence of first generation adults begins early in March and is completed by late April.

Figure 1.4.20. Pine tip moth damage.

Figure 1.4.21. Pine tip moth larva.

Figure 1.4.22. Pine tip moth adult.

Larvae that develop from the overwintering generation usually enter pine shoots during April **(Figure 1.4.21).**

The adult is a small gray moth with patches of reddish brown or copper on the forewings and buff hind wings. Wingspread is about one inch. It remains concealed among needle fascicles where it is well camouflaged by similar coloration. It is a weak flier, flying only short distances from tree to tree during evening hours. In daylight it flies only when disturbed **(Figure 1.4.22).**

Mating takes place soon after emergence, and the female begins to lay eggs during the evening the second day after emergence. Some eggs are laid on the buds and twigs, but most are laid on needles. An adult moth lives about eight days; each female lays about 25 eggs.

The egg is small, yellow and usually found on the upper surface of the needle about one inch above the base. Emergence from the egg begins in seven to eight days. An emerged larva is cream colored, but gradually turns light brown or orange. The head is dark brown to black.

Immediately upon emerging, the small first-instar caterpillar burrows into the needle. It continues to mine toward the base of the needle, where it tunnels to the outside and spins a web around itself and the needle fascicle. The larvae then continues to chew its way toward the terminal of the shoot, sometimes feeding only on the fascicles of needles but at other times on materials just under the bark of the twig. Larvae per infested shoot vary from one to ten. In most years, there are four generations in Arkansas.

Larval feeding causes the needles to yellow and infested shoots to die. New branches then develop diffusely from live buds below, resulting in poorly shaped trees with multiple leaders.

Larvae will leave the shoot and tunnel into a bud when one is present. Otherwise, they will pupate in the burrow in the shoot. Occasionally, a larva will accept a needle fascicle as a substitute for a bud and partially tunnel into it before pupating. Where larvae leave the shoot, they spin a web between the needles and the bud or the fascicle. All are soon covered with resin that oozes from the injured bud or shoot and hardens into a solid white mass.

Pupation takes about 10 days (resulting in a naked, dark brown pupa).

Survey Methods. In certain cases, sprays are the most practical means of controlling the pine tip moth. Since sprays are most effective when properly timed, you need to know when adults are active. The simplest method is the use of pheromone traps. **Note:** Sex pheromones are chemical substances that adult insects secrete to lure members of the opposite sex. The pheromone traps contain an artificial sex attractant that lures male moths inside the trap. The traps are placed among or near the pine trees and checked every day or two for moths that stick to an adhesive material inside the trap. Peak emergence can occur from 3 to 6 weeks after the first moth is collected in early spring.

If populations are very large, one trap for every 2 acres is sufficient. More traps are suggested when smaller numbers of moths are encountered. Depending on temperature, most pheromones (lures) will remain effective for 4 to 6 weeks. Traps are not control methods for pine tip moths. It would take several hundred traps per acre to provide any chance of reducing the moth population, and this would not be economically feasible.

In Arkansas, pheromone traps should be in place by March 1. Moths of the overwintering generation begin emerging sometime during March in most locations during most years. However, moths can sometimes emerge in late February in southern Arkansas.

Management. The most effective method of management in most situations is provided by systemic insecticides. Research has shown labeled granules applied per label directions to the soil around each tree in November are very effective. This application usually provides good protection from the first generation larvae.

The best chance of protection by use of sprays is with a treatment program from late March through early August. Treatments can be applied at about 20-day intervals from late March through the end of June. Following this, monthly treatments in late July and late August should provide protection from later generations.

Sprays are effective only against adults and newly hatched larvae; therefore, control can be improved by treating at the proper time.

Sprays should be timed in accordance with peak emergence of adult moths so maximum control of young larvae is achieved before they penetrate tree shoots. Generally, sprays should be applied 10 days after an emergence peak has been identified. However, grower experience suggests that this 10-day lag should be reduced in later generations as temperatures decrease the time needed for egg hatch – 4 to 5 days after peak emergence in June and 2 to 3 days in August. Retreatment may be necessary if heavy rainfall occurs within a week of a timed treatment.

Bark Beetles

Bark beetles are so named because most of them live and mine between the bark and wood of trees and shrubs. (These cause the scars or sculptured runs or tunnels one sees if the bark is peeled off.)

Adult beetles lay their eggs in tunnels that they make between the bark and wood. After the eggs hatch, the larvae mine the area, making runs that radiate out from the egg tunnels. Larval tunnels are always packed with their feces.

Extensive tunneling of this kind can girdle stems, branches or the trunk and thus kill parts of or the entire tree or shrub. When adults bore out through the bark, they leave the surface as though riddled by buckshot (thus sometimes referred to as "shot holes"). Adults are small cylindrical beetles, reddish to dark brown or black, from one-sixteenth to one-fourth inch long. The larvae are grub-like, thick-bodied, legless, generally broadly C-shaped, white or cream colored and have a distinct head. Adult egg laying habits and life cycles vary extensively with the different species.

In Arkansas, one of the most destructive bark beetles is the smaller European elm bark beetle that transmits Dutch elm disease to American elms.

Smaller European Elm Bark Beetles – Smaller European elm bark beetles (SEEBB) first entered the United States in 1909. Since that time, it has become widespread and is now the most important carrier of Dutch elm disease.

This beetle is about one-eighth inch long **(Figure 1.4.23).** A concave area is at the rear of the abdomen, and a noticeable projection points toward the rear. The female lays her eggs in niches in the side of simple, unforked egg tunnels under the bark of dead or recently cut elm wood. The egg tunnels run with the grain of the wood. After the eggs hatch, the larvae bore small tunnels around the trunk or branch and away from the centrally located egg tunnel (thus the larvae feed across the grain).

Figure 1.4.23. Smaller European elm bark borer.

Adult beetles emerge in late April or May, fly to healthy trees and feed in crotches of the twigs. It is during this time, if they emerged from the bark of diseased trees or wood, that they can introduce the fungus spores from their bodies into healthy trees.

Beetles emerge from under the bark of dead or dying elms in the spring and move to and feed on tender bark in twig crotches. Feeding injuries are most numerous in twig crotches near the outside crown of the tree. The beetles that emerge from late April to the first of July (overwintering and first generation adults) are the ones most likely to vector the disease to healthy elm trees. At this time, the long vessels of the elm's springwood are open and functioning. Feeding beetles will cut into these vessels, and they can introduce Dutch elm disease spores. The vessels that are produced later in the year are shorter, and the movement of materials throughout the tree will be slower. Dutch elm disease transmission is most likely if beetles feed in one-year-old or older twig crotches in spring or early summer **(Figure 1.4.24).**

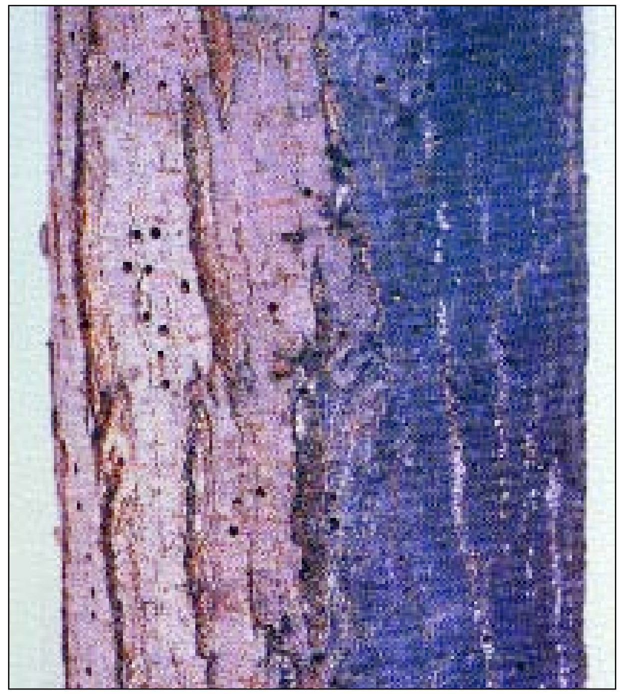


Figure 1.4.24. Smaller European elm bark beetle damage.

After feeding, the adults tunnel into the inner bark of weakened, dying or recently dead elm trees. They lay their eggs in galleries, which are parallel with the grain of the wood. The larvae hatch and feed in the layer under the bark of the tree. The life cycle may be completed in 35 to 40 days. The spring-flying adults produce a generation that emerges in June. These first generation adults also feed in twig crotches and can transmit Dutch elm disease. They then produce a second generation of larvae. Many of these larvae enter a developmental diapause and overwinter, but some continue to develop and begin to emerge in August. These adults produce a partial third generation. Second and third generation adults also feed in twig crotches, but they usually do not transmit Dutch elm disease since the trees are not as susceptible at this time. Due to overlapping of generations, adults may be present almost continuously from April to October. Thus, this insect has three full generations per year and sometimes a partial fourth.

Control of SEEBBs with respect to their potential spread of Dutch elm disease should be timed such that treatments coincide with the spring emergence of adults (usually May).

Shoot, Twig, Trunk and Root Feeders-Sucking Injury

Scales

Scale insects derive their name from the scale, a shell-like or waxy covering on their bodies. Generally, scale insects can be divided into two categories – soft scales and armored scales. Soft scales can be bare (or without shell) or covered, but they are commonly covered in a soft, cottony or powdery substance. Armored scales have a protective covering of wax under which they feed. Depending on the species involved, scale insects feed on plant stems, twigs, foliage or fruit.

Damage – Scale insects feed by sucking sap from trees and shrubs and are capable of killing the entire plant or parts of the plant. Scale insect feeding can also reduce the plant's vigor, making it more susceptible to injury caused by drought, severe winters, attack by other insects (particularly borers) or infection by diseases.

Life Cycle – The scale insects most commonly found in Arkansas overwinter either as eggs or immatures. In most species, the female deposits eggs under her shell or scale. When the eggs hatch, "crawlers" (or nymphal scales) move away from the maternal scale to locate new feeding sites. When the crawlers settle and begin to feed, the characteristic soft or armored scale covering is developed. Good scale control is generally best accomplished if treatments are applied immediately after eggs hatch (when crawlers are active).

Monitoring Suggestions for Scale Insects

When scale insects increase to levels that create a nuisance (unsightly, honeydew, etc.) or are causing extensive damage to a tree, insecticide control of the infestation can best be achieved at two different times of the year. Horticultural oils may be applied in the dormant season (per label directions) to smother overwintering scales and/or eggs, or an insecticide may be applied when the crawlers are active.

Monitoring scales in the dormant season is easy, since the insects are half-grown or larger and their coverings quite visible. In contrast, monitoring crawlers can be tedious because of their small size and because our interest is in their numbers in relation to the entire crawler emerge profile for the specific scale species (so we can time application with a reasonable certainty that virtually all are hatched and would be exposed to the insecticide).

Monitoring crawlers can be accomplished by visual observation with the aid of a hand lens; however, monitoring for the mobile immature can be facilitated by the use of two-sided sticky tape. Wrap strips of it tightly around scale-infested twigs or branches. Crawlers seeking a place to settle down will be stuck fast as they attempt to cross the sticky surface. **Note:** Try to select smooth bark as a place for bands. It is suggested that one collect the bands at least weekly and count the numbers of crawlers per band under magnification. New bands should be put back in the same place after each collection. (It helps to place a tag or indicator near each band for ease in finding it.)

The best control of the scales will normally result when treatment is made at or slightly after the peak of crawler emergence. Differences in peak crawler emergence can always be expected between years and locations because of varying environmental conditions.

If one uses some type of monitoring for crawler activity, a great deal of the"guesswork" of timing scale crawler applications will be eliminated.

Euonymus Scale

The euonymus scale is an armored scale that can infest most species of euonymus. It can attack both the leaves and stems **(Figure 1.4.25)**. Often, stems or leaves will become

Figure 1.4.25. Euonymus scale.

heavily encrusted with the male scales which are small, slender and chalky white in color. Heavy infestations make the plant appear white. The female euonymus scales are pear-shaped, brown and about twice the size of males.

Life History. Scales overwinter as fully-grown, fertilized females. Eggs are deposited in early spring beneath the dark colored female scale covering. The eggs can hatch over a two-month period from mid-April to mid-June. Nymphs, or crawlers, move to other parts of the host plant or are blown to susceptible hosts by wind. During the summer, all life stages of the scale can be found, and in most years, there are four or five overlapping broods. Control of the first/overwintering generation crawlers can be achieved if you will check for their activity in early to mid-May before treatment.

Brown Elm Scale

The brown elm scale is one of the most common soft scale insects infesting elms in Arkansas **(Figure 1.4.26).** Brown elm scale is a soft scale that is also known as the European fruit lecanium because of its origin and the fact that it infests fruit trees in some parts of the country. Brown elm scale has been found in Arkansas on ash, mulberry, plum, pecan, maple and occasionally on other trees, but it is chiefly a pest of elm. On elm, injury is usually noticed in April and May when the female scales are conspicuous and the trees are visibly injured by the insects. Heavy infestations kill smaller branches, stunt tree growth and weaken the tree until it is susceptible to attacks of borers and diseases. Heavy infestations result in large quantities of honeydew (a gummy, sticky secretion that is produced by aphids) that often coats leaves or falls on sidewalks, buildings or cars parked under the trees.

Life History. The mature female is brown with a smooth, hemispherical-shaped covering that is one-eighth to one-fourth inch in diameter. During growth, the body is soft and plastic, but at death becomes a hard, brown shell fastened loosely to the bark that may serve as a covering for several hundred white eggs. Eggs are laid in late April and early May and hatch into tiny lice-like creatures from early to mid-May. The nymphs (crawlers) come out from beneath the scale covering and migrate to the leaves and small limbs. Large numbers attach

Figure 1.4.26. Brown elm scale.

themselves on the lower leaf surfaces and to small limbs. As they grow during the summer, their bodies become opaque, and they attach along the veins of leaves as well as twigs and limbs.

Before the leaves fall in autumn, brown elm scales migrate to the bark of smaller branches, where they remain all winter. At this stage they are brown, oval shaped and about 1 mm in length. With the beginning of sap flow in the spring, the scales start to feed. The adult male is small, brown and gnat-like (1 1/4 mm long). It is incapable of feeding and lives only a short time.

Management of Scales

Dormant Oil – A superior dormant oil, applied according to label instructions just prior to “bud break,” will help control many of the scales found in Arkansas, It can be applied to most evergreen and broadleaf woody plants (but check the label prior to application). Bud break will vary with the species of plant and the severity of the spring season, but superior dormant oil sprays usually should not be applied after early April in Arkansas. Dormant oil sprays kill scale insects by suffocation.

Sprays – Insecticides applied thoroughly according to label instructions are effective in controlling the common soft and armored scales found in Arkansas. However, since these sprays will not penetrate the waxy scale covering, spraying must be timed to coincide with the presence of the crawlers. The presence of the crawler stage will vary with the species. Thus, repeated applications may be needed to kill crawlers if the species of scale encountered has multiple generations over the growing season.

Key to Common Tree and Shrub Pests

Leaves are mottled, discolored or curled.	
Numerous soft, bodied, slow-moving, tiny, winged or wingless insects are feeding on the undersides of leaves or on the bark. The foliage may be wet, sticky and dripping	Aphids
Wedge-shaped, tiny, hopping insects are feeding on foliage, giving the leaves a mottled appearance, or leaf tips may be yellowish brown. In severe cases, the leaves turn brown	Leafhoppers, treehoppers
Small, flattened insects are feeding on the undersides of leaves. White cast skins/moltings and black shiny specks are often present on undersides of leaves. The adults have lace-netted wings	Lace bugs
Microscopic, eight-legged insects are feeding and forming webs on the undersides of leaves	Mites
Wedge-shaped, nonhopping insects are feeding on new shoot growth. Leaves are first mottled, then turn brown from severe feeding	Plant bugs
Immobile insects are attached to leaves or stems. Their protective covering may be almost any shape or color. The foliage may be covered with sticky, shiny material. Tiny, aphid-like young hatch and move out from adult sites	Scale insects
Leaves have meandering lines, runs or mines	Leaf miners
Leaves show evidence of chewing; parts or all of leaves are missing.	
Dull green and black adults and yellow-and-black-spotted larvae are feeding on elm leaves, most commonly on Siberian elm. Leaves are skeletonized	Elm leaf beetle
Brown to dark reddish brown, three-fourths inch long beetles are feeding on foliage	June or May beetles
Caterpillars are living in small, spindle-shaped bags constructed of foliage and attached to twigs	Bagworms
Looping, measuring caterpillars are feeding on foliage (caterpillars may be noted to occasionally be hanging or suspended from foliage by silken threads	Cankerworms
Caterpillars are constructing tents in crotches of trees and feeding on foliage	Tent caterpillars
Webs are spun around masses of leaves and worms are feeding inside them	Fall webworms, mimosa webworm
Limbs are dead or dying; bark is raised and wounded; tunnels are evident under bark.	
Tunnels are evident under bark of newly set maples and fruit trees	Flatheaded appletree borer
Sawdust is pushed out of holes in wet areas of bark (part of pupal case may be noted sticking out of emergence holes)	Locust borer, ash borer, lilac borer
Borers are feeding under healthy bark at the edges of wounds on flowering fruit trees	Peach tree borer
Trunk of limbs have numerous small holes (shot holes as if hit by shotgun pellets) and numerous sculptured runs or mines under back	Bark beetles
Miscellaneous Symptoms	
Twigs have deep slits in somewhat of a symmetrical pattern. Branches are broken off	Periodical cicadas
Abnormal growths or swellings can be seen on leaves, twigs or limbs	Plant galls
Twigs are girdled by feeding of beetles	Twig girdlers

Seasonal Appearance of Some Ornamental and Shade Tree Pests in Arkansas

Few insects are active during January and February, but during these months one can apply dormant oils for control of scale insects, e.g., on oak, elm, and fruit trees.

***(A) indicates adults, (L) indicates larvae.**

Early-March		**Mid-March**		**Late-March**	
Host:	**Pest:**	**Host:**	**Pest:**	**Host:**	**Pest:**
crabapple-	San Jose scale.	cotoneaster-	tent caterpillars.	crabapple-	tent caterpillars,
		dogwood-	tent caterpillars.	flowering peach-	tent caterpillars.
		flowering peach-	tent caterpillars.	hawthorn-	tent caterpillars,
		hawthorn-	lent caterpillars.	wild plum-	tent caterpillars.
		pecan-	tent caterpillars.		
		pyracantha-	tent caterpillars.		
		trifoliate orange-	tent caterpillars.		
		wild plum-	tent caterpillars.		
Early-April		**Mid-April**		**Late-April**	
Host:	**Pest:**	**Host:**	**Pest:**	**Host:**	**Pest:**
elm-	elm leaf beetle (A)*.	ash-	redheaded ash borer.	arborvitae-	juniper scale.
hackberry-	gall psyllids (A).	black locust-	cowpea aphid.	crabapple-	woolly apple aphid.
hickory-	painted hickory borer (A).	black walnut-	European fruit lecanium.	crape myrtle-	crape myrtle aphid.
oak-	gall wasps (A).	elm-	European fruit lecanium,	elm-	May beetles (A),
pine-	pine tortoise scale,		elm calligrapha (A),		spring cankerworm,
	Nantucket pine tip moth (A).		elm bud sawfly (L)*.		elm leaf aphid,
redbud-	redbud aphid.	hackberry-	European fruit lecanium.		woolly elm aphid,
		lilac-	harlequin bug (A).		smaller European bark beetle (A).
		mulberry-	European fruit lecanium.	flowering peach-	spring cankerworm.
		oak-	obscure scale,	hackberry-	spring cankerworm.
			oak lecanium.	hickory-	giant bark aphid,
		pecan-	obscure scale,		hickory bark beetle.
			European fruit lecanium.	juniper-	juniper scale.
		pine-	Ips beetles (A),	oak-	spring cankerworm, forest tent
			southern pine beetle (A),		caterpillar, May beetles (A),
			pine needle aphids,		giant bark aphid, oak leaf aphid.
			Nantucket pine tip moth (L).	pecan-	May beetles (A), giant bark aphid,
		redbud-	European fruit lecanium.		phylloxera.
		willow-	willow leaf beetle (A).	sumac-	sumac leaf beetle.
				sycamore-	giant bark aphid.
				wild plum-	rusty plum aphid,
					spring cankerworm.

(Table continued on next page.)

Early-May		**Mid-May**		**Late-May**	
Host:	**Pest:**	**Host:**	**Pest:**	**Host:**	**Pest:**
euonymus-	euonymus scale (crawlers).	elm-	carpenter worm,	juniper-	bagworm (L),
hawthorn-	oystershell scale.		elm calligrapha (L),		spider mites.
honey locust-	honey locust pod gall.		elm leaf beetle (L),	pecan-	sawflies (L),
oak-	linden looper,		elm scurfy scale, elm borer (A).		black pecan aphid.
	pinoak sawfly (L).	flowering quince-	spider mites.	pine-	sawflies (L),
pecan-	blackmargined aphid.	honeysuckle-	hornworms.	redbud-	redbud leaffolder.
privet-	whiteflies.	juniper-	juniper webworm.	spirea-	spirea aphid.
pyracantha-	Forbes scale.	lilac-	lilac borer (A).		
sycamore-	sycamore lace bug.	maple-	painted maple aphid,		
willow-	giant willow aphid,		woolly alder aphid, carpenterworm.		
	sawflies (L),	mimosa-	mimosa webworm.		
	willow leaf beetle (L).	oak-	leafrollers, carpenterworm,		
			Kermes scale.		
		pine-	black turpentine beetle (A)		
			pales weevil (A)		

Early-June		**Mid-June**		**Late-June**	
Host:	**Pest:**	**Host:**	**Pest:**	**Host:**	**Pest:**
birch-	birch aphid.	black walnut-	fall webworm.	black walnut-	walnut caterpillar.
black walnut-	flatheaded appletree borer (A).	cottonwood-	cottonwood leaf beetle (A),	cottonwood-	cloudywinged leaf aphid.
boxelder-	boxelder bug.		fall webworm,	hickory-	walnut caterpillar.
catalpa-	catalpa sphinx (L).		cottonwood borer (A).	pecan-	walnut caterpillar.
cotoneaster-	hawthorn lace bug.	dogwood-	dogwood twig borer (A).		
crabapple-	flatheaded appletree borer (A).	eastern redcedar-	minute cypress scale.		
dogwood-	flatheaded appletree borer (A).	hickory-	fail webworm.		
elm-	flatheaded appletree borer (A),	Lombardy poplar-	cottonwood borer (A).		
	elm sawfly.	oak-	oak grasshopper.		
flowering peach-	peachtree borer (A).	pecan-	fall webworm.		
goldenrain tree-	boxelder bug.	persimmon-	fall webworm.		
hawthorn-	hawthorn lace bug.	pine-	pine needle scale,		
hickory-	flatheaded appletree borer (A).		southern pine sawyer (A).		
holly-	leafminer (L).	sumac-	sumac aphid.		
Lombardy poplar-	poplar borer (A).	sweetgum-	sweetgum pit scale.		
maple-	cottony maple scale,	willow-	cottonwood borer (A).		
	flatheaded appletree borer (A).				
oak-	flatheaded appletree borer (A),				
	oak lace bug.				
pecan-	flatheaded appletree borer (A).				
persimmon-	false cottony maple scale.				
pyracantha-	hawthorn lace bug.				
redbud-	flatheaded appletree borer (A).				
sycamore-	flatheaded appletree borer (A).				
willow-	black willow aphid.				

(Table continued on next page.)

Early-July		**Mid-July**		**Late-July**	
Host:	**Pest:**	**Host:**	**Pest:**	**Host:**	**Pest:**
eastern redcedar-	spider mites.	black walnut-	American walnut aphid.	privet-	spider mites.
juniper-	spider mites.	holly-	grasshoppers.		
sycamore-	sycamore tussock moth (L).	oak-	oak eriococcus, spider mites.		
willow-	black willow aphid.	privet-	hornworms.		
Early-August		**Mid-August**		**Late-August**	
Host:	**Pest:**	**Host:**	**Pest:**	**Host:**	**Pest:**
ash-	lace bugs.			elm-	spider mites.
euonymus-	spider mites.				
mulberry-	spider mites.				
Early-September		**Mid-September**		**Late-September**	
Host:	**Pest:**	**Host:**	**Pest:**	**Host:**	**Pest:**
black locust-	walkingstick.	black walnut-	twig girdler (A).	ash-	fall ash borer (A),
honey locust-	walkingstick.	elm-	twig girdler (A).		ash bark beetle (A).
oak-	walkingstick.	hickory-	twig girdler (A).	dogwood-	whitebanded dogwood aphid.
		oak-	yellownecked caterpillar,		
			variable oakleaf caterpillar,		
			dark oak scale.		
		pecan-	twig girdler (A).		
		persimmon-	twig girdler (A).		
Early-October		**Mid-October**		**Late-October**	
Host:	**Pest:**	**Host:**	**Pest:**	**Host:**	**Pest:**
black locust-	locust borer (A).	arborvitae-	arborvitae aphid.	pine-	spider mites.
pine-	pine bark aphids.			spruce-	spider mites.
November/December					
Host:	**Pest:**				
pine-	Nantucket pine tip moth.	*During November and December is the best time to apply systemic insecticide to the soil around susceptible species of pines.*			

Ornamental Weed Control

If there were no humans, there wouldn't be any weeds. There are no weeds in nature. Good or bad, we decide which plants are weeds. Opinions as to what is a weed vary widely. Divergent viewpoints on this matter have given rise to the observation that one person's weed is another's wildflower. Typically, a weed is a plant growing where someone doesn't want it.

Weed control in ornamentals may be one of the most difficult challenges in pest management. Unlike turfgrass weed control, there is rarely an opportunity to control weeds in a planting of a single species. Landscape managers are likely to encounter woody trees and shrubs along with annual and perennial herbaceous species in the same bed. Multiplying these life cycle and growth habit possibilities by the hundreds of species and varieties available yields an endless number of combinations. Other challenges include little opportunity to use traditional approaches to weed control such as mowing, selective, broad-spectrum herbicides and cultivation. Landscape weed control is almost always labor intensive due to steep slopes and other design obstacles that make it impossible to use anything but hand-held equipment.

Weed Identification

To conduct an effective weed management program, the manager should be able to identify target weeds to genus and preferably to species (for example: *Poa annua*. *Poa* is the genus name and *annua* is the species name for annual bluegrass). Accurate weed identification is essential to selecting the appropriate control technique.

Weed identification should begin with classifying weeds by type. The five most common weed types are grasses, broadleaves, sedges, rushes and other nongrass monocots such as weeds in the lily family.

Grasses are monocotyledonous plants, which mean they have only one seed leaf (cotyledon) present when a grass seedling emerges from the soil. Grasses have joints (nodes) and hollow, rounded stems. The true leaves (as opposed to seed or cotyledon leaves) have parallel veins and are several times longer than they are wide. Bermudagrass, crabgrass, goosegrass and annual bluegrass are typical grass weeds found in ornamentals.

Broadleaf weeds are dicotyledonous, which means they have two cotyledons (seed leaves) at emergence and have netlike veins in their true leaves. Broadleaves often have colorful flowers compared to the inconspicuous flowers found on grasses. Chickweed, spurge, groundsel, henbit, lespedeza, clover, dandelion and dock are typical broadleaf weeds.

Sedges have solid, triangular stems (in most species) which bear leaves extending in three directions (3-ranked). Sedges lack ligules and auricles, and the leaf sheath is continuous around the stem. Yellow and purple nutsedge, annual sedge, green kyllinga, rice flatsedge and globe sedge are examples.

Rushes have round, solid stems and favor a moist habitat. Path rush is an example of the rush family. Path rush is often found on golf cart routes, sports fields and other compacted areas.

The **lily** family also contains some important species such as wild garlic, false garlic, star-of-Bethlehem and grape hyacinth. These plants have parallel veins but are not grasses, sedges or rushes.

Weed Life Cycles

The previously listed weed classifications may be further divided into annuals, biennials and perennials. **Annuals** germinate from seed, grow, mature and die in less than 12 months. Annuals may be further classified as winter and summer annuals. **Winter annuals** germinate in the fall, grow during cool periods, mature in the spring and then die during the summer. **Summer annuals** germinate in the spring, grow actively during the summer and die in the fall. Crabgrass and goosegrass are examples of summer annual grasses. Prostrate knotweed is an example of a summer annual broadleaf, while henbit and chickweed are representative of winter annual broadleaves.

Biennials reproduce from seed and complete their life cycle in two years. Biennials form rosettes and store foods in their fleshy roots the first year and then flower the second year. Many thistle species are biennials.

Perennial weeds live more than two years. Perennials may reproduce from seed or from vegetative structures such as roots, rhizomes, stolons, tubers or bulbs. The ability to reproduce vegetatively makes perennials more difficult to control. Some perennials such as dandelion, dock and wild garlic are actively growing during cool weather, while others like dallisgrass and nutsedge grow rapidly during the summer months. Perennials are further subdivided as simple perennials and creeping perennials. **Simple perennials**, such as dock and dandelion, overwinter by means of a vegetative structure such as a perennial root with a crown, but they reproduce almost entirely by seed. **Creeping perennials** can both overwinter and produce new independent plants from vegetative reproductive structures. Vegetative reproductive structures include creeping roots, stolons (bermudagrass), rhizomes (johnsongrass), tubers (nutsedge) and bulbs (wild garlic). Most perennials can also reproduce from seed.

If you are serious, a guide to weed identification is a very useful tool because weed identification is arguably the most important part of weed control. Some recommended publications may be found in the section "Selected Ornamental References and Study Material."

Herbicides

Nomenclature

Herbicide labels contain three names: trade name, common name and chemical name. The nomenclature for Roundup would be as follows:

Trade Name: Roundup

Common Name: glyphosate

Chemical Name: N-(phosphonomethyl)glycine

The trade name is used by the chemical company to market the product and is often the most recognizable name. The common name is a generic name that is given to a specific chemical. Only one common name exists for each herbicide. It is useful to be familiar with common names when comparing products. The chemical name describes the chemistry of the herbicide. To make things confusing, the same or different chemical companies often sell the same herbicide under different trade names. For example, prodiamine is marketed by Syngenta for turf use as Barricade and for landscape use as Factor.

Herbicide Classification

Herbicides may be classified in many ways, but some of the most important groupings are selectivity, timing of application, chemistry and mode of action.

Selectivity

Selective. A selective herbicide controls or suppresses some plant species without seriously affecting the growth of another plant species. Selectivity may be due to differential absorption, translocation, morphological and/or physiological differences between ornamentals and weeds. Most ornamental herbicides are selective. Fusilade II is an example of a selective herbicide that controls many grass weeds without causing significant injury to broadleaf plants.

Nonselective. Nonselective herbicides control or suppress plants regardless of species. Glyphosate (Roundup Pro), glufosinate (Finale) and diquat (Reward) are examples of nonselective herbicides. These products are often used for trimming along sidewalks and fences and as preplant treatments when renovating or establishing ornamentals. It is important to note that the selectivity of some herbicides is based on rate. Increasing the rate of a selective herbicide such as Princep (simazine) will move it into the nonselective category.

Mode of Action

Mode of action refers to the sequence of events, which includes herbicide absorption, translocation to the site(s) of action, inhibition of a specific biochemical reaction, the degradation or breakdown of the herbicide in the plant and the effect of the herbicide on plant growth and structure.

Herbicide Movement in Plants

Systemic (sometimes referred to as **translocated**) herbicides are extensively translocated in the vascular system of the plant. The vascular system consists of the xylem and phloem. The xylem transports water and various nutrients in solution upward from the roots where they entered the plant, through the stems and into leaves, flowers and fruits. The phloem conducts food materials from their principal sites of synthesis in leaves to other locations, such as fruits and developing roots and shoots, for storage and use. Systemic herbicides are slower acting than contact herbicides because they require from several days to a few weeks to move throughout the vascular system of a treated plant. Systemic herbicides may be selective or nonselective. Glyphosate (Roundup Pro) is an example of a nonselective systemic herbicide, while Vantage (sethoxydim) is an example of a selective systemic herbicide. Most of the systemic herbicides move in the xylem and phloem with the exception of the triazines (atrazine, simazine, Sencor) which are xylem mobile only.

Contact herbicides affect only the green plant tissue that comes in contact with the herbicide spray. Thus, thorough coverage of the weed foliage is needed to achieve optimum control. These herbicides are either not translocated or only move to a limited extent within the vascular system of plants. For this reason, underground vegetative reproductive structures such as roots, rhizomes and tubers are not affected. Multiple applications of contact herbicides are needed for long-term control because plants regrow from these unaffected plant parts. Contact herbicides are fast acting. Symptoms are often visible within a few hours of application. Basagran T/O (bentazon) is a selective contact herbicide. Reward (diquat) is a nonselective contact herbicide.

Herbicide Families

Herbicides with similar chemistry are grouped into families. In general, herbicides in the same family exhibit similar absorption, translocation and mode of action. It is convenient to combine herbicide families that have similar sites of action into groups. For ornamental weed managers, the importance of knowing which herbicides have similar sites of action lies in developing weed control strategies that minimize the potential for developing herbicide-resistant weed populations.

Herbicide Resistance

A number of weed species that were once easily managed by certain herbicides have developed resistance. These weeds are no longer controlled by applications of previously effective herbicides.

Herbicide resistance probably develops through the selection of naturally occurring biotypes of weeds exposed to a family of herbicides over several years. A biotype is a population of plants within the same species that has specific traits in common. Resistant biotypes may have slight biochemical differences from their susceptible counterparts so they are no longer sensitive to certain herbicides. Resistant plants survive, go to seed and create new generations of herbicide-resistant weeds.

Dinitroaniline-resistant goosegrass and crabgrass have been documented in ornamentals. However, these plants are susceptible to other preemergence grass herbicides such as Ronstar.

Experience has shown that the potential for developing resistance is greatest when an herbicide has a single site of action. Development of johnsongrass resistant to the grass specific herbicides has already occurred in many areas in spite of their relatively short time in the market. We now have Illoxan-resistant ryegrass in the United States and several other countries.

Regardless of the mechanism for resistance, becoming familiar with the herbicide mode of action can help turf managers design programs that prevent the development and spread of herbicide-resistant weeds. Management programs for herbicide resistance should emphasize an integrated approach that stresses prevention. Dependence on a single strategy or herbicide family for managing weeds will surely increase the likelihood of additional herbicide resistance problems.

Some Strategies for Managing Resistance

1. Rotating herbicides having different modes of action. This is a problem in landscape weed control because there are a limited number of modes of action from which to choose.
2. Using tank mixtures of herbicides having different modes of action.
3. Avoiding sequential application of the same herbicides (over several years) or herbicides having the same mode of action.
4. Controlling weedy escapes in border areas and ditch banks.
5. Practicing good sanitation to prevent the spread of resistant weeds.
6. Integrating cultural, mechanical and chemical weed control methods.

Ornamental Herbicides With the Same Mode of Action

Dinitroanilines (root growth inhibitors)	Lipid Inhibitors	ALS Inhibitors
Balan 2.5G (benefin)	Acclaim Extra (fenoxaprop)	Image (imazaquin)
Biobarrier II (trifluralin)	Envoy (clethodim)	Manage (halosulfuron)
Biobarrier Root Control (trifluralin)	Fusilade II (fluazifop)	
Dimension 1 EC (dithiopyr)	Ornamec 170 (fluazifop)	
Barricade 65 WDG (prodiamine)	Vantage (sethoxydim)	
Ornamental Weedgrass Control (pendimethalin)		
Pendulum 2G (pendimethalin)		
Pendulum 3.3 EC (pendimethalin)		
Pendulum WDG (pendimethalin)		
Pre-M 3.3 EC (pendimethalin)		
Pre-M 60 DG (pendimethalin)		
Treflan 5G (trifluralin)		
Surflan (oryzalin)		

Timing of Application

Herbicides are also classified by when the chemical is applied relative to turfgrass and/or weed seed germination. The majority of herbicides may be classified into one of three timing categories: preplant, preemergence or postemergence. However, several herbicides have pre and postemergence activity. Examples include imazaquin (Image), simazine (Princep) and pronamide (Kerb).

Preemergence Herbicides

Preemergence herbicides are the foundation of an ornamental weed management program. Preemergence herbicides are applied to the site before weed seed germination. After being activated by rainfall or irrigation, these herbicides form an herbicide barrier at or just below 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 are cell division inhibitors affecting the emerging root and shoot, which are sites of rapid cell division. Weeds that have already emerged (visible) are not consistently controlled because their growing point has escaped contact with the herbicide. The primary target of preemergence herbicides is annual grass, but some small-seeded annual broadleaves will be controlled.

A variety of factors affect the performance of preemergence herbicides. These include timing of application in relation to weed seed germination, soil type, environmental conditions (primarily temperature and rainfall), target weed species and biotype and cultural practices that follow application. Soil organic matter and clay content have the greatest influence on the activity of preemergence herbicides.

Ideally, preemergence herbicides should be applied just before weed seed germination begins. Applying too early may result in reduced control or no control due to leaching and/or normal herbicide degradation. Preemergence herbicides must be in place and activated before the onset of weed seed germination. Activation of preemergence herbicides requires 0.25 to 0.5 inch of rainfall or overhead irrigation. For optimum performance, rainfall or irrigation should occur within 24 hours of application. Water moves the herbicides into the upper layer of the soil. Failure to incorporate herbicides will result in loss through processes such as breakdown by sunlight and escape into the atmosphere as a gas. The critical period between application and activation by rainfall or irrigation varies with herbicide, rate and environmental conditions. However, it is safe to assume that sooner is better and, if irrigation is available, water-in preemergence herbicides immediately after application.

In warm weather, herbicides begin to degrade soon after application, eventually reaching a level at which weed emergence and growth can occur. Preemergence herbicides will degrade to the point of ineffectiveness from one to four months after application. For this reason, repeat or sequential applications are needed for full-season control.

A typical cycle of preemergence herbicide applications would include an initial application in late winter to early spring to control summer annuals followed by second application in late summer to early fall to control winter annuals. In some parts of the country, such as the humid South, an application in late May or early June may be needed because the spring application will have dissipated by that time.

Postemergence Herbicides

Postemergence herbicides are intended for use on weeds that have emerged and are visible. Postemergence herbicides are applied directly to emerged weeds. In contrast to preemergence herbicides, most postemergence herbicides have little or no soil activity. It is possible to conduct a total postemergence weed control program in ornamentals provided multiple applications are used throughout the year. Disadvantages of total postemergence weed control include the need for frequent applications and the possibility of temporary ornamental injury. Most weed control professionals use a combination of preemergence and postemergence herbicides. Preemergence herbicides form the basis of most programs, with postemergence herbicides used to control weeds that escape the preemergence treatments. Established perennial weeds, both grasses and broadleaves, must be controlled with post-emergence herbicides.

General guidelines for best results with postemergence applications are small weeds, adequate soil moisture and air temperatures between 60 and 90ºF. Weeds that are small (two- to four-leaf stages) and actively growing are much easier to control with postemergence herbicides. Control is improved at this stage because young weeds readily absorb and translocate herbicides.

Weeds that are stressed due to dry weather, heat or other environmental factors are more difficult to control with postemergence herbicides. Applying postemergence herbicides at temperatures above 90ºF increases the risk of ornamental injury.

The resistance of postemergence herbicides to wash-off by rainfall or irrigation varies among products. Typically, a rain-free period of 6 to 24 hours is sufficient to avoid a reduction in effectiveness. Even if rain falls soon after application, some degree of control will be achieved.

Rather than a single rate, a range of post-emergence herbicide rates for a product usually is given. Repeat applications at moderate rates are generally more effective than a single application of the higher rate. The followup application is timed to be 7 to 14 days after the first, or when regrowth appears.

Spot Spraying

Directed spot spraying with a hand-held, pump-up sprayer or lever-operated backpack sprayer is one of the most commonly used methods of applying herbicides in and around landscape plantings. Lack of herbicide selectivity and the obstructions created by landscape plants often dictate the use of this approach. Spot spraying solutions are typically prepared by adding a certain amount of liquid herbicide per gallon of spray mix. These are usually given on a percent of total volume basis. For example, to make a 2% mixture of Roundup and water, add 2.66 ounces of Roundup per gallon of water. This method is best for herbicides with little or no soil activity. Soil active herbicides should be carefully applied on a per unit area basis (per 1,000 square feet or per acre).

Most pump-up sprayers do not have pressure gauges or pressure controls. The pressure in the tank will drop as the material is sprayed from the tank. This pressure drop can be partly overcome by filling the tank only 2/3 full with spray solution, so that considerable air space is left for initial expansion, and by repressurizing the tank frequently. If the sprayer has a pressure gauge, repressurize when the pressure drops approximately 10 psi from the initial reading.

When spraying, do not overapply. The coverage should be similar to that resulting from a light rain. Just wet the foliage of the target weed and move on. Do not spray until runoff.

Use a funnel or some other shield attached just above the nozzle when applying nonselective herbicides such as Roundup, Reward or Finale. Solo sells an attachment for this purpose called a

Drift Guard, or you can improvise. A normal plastic funnel may be adapted, or cutting the top of a 2-liter coke bottle makes a cheap alternative. Attach it with duct tape or a hose clamp. Beware of dripping or tracking herbicide with your feet when moving from one location to another.

Principles of Herbicide Use

Before selecting any herbicide, determine whether or not the desirable landscape plants are tolerant of the chemical being considered. Consult the label to determine which herbicides may be safely used on the ornamentals in question. The majority of ornamental herbicide failures and mistakes are not from the weakness of the herbicide but from:

1. Choosing the wrong herbicide due to misidentification or lack of research into herbicide selection.
2. Applying at the wrong time.
3. Treating an ornamental species that is sensitive to the herbicide and will be damaged.
4. Poorly calibrated application equipment.
5. Failure to distribute the herbicide uniformly across the target area.
6. Using application equipment not suited to the job.
7. Inadequate spray tank agitation.
8. Treating the target weed at the wrong stage of growth (too large, too small).
9. Applying when environmental conditions are not conducive to good weed control (dry, hot, cold windy, rainfall imminent).

Herbicide Selection Criteria

1. Does it control most of the weeds present?
2. Are the existing ornamentals listed on the label?
3. How close are susceptible ornamentals and other nontarget species?
4. Is there potential for damage to future plantings due to residual herbicide remaining in the soil?
5. How will the herbicide be applied? Spread or sprayed?

Site Preparation

Because weed control in landscape plantings is difficult under the best conditions, it is nearly impossible to spend too much time on preplant weed control. There are always exceptions to this admonition, but many years of experience have taught us that people rarely expend excessive effort on preplant weed control in turfgrass and ornamentals. This may be all right on some sites, but if there are tough perennial weeds present it is a mistake. Fumigation using methyl bromide, Basamid or soil solarization is an option for landscape beds. Solarization may not be practical because it must be done during the hottest part of the year, and the covers must left in place for six weeks.

Preplant Herbicide Application

One application of Roundup Pro or another labeled glyphosate product at least two weeks before planting is a cheaper but less effective alternative to soil fumigation. Complete control of some perennial weeds may require multiple applications of Roundup. The treatments should be timed to the appearance of regrowth of the target weed. It should be noted that a full growing season of repeated Roundup treatments (usually three or four) will control bermudagrass but not yellow or purple nutsedge.

Soil Fumigation

Soil fumigants are volatile liquids or gases that control a wide range of soilborne pests. Soil fumigants are also highly toxic and are expensive. Their use is often limited to high-value crops such as putting greens, propagation beds and ornamentals. A cover, usually plastic film, is placed over the treated area to trap the fumigant vapors in the soil. In addition to many weeds, fumigants also control diseases, nematodes and insects. Weed seeds that have hard, water-impermeable seed coats such as mallow, sicklepod, white clover, redstem and morningglory are not controlled by fumigants. In addition, nutsedge control with fumigants is not dependable. Factors to consider before choosing a soil fumigant include expense, soil moisture level, soil temperature and time available before planting. There are three compounds available for soil fumigation in ornamentals: (1) methyl bromide, (2) metham or metam-sodium, and (3) Basamid (dazomet).

Methyl bromide is a colorless, nearly odorless liquid or gas. At 38ºF, the liquid becomes a gas and at 68ºF is 3.2 times heavier than air. These properties require that a cover is used or methyl bromide will escape. Methyl bromide is extremely toxic (acute vapor toxicity is 200 ppm) due to inhalation hazard, and it is commonly combined with a warning agent such as chloropicrin (teargas) to warn the user of escaping gas.

Before using methyl bromide, the soil should be in a condition suitable for planting, including seedbed preparation by tilling. Control will be only as deep as the soil is adequately tilled. Soil should be moist for adequate soil penetration and dispersion. Saturated soils or extremely dry soil will limit fumigant movement through the soil, thus reducing the level of weed control. Soil temperature at 4 inches should be a minimum of 66ºF. Fumigation will not be effective if soil temperature is below 50ºF. Before or during application, the site should be covered with plastic film with the edges properly sealed to prevent gas leakage. The treated area should be covered for 24 to 48 hours. The cover should then be removed and the soil aerated for 24 to 72 hours before planting.

Metham or **metam-sodium**. Metham (methyl-dithiocarbamate) is a member of the thiocarbamate herbicide family. Metham is water-soluble, and upon contact with the moist soil breaks down to form the highly toxic and volatile chemical methyl isothiocyanate. Metham should be applied to moist soil with a temperature of at least 60ºF. It is most effective when used with a cover, but it may be used with a water and soil-seal method. With the water soil-seal method, the soil is cultivated and kept moist for a week before treatment. The material is applied, roto-tilled and watered in to the desired depth of control (usually 4 to 6 inches). Approximately 7 days after treatment, the area should be cultivated to help release any residual gas. One to 2 weeks later (2 to 3 weeks after initial application), the treated area may be planted. Disadvantages of metham use include the lowered effectiveness when used without a cover and the longer waiting period before planting. The oral LD_{50} of metham is 820 mg/kg while the dermal LD_{50} is 2,000 mg/kg.

Basamid (dazomet) has recently been introduced as a soil fumigant. Dazomet is a granular formulation and is not a restricted use pesticide. Dazomet must be applied accurately and uniformly and then incorporated into the soil. Its use and effectiveness are very similar to metham. One of its main attractions is that, unlike methyl bromide, it can be handled without any special equipment. We have used Basamid in our research program on native soil with good success. While, the label gives other options, use a plastic film to seal the site just as you would with methyl bromide. We consider Basamid to about 80% as effective as methyl bromide.

Planters

When planting containers it is a good idea to use sterile or weed-free potting soil whenever practical. Even if clean planting media is used, there will be some weed encroachment. The most practical method of weed control for a small number of planters is the use of hand weeding and mulches. The key to successful hand weeding is frequent inspection. It is important to make regular weed removal rounds during the growing season before the number of weeds present becomes overwhelming. A single smooth pigweed may produce up to 200,000 seeds; a single annual bluegrass plant is capable of producing 2,000 seeds. The other option is the use of herbicides to control most of the weeds. Do not enter into herbicide use in planters lightly. Accurate application and careful herbicide selection is critical. The limited soil volume in containers provides less herbicide buffering capacity compared to field plantings. As always, when using herbicides, it is a good idea to try new products and techniques on a small trial area before treating everything in the landscape. Not all ornamental herbicides are labeled for use in containers. Some are designated for field use only. Consult the label for use options. Ornamental Herbicide II and Rout herbicide are two of the most popular preemergence products for containers. Both products contain Goal (oxyfluorfen), which will cause contact burn of foliage if not washed off with irrigation water immediately after application. Ronstar (oxadiazon) also has the potential for foliar burn. Some of the other products registered for container use include Treflan, Ronstar and Devrinol.

Annual Flower Beds

In a perfect world, all annual beds would be fumigated before planting. If time and money allow, fumigation should be the first choice on high value annual beds. While under scrutiny at this time, methyl bromide is still available for soil fumigation. The other products available for this use are Vapam and Basamid. Methyl bromide remains the most effective of the three, although its high level of toxicity restricts its use to professional applicators.

Short of fumigation, hand weeding, frequent cultivation, mulches, herbicides or a combination of all these methods are used for weed control in annuals. Cultivation has limitations as a weed control method in landscape beds. Cultivation may damage roots, spread perennial weeds and encourage germination of weed seeds by bringing them to the soil surface. Perennial weeds should be controlled before planting. Select annual species that are compatible with effective herbicides.

Use of landscape fabrics is not practical for annual beds due to the short-term nature of the planting. Organic mulches are the most practical. Preemergence herbicides may be applied to the soil before mulching or applied to the mulch and watered in after planting. Place transplants into weed-free soil. When using a preemergence herbicide in an annual bed, irrigate to settle the soil around the plants before applying the herbicide. A granular product such as Pendulum 2G is easy to apply and labeled for use on many popular bedding plants. Planting to encourage the rapid formation of a canopy will help shade weeds. Avoid small, odd shaped flowerbeds. They are difficult to maintain and mow around. When mowing, blow clippings away from beds to prevent the introduction of weed seeds. Prepare the soil and apply the mulch before planting annuals. It is easier to install transplants through the mulch than to attempt to mulch around them after planting.

Cultivation when changing plantings will suppress some weeds but may bring additional weed seeds to the soil surface. A preplant application of a nonselective herbicide between plantings will help reduce weed competition without disturbing the soil. Do not try to use nonselective herbicides such as Roundup Pro or Finale while annuals are present. It is too easy make a mistake. Envoy, Fusilade II or Vantage may be used postemergence to selectively control weedy grasses after planting. No wide spectrum, selective, postemergence herbicide exists for broadleaf weeds and sedges.

Herbaceous Perennial Beds

The major differences in weed management for herbaceous perennial beds (as compared to annuals) are (1) preplant perennial weed control is more important because there won't be an opportunity for cultivation or renovation for several years and (2) geotextiles may be used in many instances. Mulches may be used over landscape fabrics and supplemented with preemergence herbicides and hand weeding. Apply preemergence herbicides soon after transplanting. Perennial weeds in herbaceous perennial beds may be controlled with carefully directed applications of Roundup. Do not allow the Roundup to contact the foliage of the desirable plants. Care must be taken when using Roundup in beds due to the many possibilities for getting Roundup on nontarget plants. Dripping spray wands, accidental wiping of foliage or tracking the herbicide onto turfgrass or onto another bedding plants are common Roundup use mistakes. While close planting will produce a rapid canopy to discourage weeds, perennials should be spaced to allow 3 to 5 years of growth. Open areas will make weed control more difficult but will eliminate the hassle of removing crowded plants to change the spacing.

Woody Groundcover Beds

After they are well established, woody groundcovers will crowd out most weeds. However, during establishment, weed control will be more difficult. The need to control perennial weeds before planting becomes increasingly important because injury-free spot spraying with Roundup is almost impossible in a dense groundcover bed. Plan ahead and chose groundcovers that are tolerant of the herbicides that fit the weed spectrum present. Annual weeds may be controlled with a combination of mulch, preemergence herbicides and hand weeding. Envoy, Vantage, Fusilade II are excellent for postemergence control of annual and perennial grasses. Use landscape fabrics where possible, but not where groundcovers are expected to root and spread.

Woody Tree and Shrub Beds

Beds made up exclusively of woody plants offer more weed control options due to greater herbicide tolerance. Depending on the growth habit of the species selected, the opportunity for directed applications of herbicides such as Roundup Pro or Finale is greatly enhanced. Care should be taken to avoid applying Roundup Pro to green bark or trees with fresh wounds from pruning, string trimmers, mowers, etc. Suckers and low hanging branches should be removed well in advance of spraying to allow the wounds to heal. In situations where brownout is not objectionable, Finale may be used to prune suckers or contain low growing creeping plants. Finale (glufosinate) does not translocate in most species. Mulches, landscape fabrics and herbicides may be readily combined to provide broad-spectrum weed control. A landscape fabric combined with a shallow layer of mulch or a deep mulch layer without landscape fabrics are two reasonable approaches. Supplement these measures with a preemergence herbicide. Escaped weeds may be controlled with directed applications of nonselective herbicides. Hand weeding may be sufficient for scattered infestations. The greater range of control options available reduces the importance of preplant weed control. In some instances, dormant season application of Casoron (dichlobenil) may be useful for perennial weed control. Design plantings to provide a dense canopy that will shade weeds.

Mixed Plantings of Woody and Herbaceous Species

Consider planting the woody species first and then spending two years controlling perennials with nonselective herbicides. After the perennial weeds are under control, then plant the herbaceous species. Space the woody plants to provide plenty of shade to suppress weeds. Given the greater herbicide tolerance of woody plants, it may be necessary to develop separate weed management programs for different areas in the same planting.

Paved Areas

Before installing paving, regardless of the material used, perennial weeds such as nutsedge and bermudagrass should be controlled. Minimizing the number of cracks in the paving will reduce weed control problems in the future. When treating cracks in paving with Roundup or another nonselective herbicide, adding a nonstaining, residual herbicide such as Factor will reduce the number of applications needed per season. Do not apply industrial vegetation management herbicides such as Hyvar (bromacil), Velpar (hexazinone), Tordon (picloram), Spike (tebuthiuron), Pramitol (prometone) and Arsenal (imazapyr) to control weeds in paved areas near ornamentals. Plants whose roots extend into the treated area may be killed or injured by these products. Remember that tree roots can grow under paving and pick up herbicides that were applied before the paving was installed. Large shade trees have roots that extend well beyond the drip line. An additional hazard associated with these herbicides is runoff onto sites with desirable vegetation. Every year desirable ornamental trees and shrubs are killed by the use of this category of herbicides. Roundup Pro can be safely used to control most annual and perennial weeds growing under trees and shrubs. Grass encroachment onto paved areas can be reduced with the use of Roundup Pro. A neater edge can be accomplished with the use of Finale when edging creeping grasses. Finale is translocated very little, thus leaving a uniform line of dead grass. Primo (trinexepac-ethyl) will also reduce the amount of edging needed when trying to control the growth of grasses that produce runners.

Spray Tips for Edging Paved Areas

Standard flat fan tips deliver a tapered pattern, which means that the application rate on the outside of the pattern is less than that in the center of the pattern. This is overcome in boom spraying applications by overlapping the spray patterns. When applying an edging spray with a single nozzle, use an even flat fan tip. These tips have an E designation such as 8003E on the tip. Typical nozzles such as 80° or 95° are often too wide for edging. A 4003E flat fan works very well for this purpose. It is not a commonly available tip and will have to be ordered. The narrower pattern produced by the 4003E makes it a good tip for spot spraying.

Mulches

Mulches prevent weed emergence by blocking light needed to stimulate germination.

While very effective, mulches will not provide complete weed control. Hardwood and pine barks are two of the most popular materials. One common error made with using mulches is applying them too deep. Excessive mulching creates a constantly wet environment, which prevents oxygen penetration into the soil. Coarse bark mulch should be about 4 inches deep and fine textured bark about 2 inches deep. Coarse mulches provide less water holding capacity and are less likely to have weeds growing in the mulch. Fine mulches hold water and provide a favorable environment for weed seed germination. Fine mulch has greater potential for tying up preemergence herbicides. Thin mulch layers make preemergence herbicides more effective. Biobarrier II, a landscape fabric that contains plastic nodules impregnated with Treflan, is an alternative to mulching and then applying a preemergence herbicide. Bark and other organic mulches need periodic replenishment due to decomposition. Some perennial weeds such as nutsedge and field bindweed have sufficient root reserves to penetrate all mulches. Another problem often associated with organic mulches is weed seed germination on top of the mulch. Seeds that are readily carried by the wind such as groundsel, prickly lettuce and sowthistle may be deposited on the mulch from remote sites. Avoid mulches that are contaminated with weed seed. Do not use foul smelling mulches. They have gone anaerobic and may contain compounds that are toxic to plants.

Landscape Fabrics for Weed Control In Commercial and Home Landscapes*

A number of fabrics are currently available for landscape weed control. They were developed in part as replacements for black plastic (solid polyethylene). We discourage the use of black plastic in landscapes due to plastic's lack of porosity. This lack of porosity restricts water and gas penetration through solid polyethylene.

Carbon dioxide can accumulate under black plastic, which poses a problem since plant roots require oxygen for development. If black plastic is placed over dry soil, subsequent rainfall may not be able to reach plant roots. If placed over wet soil, the soil may not be able to dry out properly. Black plastic is still recommended for short-term weed control in areas such as vegetable gardens.

Because these landscape fabrics do allow for water and gas exchange, they overcome the major problem of black plastic, namely its lack of porosity. Not only have we evaluated these fabrics for weed control, we have also recorded soil moisture and temperature under landscape fabrics and have monitored the growth of landscape trees and shrubs.

These materials, also called geotextiles or weed barriers, are made of fibers that are woven (fiber runs in two directions) or nonwoven (in which fibers run in various directions and are attached at random spots using heat or glue). The fabrics are primarily composed of polypropylene, but some are made of polyester, polyethylene or a combination of various materials. A few other weed barriers are made of solid polyethylene, in which small holes are punched through the material to allow for water penetration. Spun-bonded fabrics tend to be more expensive than woven ones, and while most fabrics are black, some are white, gray or brown.

We have attempted to evaluate all of the major brands of landscape fabrics currently being sold. In our research, solid black plastic has provided better weed control than any landscape fabric or other weed barrier. Weed shoots and weed roots were able to penetrate through holes present in the fabrics. Perennial weeds such as yellow nutsedge can penetrate all of the fabrics we have tested. The landscape fabrics are more effective in suppressing annual weeds. Not all fabrics are equal in their ability to control weeds. Dalen's Weed-X has provided the greatest suppression of weeds, with DeWitt Weed Barrier ranked second. Weed-X was also the best fabric for retarding weed root penetration.

Another important difference we noted among fabrics was their ability to withstand breakdown by sunlight. Some fabrics such as Duon and Typar broke down more quickly than fabrics such as Visqueen or DeWitt, probably due to differences in UV light stabilization. This can be important if the mulch shifts due to wind or rainfall, exposing the fabric to sun.

*Jeffrey F. Derr, Weed Scientist Virginia Tech

Advantages of Landscape Fabrics

1. Fabrics reduce the need for, or replace the use of, chemicals for weed control.
2. These products allow for water and gas exchange.
3. The rougher surface tends to hold mulch better than black plastic.
4. They provide long-term weed control if kept covered by mulch.
5. They improve weed control over mulch alone.

Disadvantages of Landscape Fabrics

1. They are more expensive than black plastic.
2. Installation is more difficult.
3. These materials will not control all weeds, especially perennial ones.
4. They may stimulate surface rooting of trees and shrubs.
5. Weed roots and shoots may grow through and become intertwined in the fabric.
6. The roots of ornamentals may grow through and into the fabric.
7. Seems to create a favorable environment for rodents.

Recommendations for Using Landscape Fabrics (Geotextiles)

1. Control perennial weeds prior to fabric installation.
2. Overlap fabric pieces; use U-shaped nails to peg down the fabric. The big staples that are used to hold big roll sod together work very well for this purpose. Another source of staples for this use is cutting the ends off wire coat hangers. Each hanger yields two staples.
3. Cut an X pattern for planting.
4. Do not leave soil from planting holes on top the fabric because it will provide a medium for seed germination.
5. Maintain shallow mulch layer to prevent photodegradation, but do not use excess amounts because organic mulches such as pine bark become good growing media for weeds as they decompose.
6. Control weeds that germinate in the mulch layer when small.
7. Choose a fabric with a low ratio of open to closed space (fiber arrangement), such as Weed-X.
8. Landscape fabrics provide more effective weed control if used in combination with rock or other inorganic mulches rather than organic mulches.
9. Remember that yellow nutsedge will penetrate all mulches. Pennant applied under mulch will reduce yellow nutsedge emergence.
10. Compare the advantages and disadvantages of landscape fabrics to other weed control options for specific weed problems.

Weed IPM for Ornamentals

Weed prevention is avoiding the introduction of weeds into an uninfested area. One of the keys to making integrated pest management effective in controlling ornamental weeds is not allowing weeds to become established. Some common sense steps to weed prevention include:

1. Using weed-free mulch.
2. Using weed-free plant materials. Container nursery stock and balled and burlapped material may contain weeds. While it may not be practical to return the plants, it will be possible to get a jump on controlling these weeds.
3. Keeping border areas weed-free and preventing weeds from producing seeds.
4. Washing equipment between uses.

Landscape weed control is not herbicides alone. Approach weed control as an integrated process that combines good cultural practices that will produce dense, vigorous landscape plants with intelligent selection and use of herbicides. To conduct an effective weed control program:

1. Provide proper cultural practices.
2. Have the ability to identify specific weeds.

3. Be familiar with the growth and reproductive characteristics of weeds. Scout for weeds and pay attention to perennial species because they have the greatest potential for creating future problems. The best time to identify perennials is during late summer or early fall. Note the location of various weed infestations. This information will allow you to be ready with the correct plan of attack come treatment time.
4. Have knowledge of the control measures available and have the ability to select and use them properly.

Too often weed control measures are a reaction to an immediate problem rather than part of a well-planned and coordinated program. Weed control professionals should spend at least as much time learning the conditions that lead to weed infestation as they do studying control options after weeds have become established.

Herbicide Management

Remember that herbicides can injure nontarget or desirable plants. When using any herbicide, research the characteristics of the product and manage the application carefully. Take steps to ensure that herbicides are directed to the target. Use them at the proper rate, at the right time and on a site that the label permits. Control each application so there is no off-target movement. Herbicide movement may result from drift of spray droplets, volatilization (movement as a gas), contaminated surface runoff water or by tracking with feet or equipment. One way to avoid injury to desirable plants is to make treatments when the nontarget plants are not present or not actively growing. For example, applying Roundup or preemergence herbicides in late winter before ornamentals break dormancy will reduce the chances of accidental injury. Always remember that some herbicides are mobile. Avoid applications during windy conditions. Always follow label directions and heed label precautions. Volatile herbicide labels have restrictions to avoid vapor drift. Do not use these products during hot weather. Do not apply a volatile product during the heat of the day or in the morning of a day when very warm temperatures may occur.

Use extreme care when applying nonselective herbicides. Directed sprays are used to prevent contact with leaves or shoots of desirable plants. Droplets too small to be seen will readily move through the air and damage sensitive plants. Shielded sprays, where a cone surrounds a nozzle, can prevent the spray from hitting the foliage of a desired plant. A wiper (wick) application, where an herbicide solution is wiped on weed foliage only, is another way to use nonselective herbicides safely around desired plants.

Be aware that some herbicides will leach vertically through the soil profile. They may injure or even kill sensitive trees and shrubs if their roots extend under the treated soil. Rainfall may move these products into the root zone, leading to injury. Atrazine and simazine are herbicides with potential for vertical and lateral movement.

When finished applying granular herbicides or fertilizers, sweep or blow them off hard surfaces such as parking lots, driveways, sidewalks and streets to prevent contamination of runoff water. Turf acts as a filter but the materials left on impervious surfaces go directly into storm sewers or ditches and eventually into the water supply. Monitoring of rivers in the Atlanta area has shown a sharp increase in the levels of pesticides and fertilizers used in turfgrass management during the busy spring-early summer lawn care season.

Herbicide Formulations

The two big groups of herbicide formulations are dry and liquid. The amount of active ingredient in a dry formulation is designated as a percent of the weight. Active ingredient in liquid forms is listed in pounds per gallon. Within the dry formulations, there are granular or pelletized herbicides that are spread directly on the target in dry form. These products usually contain very low percentage of active ingredient (0.1 to 2.0%) and are designated by the abbreviation **G** or **GR** (granule) or **P** (pellet). Other dry formulations are mixed with water and sprayed on the target. These products are designated as, **SP** (soluble powder), **W** or **WP** (wettable powder), **WSP** (water soluble packet), **DF** (dry flowable), **SG** (soluble granule) or **WG**, **DG** or **WDG** (water dispersible granule). Liquid formulation designations include, **L** or **F** (liquid suspension), **E** or **EC** (emulsifiable concentrate), **SC** (suspension concentrate), **SL** (soluble liquid), **ME** (microencapsulated) and **CS** (capsule suspension).

Some herbicide formulations may be incompatible. MSMA and 2,4-D amine will sometimes form sludge when mixed. Liquid nitrogen and 2,4-D amine will always form sludge when mixed. In addition to physical incompatibility, two herbicides may mix well but may be chemically incompatible resulting in a reduction in herbicidal activity. For example, mixing 2,4-D with Fusilade, Vantage or other grass specific herbicides will result in decreased grass control. This is referred to as antagonism. The label will give instructions on what can and cannot be mixed with that herbicide. When tank mixing different formulations: (1) fill the tank 2/3 full of water, (2) start the agitation and keep it running, (3) add the respective formulations in this order: wettable powders > dry flowables > liquid suspensions > emulsifiable concentrates > soluble concentrates.

Herbicide Spray Additives and Their Uses

Adjuvant: Any additive used with an herbicide that enhances the performance or handling of the herbicide.

Compatibility agent: A material that allows the mixing or improves the suspension of two or more formulations when applied together as a tank mix. They are used most frequently when a liquid fertilizer is the carrier solution for an herbicide.

Crop oil concentrate: Oil-based material that enhances herbicide penetration through the leaf cuticle.

Defoamer: A material that eliminates or suppresses foam in the spray tank so that pumps and nozzles can operate correctly.

Drift control agent: A material used in liquid spray mixtures to reduce spray drift.

Fertilizer: Certain fertilizers added to the spray tank can enhance penetration of the herbicide into the leaf. Ammonium sulfate and 10-34-0 are commonly used as additives in some parts of the country. Ammonium sulfate is sometimes mixed with glyphosate to treat weeds under marginal conditions such as drought stress. 10-34-0 has been used as an herbicide additive for velvetleaf control in the upper Midwest.

Surfactant: A material that improves the emulsifying, dispersing, spreading, wetting or other surface modifying properties of liquids.

Wetting agent: A material that reduces interfacial tensions between water droplets and the leaf cuticle.

25 Rules of Thumb for Weed Control in Ornamentals

1. When confronted with difficult-to-control perennial weeds, consider the herbicide tolerance of the ornamentals to be planted. Plant yellow nutsedge-infested sites with ornamentals that tolerate Pennant or allow post-directed applications of Roundup, Manage or Basagran.

2. Make the minimum preplant weed control procedure one application of Roundup at least 2 weeks before planting. If possible, plan 1 year ahead. For tough perennials such as bermudagrass, it is best to spend an entire growing season making repeat applications to get complete control. Use a 2% solution of Roundup Pro (2 2/3 ounces per gallon) or broadcast 3 quarts per acre.

3. Apply grass specific herbicides such as Fusilade, Vantage and Envoy to seedling annual grasses (two to five leaves) during good growing conditions. Mature grasses are much more difficult to control. Consult the label for the proper growth stage to treat perennial grasses. Grass specific herbicides only affect true grasses, not other monocots such as monkey grass, liriope, lilies and iris.

4. Apply and water-in preemergence herbicides with 0.25 to 0.5 inch of rainfall or irrigation as soon as possible after planting. Remember that weed seeds will often germinate within a few days of tillage or a burndown herbicide application.

5. If possible, combine preemergence grass and broadleaf herbicides to broaden the spectrum of weed control. An example would be using a premix such as Snapshot or tank mixing Gallery and Surflan or Barricade or Pendulum.

6. Use a funnel or some other shield when applying nonselective herbicides such as Roundup or Finale. The top of a 2-liter soft drink bottle makes an acceptable funnel to attach to the end of a spray wand.

7. Do not allow weeds in landscape beds to produce seeds. The old saying, “One year’s seeding – seven years’ weeding,” is pretty accurate.
8. Do not apply granular herbicides to ornamentals when the foliage is wet.
9. Delay irrigation following application of postemergence herbicides according to the label.
10. Repeat preemergence herbicide applications on an 8- to 12-week interval or two to four times per season depending on weed pressure and environmental conditions.
11. Bear in mind that there is no really good postemergence, selective herbicide available for broadleaf weed control over the top of ornamentals.
12. Use Roundup as a wipe-on if possible.
13. When spraying over the top of ornamentals with grass herbicides such as Vantage, Fusilade II and Envoy use a nonionic surfactant rather than crop oil concentrate.
14. Avoid applying postemergence herbicides when temperatures are over 90ºF.
15. Don’t cultivate for 5 to 7 days before and after applying a translocated or systemic herbicide such as Roundup.
16. Do not tank mix Roundup with contact herbicides such as Reward or Finale. They destroy the plant tissue before the Roundup has a chance to translocate through the weed.
17. Nutsedge will not be eradicated by repeat applications of Roundup. It will come back. Roundup does not translocate to the nutsedge tubers. Roundup is more effective than Finale or Reward on nutsedge and other perennials.
18. Cover outdoor soil and mulch piles to prevent weed seed contamination.
19. Keep cultivation for weed control very shallow. Cultivation may bring new weed seeds to the surface, scatter roots, rhizomes, tubers, etc., of perennial weeds or damage roots of ornamentals.
20. Cut woody sprouts in landscape beds with pruning shears and treat the cut end with undiluted Roundup or a 50% triclopyr + water solution to prevent resprouting.
21. Seal the soil around newly transplanted ornamentals with irrigation before applying soil-active herbicides.
22. Install edging that is wide enough for a mower wheel to ride. This will eliminate scalping and leaving an unmowed band of grass.
23. Contact herbicides such as Finale will create a straighter line than a systemic herbicide such as Roundup when edging bermudagrass or other stoloniferous grasses. However, bermudagrass will recover faster from the Finale application. Cutting bermudagrass runners that have rooted in a bed before spraying them will prevent translocation back to the mother plant.
24. Use an even flat fan tip for edging to insure uniform application across the spray pattern.
25. Use granular formulations of preemergence herbicides for greater crop safety.

Vertebrate Pests (Ornamentals)

Problems with vertebrate pests rarely approach the magnitude of the problems caused by weeds, diseases, weather and insects. Under certain circumstances, however, vertebrate pests problems can be significant and difficult to deal with. Specific questions about laws regulating vertebrate pest control should be directed to the Arkansas Game and Fish Commission, 2 Natural Resources Drive, Little Rock, Arkansas 72205, (800) 364-4263 or (501) 223-6300, www.agfc.com. The following information will offer some basic guidelines for determining if vertebrates are a problem and how to control them if they become a problem.

Factors Affecting Control

Several factors complicate the control of vertebrates, including:

- **Mobility.** Certain mammals and birds may come from long distances to damage crops. Thus, they may spend most of their time where they are not a problem.
- **Unpredictability.** Many factors, such as population density, weather and availability of natural food, influence the transition of a normally harmless vertebrate population into the role of a pest problem.
- **Public perception.** The public holds most vertebrates, especially larger ones such as geese or deer, in high esteem. Efforts to control them can then become a complex social problem as well.
- **Legal status.** Most mammals and birds are provided some protection under state and/or federal law as game animals, migratory birds or endangered species. Thus, you need to be aware of the species involved in damage and the legal restrictions relative to controlling it.
- **Control techniques.** Often because of environmental complications or the legal status previously mentioned, control techniques are limited for vertebrate problems. Control may incorporate cultural practices or physical barriers, which admittedly break down under some conditions.

In ornamental plantings in Arkansas, some vertebrate pests that may occur include moles, skunks, armadillos, beavers, rabbits, deer and geese. All of the above except moles and armadillos are either furbearers or game species and are protected under Arkansas and/or federal wildlife laws. The Arkansas Game and Fish Commission should be consulted for appropriate legal aspects concerning relief from nuisance animals.

Moles

The eastern American mole is the only mole of concern in Arkansas. Moles are not rodents and live underground, preferring moist soil. Moles are 4 to 9 inches long and have a rather short tail. Though rarely seen above ground, the eastern mole can be distinguished from other small mammals by its soft, velvety fur and huge, flattened front feet that are equipped with large, broad claws for digging. Eyes are tiny, like a pinhead, and the tail and feet are usually pink. Moles have no visible ears. Earthworms and insect larvae/grubs are their main food source.

Moles owe their status as pests to the feeding tunnels they construct as they burrow in the surface of lawns and golf courses. Moles dig two kinds of tunnels. The feeding tunnel is made only an inch or two below the surface of the ground by the mole "swimming" through the loose topsoil. This kind of runway leaves a ridge of earth on the surface of the ground. The tunnels interfere with mowing and expose roots to air, sometimes killing grass or other plants. More permanent tunnels are made 6 to 10 inches below the surface, and mounds of earth are thrown up at intervals. From the main tunnel of the mole run, a short shaft extends straight up to the surface. The soil that is expelled from this vertical shaft wells up like water, and successive loads form a nearly circular mound of which there may be "ripple marks" in the form of complete circles.

Toxic baits and fumigants are available for controlling moles; however, these control measures often are not very effective. Toxic baits are often based on peanuts, grain or other food items that are not the mole's preferred food, and thus moles seldom take poisonous baits. Fumigants may be inserted in surface feeding tunnels and may kill moles if they happen to be in the tunnels at the time of the treatment. When the use of poisons seems to be effective, the user has probably either frightened the mole out of his present runway by the scent or has killed the food upon which the mole feeds. If moles are deprived of their food supply, they will be forced to seek another area. Several insecticides are capable of reducing populations of earthworms and soil insects to a point where the soil no longer provides sufficient food to fulfill the mole's daily requirements. The effect on the moles cannot be expected for several weeks, and moles can cause increasing damage as they search in a decreasing food supply.

Mole Control Techniques

The most effective method for controlling moles is the use of lethal traps, though this method is also time-consuming. Traps must be carefully placed so as not to arouse the suspicions of moles, which are very sensitive to unnatural changes in their environment.

To establish which tunnels are active, step down on tunnels in several places in the yard. Mark the tamped area with a peg or wire flag. If the tunnel has been pushed back up in a day or so, set the trap in that section of the tunnel. Seek a long, straight runway for setting the trap.

Three trap types are the harpoon, scissor-jawed and choker loop. The scissor-jawed and choker traps require digging and exposing the tunnel. The jaws or loops are set to encircle the tunnel and are triggered when the mole moves through the trap. The harpoon trap is set directly over the runway so that the supporting stakes straddle the runway and its spikes go into the runway. The trap is triggered when the mole's tunneling activity causes the soil to strike the pan and trigger the spikes. Set the trigger pan where it just touches the earth where the soil is packed down. Setting the trigger too high or too low will result in misfires. If any of these traps fail to catch a mole after 2 or 3 days, move the trap to a new location.

When using traps:

- Place a plastic pail with a warning sign over each trap.
- An average set will require 3 to 5 traps per acre.
- Check the trap every day.

Skunks

The striped skunk is the species most commonly encountered in Arkansas. They are black in color with distinctive white stripes that extend laterally over the back. The adults normally weight about 6 to 8 pounds and are 24 to 30 inches long. Skunks have short, stocky legs and disproportionately large feet equipped with will-developed claws for digging. Skunks are usually active from early evening through most of the night. During the day they usually sleep in dens under logs, woodpiles or buildings.

The high nuisance value attributed to skunks is caused by their habit of burrowing in flowerbeds, lawns and golf courses in search of food. Skunks are carnivores and eat insects such as grasshoppers, beetles and crickets, as well as mice, moles, young rabbits, grubs, bees, wasps and their hives. Skunks also eat fruits, some grasses, leaves, buds, roots, nuts and grains. Insects, however, are a preferred food, and skunks often tear up and destroy turf during their search for white grubs and other insect larvae. Digging normally appears as 3- to 4-inch cone-shaped holes or patches of overturned sod. This grubbing activity is most common in the spring and fall when larvae are found near the soil surface.

Skunks are classified as furbearers and as such are protected in Arkansas by state regulations. A hunting license is required from the Arkansas Game and Fish Commission for either live trapping or administering lethal methods of control. With a hunting license, skunks may be live-trapped or killed during furbearing season. If skunk problems need to be handled outside furbearing season, a depredation permit is required. Contact the Arkansas Game and Fish Commission for information on obtaining this permit. Note that a depredation permit does not include permission to shoot skunks when local law prohibits discharge of firearms.

Skunks can carry rabies, and thus skunks that are overly aggressive or show abnormal behavior should be treated cautiously. The Arkansas Department of Health suggests that any skunk that is observed during daylight is acting abnormally and should be destroyed to prevent the spread or rabies. Contact the local animal control or sheriff's office for assistance with disposing of a rabid skunk. Avoid shooting or striking the head to protect against damaging the brain for testing for rabies, and keep in mind that most skunks will release their scent when shot, so try to avoid shooting them near buildings. If removing a potentially rabid skunk, gloves and/or shovels should be used. Place the skunk in a sealed plastic bag and bury the carcass where pets will not dig it up.

Skunk Control Techniques

Removal and relocation in combination with exclusion methods oftentimes is the best option for addressing skunk problems. Shooting is also an option, where legal and with proper hunting license or depredation permit. There are no toxicants or repellents registered for skunks.

Typically, skunk problems involve removing and excluding skunks from a den site. Avoid skunk removal from May through early August when den-bound, immobile young may be present. A combination of live trapping, relocation and exclusion are recommended as follows.

- **Live trapping.** Bait live traps with a few tablespoons of pet food having a fish base. When using a wire cage trap, place a tarp or plywood shell around the cage. Check the trap frequently, particularly in the summer, as skunks could die from excessive heat, leading to accusations of inhumane treatment. After a skunk is trapped, cover the opening so the skunk cannot see. With a minimum of jarring or shaking, the trapped skunk can be transported and released with little concern for a musk discharge. Leg-hold traps can be used to catch skunks, but because of odor problems, this method should not be used near housing.
- **Relocation.** When relocating skunks, transport them at least 10 miles and release in habitat far from human dwellings.
- **Exclusion.** Typically, more than one skunk occupies a denning site. Seal off all foundation openings except one. Cover openings with wire mesh, sheet metal or concrete. Skunks may dig to gain entry, so obstructions such as fencing should be buried 1 1/2 to 2 feet. In front of the remaining opening, spread a layer of flour on the ground. Typically, skunks are active at night. Check at night for tracks indicating the skunks have left the den and then seal the opening. To ensure no skunks are sealed inside, use one or both of the following approaches.
  - For several successive nights, unseal one opening at dark and place flour on the ground. After a couple hours, check for tracks exiting the den and reseal the opening. If no tracks are detected after several nights, seal the opening permanently.
  - Place a trap inside the sealed up area. Bait with pet food and water. Remove and translocate any trapped skunks. Repeat until no skunks are trapped on successive days.

Odor Abatement

When a skunk raises its tail, it is a warning. When a skunk's hind legs begin hopping, leave the vicinity as quickly as possible. Ordinarily, there is no discharge. But, if a skunk believes it is in danger, one discharge will not empty the reservoir. Many people find the odor repugnant or even nauseating. Because of its persistence, the scent is difficult to remove. Diluted solutions of vinegar or tomato juice can have limited effectiveness when applied to pets, people or clothing. Clothing can be soaked in weak solutions of household chlorine bleach or ammonia, but oftentimes the clothing is also ruined using this treatment. For spraying under foundations or structures, a number of skunk deodorizers are on the market. These offer some relief by masking, rather than removing, the odor.

Armadillos

The armadillo is mainly nocturnal during the summer and may be diurnal during the winter. It digs burrows that are usually 7 inches to 8 inches in diameter and as much as 15 feet in length. The burrows are located in rock piles and around stumps, brush piles and dense woodlands. More than 90 percent of the armadillo's diet consists of insects, but the animals also feed on lizards, frogs, snakes, bird eggs, berries, fruits and roots. An armadillo pursuing insects in the ornamental landscape or in turf will tear and uproot an area similar to skunks but at somewhat deeper depths.

The young are born in a nest within the burrow. The female produces only one litter each year in March or April. The litter always has quadruplets of the same sex and each appears identical since they are derived from a single egg. The armadillo has poor eyesight but a rather keen sense of smell. In spite of its cumbersome appearance, the agile armadillo can run well when in danger.

Armadillo Control Techniques

Since most of the damage caused by armadillos is a result of their rooting for insects and other invertebrates in the soil, an insecticide may be used to remove the food sources and make areas less attractive to armadillos. Also, trapping armadillos has proven to be a fairly successful elimination method. Armadillos can be captured in live or box traps such as the Havahart or Tomahawk. If bait is desired, use overripe or spoiled fruit. Other suggested baits are fetid meats or mealworms.

Beavers

Beavers are classified as furbearers and as such are protected in Arkansas by state regulations. A hunting license is required from the Arkansas Game and Fish Commission for either live trapping or administering lethal methods of control. With a hunting license, beavers may be live-trapped or killed during furbearing season. If beaver problems need to be handled outside furbearing season, a depredation permit is required. Contact the Arkansas Game and Fish Commission for information on obtaining this permit. Note that a depredation permit does not include permission to shoot beavers when local law prohibits discharge of firearms.

In Arkansas, beavers rarely present a problem in the urban landscape, but when they do, they gnaw and fell trees and dam drainages, flooding yards, parks and other areas. The only way to manage a beaver problem in urban landscapes is to live trap and relocate the beavers. Shooting is seldom an option in urban situations. Likewise, there are no pesticide products for repelling beavers. To obtain assistance in controlling beavers, contact the Arkansas Game and Fish Commission

Rabbits

Rabbits are considered game species and are protected under Arkansas and/or federal wildlife laws. The Arkansas Game and Fish Commission should be consulted for appropriate legal aspects concerning relief from nuisance animals. While being desired as small-game animals, rabbits can also be serious pests, particularly during the winter when they browse on the bark and branches of ornamental trees and shrubs. When natural controls fail to keep rabbit populations within tolerable limits, nursery and landscape managers may be forced to implement control measures on their properties.

One frequently overlooked control measure is removing brush piles, stone and trash heaps, weed patches and other structures that rabbits use for refuge. By eliminating this "cover," managers are making their properties less desirable rabbit habitats.

No lethal chemicals are registered for rabbit control, although a wide variety of repellents is available. Repellents are sometimes used to help reduce plant damage. Rabbits may eat repellent-treated plant parts when more palatable food is not available. Repellents should be applied to plant parts that will be within the reach of rabbits when snow is on the ground. Because all repellents degrade due to rain, wind and sunlight, several applications may be necessary.

Live trapping and removal is another approach to rabbit control that helps reduce plant damage and preserves a small-game resource. Generally, rabbits forage in an area of only a few acres. Transferring captured rabbits to an appropriate area outside this range makes their return unlikely.

Tree guards are probably the surest way to prevent rabbit damage. When installing these guards, be certain that the barrier will extend above the snow cover. A two-foot chicken wire fence around the perimeter of a garden can eliminate damage problems for a relatively small investment. In some areas, rabbit problems will reoccur, although sporadically.

Deer

Deer are one of the most prized of Arkansas' wildlife species. Deer hunting alone contributes millions of dollars to the state's economy, but the big-game animal is also a cherished sight for vacationers and landowners alike. Deer, however, also feed on nursery and landscape plants, sometimes causing serious losses. Because deer are a public resource, managers whose plants are killed or damaged by feeding must rely on protective controls like frightening devices, repellents and fences. Where allowed, hunting during the legal season may also be a solution to deer problems. A variety of repellents are available. These repellents range from human hair placed in small mesh bags and hung from branches to a number of commercial products. Two types of repellents, contact and area, are frequently used. Contact repellents, such as hot pepper sauce, are applied directly on the plants to be protected. Unlike contact repellents, which make treated plant parts unpalatable, area repellents repel by smell alone.

Fences are the only sure way to eliminate deer damage. Both wire-mesh and electric fences are used. Electric fences are cheaper to build than mesh fences but are more expensive to maintain and may fail for a variety of reasons. There are a number of deer-fence designs, and researchers are continually working on improvements.

Geese

Wild geese are a federally protected migratory species. Domestic geese, such as white geese and graylags, are not under the jurisdiction of the Arkansas Game and Fish Commission or the federal government. Because wild geese are federally protected, USDA Wildlife Services (501-362-5382, 870-673-1121) can provide the best information concerning alternatives for controlling geese problems. Resident Canada geese should be referred to the Arkansas Game and Fish Commission (800-364-4263).

Canada geese need a permanent body of water on which to land, escape, rest and roost. They also need a suitable open feeding area that provides a place to land, has good visibility of the surrounding territory and has abundant tender young grass and other vegetation for feeding. Canada geese in Arkansas consist of both migratory and nonmigratory populations. Migratory birds nest in Canada and migrate south for the winter.

Most complaints about damage come from areas where birds congregate in public or private ponds and feed in mowed areas in parks, near beaches and on golf courses and lawns. Fecal droppings damage lawns and golf greens and can limit recreational use of the area. Fecal contamination of water may pose a local pollution problem, although typically it is not a threat to human health. Geese defending their territory can injure people who come too close.

Goose Control Techniques

Hunting

Geese may be taken during declared open hunting seasons. Hunting, where safe and legal, is the preferred method of reducing nonmigratory waterfowl, and over time, may serve to decrease damage. Hunting also makes frightening techniques more effective. In some cases, local ordinances would need to be changed to permit hunting in nontraditional areas such as parks and golf courses. Special restrictions on hours and dates open to hunting can be implemented. Contact the Arkansas Game and Fish Commission for current information on waterfowl hunting regulations and seasons.

Discontinue Feeding

Well-fed domestic "park ducks" and geese serve as decoys, encouraging wild birds to congregate in unnaturally high concentrations. Therefore, discontinued feeding should be the first control measure.

Frightening

Geese can be repelled by almost any large foreign object or mechanical noise-making device. Frightening devices should be in place before the start of the damage season to prevent geese from establishing a use pattern. To prevent birds from becoming accustomed to the frightening device, it should be moved every 2 or 3 days and used in varying combinations.

Visual repellents such as flags, balloons and scarecrows can be used at a density of one per 3 to 5 acres before waterfowl settle into the area. If birds are already present, an additional one or more visual repellents per acre may be necessary. Because geese can quickly acclimate to stationary visual repellents, reinforcement with audio repellents may be necessary. A unique "nonstationary" visual repellent on the market is a simulated floating alligator head for small ponds. However, the effectiveness of this product has not been studied.

Pyrotechnics, shell crackers or other noise-making devises can be effective if used before birds become established. A disadvantage is that neighbors may not appreciate the loud noises that are produced. A less-invasive product on the market is a programmable electronic devise that plays recorded goose alarm calls in random combinations. The recordings can be set to play at dawn and dusk using multiple speakers to create natural sound patterns of disturbed geese.

Dogs trained to chase waterfowl have been used to protect golf courses and orchards. In certain situations, they can be very effective, such as when geese become adapted to pyrotechnics and other forms of hazing. Dogs can be free running, on slip-wires, tethered, contained by an underground "invisible fence" or controlled by a handler. On one golf course in Oregon, a professional dog trainer used four border collies to frighten geese three to five times per day for the first several days. The geese soon left, and hazing diminished over time. The golf course purchased one dog to continue the program.

All applicable laws must be observed when using these devices, particularly those governing loud noises, discharging of firearms, use of pyrotechnics and use of free-ranging dogs. Note that nesting waterfowl cannot be harassed without a federal permit. In addition, flightless geese should not be harassed.

Habitat Modification

There are several ways to make a pond and its surroundings unattractive to waterfowl. However, these practices may also degrade habitat quality for other wildlife and fish species, so use with caution. Constructing an abrupt 18- to 24-inch vertical bank at the water's edge will deter geese. On levees or banks, use large boulder riprap, which geese cannot easily climb over. Eliminate emergent aquatic vegetation with herbicides or an aquatic weed harvester or by temporarily draining the pond. If possible, allow woody brush to grow around shorelines.

On lawns or areas surrounding ponds, reduce or eliminate fertilizer applications so that grass is less nutritious for grazing waterfowl. If possible, increase grass height to 10 to14 inches, especially along shorelines. Consider replacing large lawn areas with clumps of shrubs or trees, ground covers such as myrtle or less palatable grass species such as fescue. Planting trees will interfere with the birds' flight paths, and shrubs reduce the birds' ability to see from the ground. Landscaping techniques that reduce the birds' view to less than 25 to 30 feet discourages grazing, especially if harassment programs are also used.

Exclusion

Canada geese may be discouraged from using ponds by installing a 30- to 36-inch high poultry wire fence at the water's edge. (This technique, however, is not effective for ducks.) Geese are reluctant to pass under a wire fence, so installing a single-strand fence or one made of Mylar flashing tape at a height of about 15 inches may discourage geese from entering an area. Good results have been reported using 20-pound test, or heavier, monofilament line to make a two- to three-strand fence in situations where aesthetics preclude the use of wire fencing. String the first line 6 inches off the ground, with each additional line spaced 6 inches above the preceding line. Suspend thin trips of aluminum foil at 3- to 6-foot intervals along lines to increase visibility of the barrier for wildlife and people.

To stop waterfowl from using lakes, ponds or reservoirs, construct overhead grids of thin cable visible to both humans and waterfowl. White or brightly colored cables may improve visibility. Because these materials are extremely light, several hundred feet can be supported between two standard 5-foot steel fence posts. Grids on 20-foot centers will stop geese, and grids on 10-foot centers will stop most ducks. When necessary, grid lines should be installed high enough to allow people and equipment to move beneath them. Excessive rubbing will result in line breakage, so grid wires should be tied together wherever lines cross. Attach lines independently to each post and not in a constant run, to prevent having to rebuild the entire grid if a line breaks. Polypropylene UV-protected netting can be used to provide total exclusion from a lake or pond. Support the netting with 0.19-inch 7 x 19 strand galvanized coated cable on 20-foot centers.

Repellents

Repellents can be effective for short-term control. Methyl anthranilate is a chemical that has taste and olfactory repellent properties that can be sprayed on turf. Other chemicals may be on the market as well. Once the repellent dries, it does not wash off the grass, even in heavy rain. However, mowing treated grass will expose untreated grass to geese and reduce the repellent's effectiveness. One study of a product with methyl anthranilate indicated that treating the first 100 feet of turf from the water's edge reduced bird activity over the remainder of the area; therefore, treating the entire area was unnecessary. Additionally, methyl anthranilate was mixed and applied with the herbicide 2,4-D, which did not change its effectiveness in repelling geese. Repellents, when used in combination with other techniques, may help reduce goose damage to lawns, golf courses and other turf areas.

Summary

The key to controlling nuisance flocks of geese is promptness and persistence. Methods of controlling damage will work only as well as their implementation. Once nuisance waterfowl are gone from an area, the area must be made unattractive to waterfowl so they will not return. As soon as one goose or duck lands, it should be frightened until it leaves. Otherwise, the bird will act as a decoy and attract others.

Calibration of Commercial Pesticide Application Equipment (Ornamentals)

The performance of any pesticide depends upon the proper application over a given area. This section will cover calibration of equipment used by commercial landscape applicators for liquid and dry applications of pesticides. For ornamentals such as shrubs and small trees, manually operated sprayers or low-pressure, power sprayers fitted with single-nozzle spray guns are normally used. For spraying tall shade trees, high-pressure, high-volume hydraulic or air-carrier sprayers are commonly utilized.

Manual Sprayers

Manual sprayers such as compressed air and knapsack sprayers are designed for spot treatment and for restricted areas unsuitable for larger units **(Figure 1.7.1)**. For pressurizing the supply tank, most manual sprayers use compressed air or carbon dioxide which forces the spray liquid through a nozzle. Several types of small power sprayers that deliver 1 to 3 gallons per minute (GPM) at pressures up to 300 pounds per square inch (psi) are available. Adjustable handguns are usually used with these units, but spray booms are available on some models. These sprayers are relatively inexpensive, simple to operate, maneuverable and easy to clean and store.

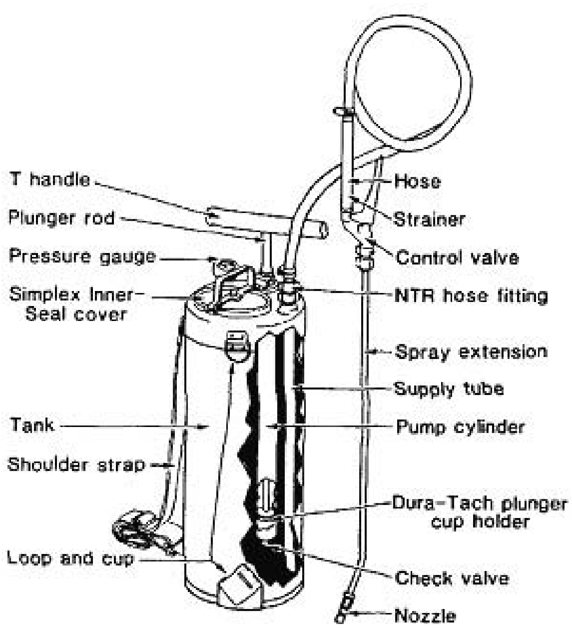


Figure 1.7.1. Compressed air sprayer.

How Do I Calibrate My Manual Sprayer?

Manual sprayers are generally used on small areas, so it is recommended that the amount of spray to be applied should be determined on small areas, such as 1,000 square feet. Most manual compressed air sprayers do not have pressure gages or pressure controls. The pressure in the tank will drop as the material is sprayed from the tank. This pressure drop can be partly overcome by filling the tank only two-thirds full with spray material, so a considerable air space is left for initial expansion, and by repressurizing the tank frequently. If the sprayer has a pressure gage, repressurize when the pressure drops approximately 10 psi from the initial reading.

When spraying, either hold the nozzle at a steady, constant height and spray back and forth in swaths, or swing the nozzle back and forth at a uniform speed in a sweeping, overlapping motion. A uniform walking speed must be maintained during application.

The amount of spray solution applied per 1,000 square feet can be determined as follows:

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

Step 2. Place a measured amount of water in the tank, spray the area and then measure the amount of water remaining in the tank. The difference between the amount in the tank before and after spraying is the amount used.

Example: 2 gal. added, minus 0.5 gal. left = 1.5 gal./1,000 sq. ft.

Power Sprayers

How Do I Select the Proper Tip Size for a Self-Propelled Sprayer?

The size of the nozzle tip will depend upon the application rate (gallons per acre, or GPA), ground speed (miles per hour, or mph) and effective sprayed width (W) that you plan to use. Some manufacturers advertise gallons-per-acre nozzles, but this rating is useful only for standard conditions (usually 30 psi, 4 mph and 20-inch spacings). The gallons-per-acre rating is useless if any one of your conditions varies from the standard.

A more exact method of choosing the correct nozzle tip is to determine the gallons per minute (GPM) required for your conditions and then select nozzles that provide this flow rate when operated within the recommended pressure range. By following the five steps described below, you can select the nozzle required for each application well ahead of the spraying season.

Step 1. Select the spray application rate in gallons per acre (GPA) that you want to use. Pesticide labels recommend ranges for various types of equipment. The spray application rate is the gallons of carrier (water, fertilizer, etc.) and pesticide applied per treated acre.

Step 2. Select or measure an appropriate ground speed in miles per hour (mph), according to existing field conditions. Do not rely upon speedometers as an accurate measure of speed. Slippage and variation in tire sizes can result in speedometer errors of 30 percent or more. If you do not know the actual ground speed, you can easily measure it. (See the section entitled, "How Is Ground Speed Measured?")

Step 3. Determine the effective sprayed width per nozzle (W) in inches. For broadcast spraying, W = the nozzle spacing.

Step 4. Determine the flow rate required from each nozzle in gallons per minute (GPM) by using a nozzle catalog, tables or the following equation.

Table 1.7.1. Regular flat fan nozzles.

Delavan Tip No.	Spraying Systems Liquid Tip No.	Capacity Pressure in psi	1 Nozzle in GPM
LF-67	800067	20	.05
(100 mesh)	(100 mesh)	25	.055
		30	.06
		40	067
		50	.07
LF-1	8001	20	.07
(100 mesh)	(100 mesh)	25	.08
		30	.09
		40	.10
		50	.17
LF-1.5	80015	20	.11
(100 mesh)	(100 mesh)	25	.12
		30	.13
		40	.15
		50	.17
LF-2	8002	20	.14
(50 mesh)	(50 mesh)	25	.16
		30	.26
		40	.20
		50	.23
LF-3	8003	20	.21
(50 mesh)	(50 mesh)	25	.24
		30	.26
		40	.30
		50	.34
LF-4	8004	20	.28
(50 mesh)	(50 mesh)	25	.32
		30	.35
		40	40
		50	.45
LF-5	8005	20	.35
(50 mesh)	(50 mesh)	25	.40
		30	.43
		40	.50
		50	.56
LF-6	8006	20	.42
(50 mesh)	(50 mesh)	25	.47
		30	.52
		40	.60
		50	.67
LF-8	8008	20	.57
(50 mesh)	(50 mesh)	25	.63
		30	.69
		40	.80
		50	.89
LF-10	8010	20	.71
	(no strainer)	35	.79
		30	.67
		40	1.00
		50	1.12
LF-15	8015	20	1.06
	(no strainer)	25	1.19
		30	1.30
		40	1.50
		50	1.68

$$GPM = \frac{GPA \times mph \times W}{5{,}940} \quad \textbf{(Equation 1)}$$

GPM = gallons per minute of output from each nozzle.
GPA = gallons per acre desired from Step 1.
mph = miles per hour from Step 2.
W = inches sprayed per nozzle from Step 3.
5,940 = a constant to convert gallons per minute, miles per hour, and inches to gallons per acre.

Step 5. Select a nozzle that will give the flow rate determined in Step 4 when the nozzle is operated within the recommended pressure range. You should obtain a catalog listing available nozzle tips. These catalogs may be obtained free of charge from equipment dealers or nozzle manufacturers. If you decide to use nozzles that you already have, return to Step 2 and select a speed that allows you to operate within the recommended pressure range.

Example: You want to broadcast an herbicide at 25 GPA (Step 1) at a speed of 5 mph (Step 2), using regular flat-fan nozzles spaced 20 inches apart at the boom (Step 3). What nozzle tip should you select?

The required flow rate for each nozzle (Step 4) is as follows:

$$GPM = \frac{GPA \times mph \times W}{5{,}940}$$

$$GPM = \frac{25 \times 5 \times 20}{5{,}940} = \frac{2{,}500}{5{,}940} = 0.42 \text{ gal.}$$

The nozzle that you select must have a flow rate of 0.42 GPM when operated within the recommended pressure range of 15 to 30 psi. **Table 1.7.1** shows the GPM at various pressures for several Spraying Systems and Delavan nozzles. For example, the Spraying Systems 8006 and Delavan LF6 nozzles have a rated output of 0.42 GPM at 20 psi (Step 5). Either of these nozzles can be purchased for this application.

How Do I Select the Proper Nozzle Tip Size for My Hand-Held Boom?

The size of the nozzle tip will depend upon the application rate (gallons per 1,000 square feet), the walking speed (seconds per 1,000 square feet) and the effective sprayed width (feet between the nozzles, multiplied by the number of nozzles).

An exact method for choosing the correct nozzle tip is to determine the gallons per minute (GPM) required for your conditions and then select nozzles from a nozzle manufacturer's catalog that provide this flow rate when operated within the recommended pressure range. By following the steps described below, you can select the nozzles required for each application well ahead of the spraying season.

Step 1. Determine the application rate in gallons per 1,000 square feet. Pesticide labels contain recommended volume ranges for various types of equipment and pests. The spray application rate may be given in gallons of carrier (water, fertilizer, etc.) and pesticide applied per acre (GPA) rather than gallons per 1,000 square feet. GPA can be converted to gallons per 1,000 square feet by the following equation:

$$\text{Gal./1,000 sq. ft.} = \frac{\text{Gal./acre} \times 1{,}000 \text{ sq. ft.}}{43{,}560 \text{ sq. ft./acre}} \quad \textbf{(Equation 2)}$$

Example: A fungicide label recommends using 50 gal./acre. What is the application rate in gal./1,000 square feet?

$$\text{Gal./1,000 sq. ft.} = \frac{50 \text{ gal./acre} \times 1{,}000 \text{ sq. ft.}}{43{,}560 \text{ sq. ft./acre}}$$

$$\frac{50{,}000}{43{,}560} = 1.15 \text{ gal./1,000 sq. ft.}$$

Step 2. Determine the effective sprayed width in feet. For hand-held booms, this is the distance between the nozzles multiplied by the number of nozzles on the spray boom.

Example: Your walking boom has two nozzles spaced 30 inches apart. What is the effective sprayed width? (30 inches = 2.5 feet) Effective sprayed width = 2 nozzles x 2.5 feet = 5 feet.

Step 3. Measure the time in seconds required to spray a 1,000 square foot area. This can be easily determined by using your sprayed width from Step 2 and laying out a course of 1,000 square feet. To lay out a single pass course that has 1,000 square feet, use the following equation:

$$\text{Length of course (ft.)} = \frac{1{,}000 \text{ sq. ft.}}{\text{(ft.) sprayed width}} \quad \textbf{(Equation 3)}$$

Example: Your boom has a five-foot effective sprayed width. What length course would be required for 1,000 square feet?

$$\text{Length of course (ft.)} = \frac{\text{1,000 sq. ft.}}{\text{5 ft. sprayed width}} = \text{200 ft.}$$

Mark off a 200-foot course, and time your walking speed through this course. Do this several times and record the average time.

Example:

$$\text{Average time} = \frac{44 + 46}{2} = \text{45 seconds}$$

$$\frac{\text{45 sec.}}{\text{60 sec./min.}} = \text{0.75 min. to walk 200-ft. course}$$

This means that it will take you 0.75 minutes to cover 1,000 square foot area with your two-nozzle hand boom.

Step 4. Determine the flow rate required from each nozzle in gallons per minute (GPM) by using the following equation:

$$\text{GPM} = \frac{\text{gal./1,000 sq. ft.}}{\text{min./1,000 sq. ft.}} \qquad \textbf{(Equation 4)}$$

Example: The gal./1,000 square feet is 1.15 (Step 1) and 0.75 minute is required to spray 1,000 square feet (Step 3). What is the required nozzle flow rate from the boom?

$$\text{GPM} = \frac{\text{1.15 gal./1,000 sq. ft.}}{\text{0.75 min./1,000 sq. ft.}} = \text{1.5 gal./min.}$$

Since there are two nozzles per boom, the required flow rate per nozzle is 0.75 gal./min. (1.5 ÷ 2 = 0.75).

Step 5. Select a nozzle that will give the flow rate determined in Step 4 when the nozzle is operated within the recommended pressure range. You should obtain a catalog that lists available nozzle tips. These catalogs may be obtained free of charge from equipment dealers or nozzle manufacturers.

How Do I Calibrate My Sprayer?

Precalibration Check

After making sure that your sprayer is clean, install the selected nozzle tips, partially fill the tank with clean water and operate the sprayer at a pressure within the recommended range. Place a container (for example, a container marked in inches) under each nozzle. Check to see whether all of the jars fill at about the same time. Replace any nozzle that has an output of 5 percent more or less than the average of all the nozzles, an obviously different fan angle or an uneven appearance in spray pattern.

To obtain uniform coverage, you must consider the spray angle and height of the nozzle. The height must be adjusted for uniform coverage with various spray angles and nozzle spacings. Do not use nozzles with different spray angles on the same boom for broadcast spraying.

Worn or partially plugged nozzles produce uneven patterns. Misalignment of nozzle tips is a common cause of uneven coverage. The boom must be level at all times – coverage will be uneven if one end of the boom is allowed to droop. A practical method for determining the exact nozzle height that will produce the most uniform coverage is to spray on a warm surface, such as a road, and observe the drying rate. Adjust the height to eliminate excess streaking.

Sprayer Calibration

Now that you have selected and installed the proper nozzle tips (Steps 1 and 5), you are ready to complete the calibration of your sprayer (Steps 6 to 10). Check the calibration every few days during the season or when changing the pesticides being applied. New nozzles do not lessen the need to calibrate, because some nozzles "wear in" and will increase their flow rate rapidly during the first few hours of use. Once you have learned the following calibration method, you can check application rates quickly and easily.

Step 6. Determine the required flow rate for each nozzle in ounces per minute (OPM). To convert the GPM (Step 4) to OPM, use the following equation:

$$\text{OPM} = \text{GPM} \times 128 \qquad \textbf{(Equation 5)}$$

(1 gallon = 128 ounces)

Example: The required nozzle flow rate = 0.56 GPM. What is the required OPM?

$$\text{OPM} = 0.56 \times 128 = 71.7 \text{ OPM}$$

Step 7. Collect the output from one of the nozzles in a container marked in ounces. Adjust the pressure until the ounces per minute (OPM) collected is the same as the amount that you calculated for their outputs to fall within 5 percent of the desired OPM.

If it becomes impossible to obtain the desired output within the recommended range of operating pressures, select larger or smaller nozzle tips and recalibrate. It is important for spray nozzles to be operated within the recommended pressure range. (The range of operating pressures is for pressure at the nozzle tip. Line losses, nozzles check valves, etc., may require the main pressure gage at the boom or at the controls to reach a much higher level.)

Step 8. Determine the amount of pesticide needed for each tankful or for the area to be sprayed. (See the "Mixing and Loading Pesticides" section.) Add the pesticide according to label directions or to a partially filled tank of carrier (water, fertilizer, etc.), then add the carrier with continuous agitation to the desired level.

Step 9. Operate the sprayer at the speed and pressure determined in Step 7. You will be spraying at the application rate that you selected in Step 1. After spraying a known area, check the liquid level in the tank to verify that the application rate is correct.

Step 10. Check the nozzle flow rate frequently. Adjust the pressure to compensate for small changes in nozzle output resulting from nozzle wear or variations in other spraying components. Replace the nozzle tips and recalibrate when the output has changed 10 percent or more from that of a new nozzle or when the pattern has become uneven.

How Is Ground Speed Measured?

To apply pesticides accurately, you must maintain the proper ground speed. When using trucks or tractor-powered equipment, do not rely on speedometers as an accurate measure of speed. Slippage can result in errors of 30 percent or higher in speedometer readings. Changes in tire size also affect speedometer readings, and the accuracy of all speedometers should be checked periodically. Speedometer kits are available that do not use drive wheels for speed measurements. Ground speed must also be determined for hand-held application equipment. Ground speed is determined the same way for both power-driven and hand-held equipment.

To determine ground speed, measure a distance in the area to be sprayed or in an area with similar surface conditions. Suggested distances are 100 feet for speeds up to 5 mph, 200 feet for speeds from 5 to 10 mph and at least 300 feet for speeds above 10 mph. At the engine throttle setting and gear that you plan to use during spraying with a loaded power sprayer, determine the travel time between the measuring stakes in each direction. Average these speeds and use the following equation to determine ground speed:

$$\text{Speed (mph)} = \frac{\text{distance (feet)} \times 60}{\text{time (seconds)} \times 88} \qquad \textbf{(Equation 6)}$$

(1 mph = 88 feet in 60 seconds)

Example: You measure a 200-foot course and discover that 22 seconds are required for the first pass and 24 seconds for the return pass.

$$\text{Average time} = \frac{22 + 24}{2} = 23 \text{ seconds}$$

$$\text{mph} = \frac{200 \times 60}{23 \times 88} = \frac{12{,}000}{2024} = 5.9 \text{ mph}$$

Once you have decided upon a particular speed, record the throttle setting and drive gear used.

How Do I Check the Spray Rate When Using Existing Nozzles?

You may already have a set of nozzle tips in your boom, and you want to know the spray rate (GPA or gal./1,000 sq. ft.) when operating at a particular nozzle pressure and speed.

Add water to the spray tank and make a precalibration check to be sure that all of the spray components are working property. Remember, the type, size and fan angle of all the nozzle tips must be the same. The flow rate from each nozzle must be within 5 percent of the average flow rate from the other nozzles.

Step 1. Operate the sprayer at the desired operating pressure. Use a container marked in ounces to collect the output of a nozzle for a measured length of time, such as 1 minute. Check several other nozzles to determine the average number of ounces per minute (OPM) output from each nozzle.

Step 2. Convert OPM of flow to GPM of flow by dividing the OPM by 128 (the number of ounces in 1 gallon),

Step 3. Determine the spraying speed. For mounted boom sprayers, the speed in mph can easily be measured (Equation 7).

Step 4. Determine the sprayed width per nozzle (W) in inches. For broadcast spraying, W = the nozzle spacing.

Step 5. Calculate the sprayer application rate. For mounted boom sprayers, use Equation 1.

$$\text{GPM} = \frac{\text{GPM x 5,940}}{\text{mph x W}}$$

Example: The measured nozzle output is 54 OPM, the measured ground speed is 6 mph and the nozzle spacing (W) is 20 inches.

$$\text{GPM} = \frac{54}{128} = 0.42$$

$$\text{GPA} = \frac{0.42 \text{ x } 5{,}940}{6 \text{ x } 20} = \frac{2{,}495}{120} = 20.8 \text{ GPA}$$

Application rate can be adjusted by changing the ground speed or nozzle pressure and then recalibrating. Changes in nozzle pressure should be used only to make small changes in output and must be maintained within the recommended pressure range.

Granular Applicators

Many lawn and ornamental care service applicators use granular products as a part of their program or even as a complete program. Proper selection, care, calibration and use of granular applicators can minimize costs and maximize the results obtained. Improper use of granular applicators can reduce product efficiency, cause injury to ornamentals, increase costs and harm the environment.

What Type of Granular Applicator Should I Select?

Drop (gravity) and rotary (centrifugal) spreaders are available for applying granules. Drop spreaders **(Figure 1.7.2)** are generally more precise and deliver a better pattern. Since the granules drop straight down, there is less pesticide drift and better control. Some drop spreaders will not handle large granules, and ground clearance in ornamental settings can be a problem. Since the edge of the drop spreader is the limit of pesticide distribution, the applicator must be very careful to align the swaths correctly to provide proper application. It is easy to either overlap or skip areas with drop spreaders if one is not attuned to the pattern of the spreaders.

Rotary or centrifugal spreaders **(Figure 1.7.3)** cover a wide swath and thus cover a given area faster. However, they are less precise than drop spreaders in terms of uniformity and distribution. Because of pattern feathering, steering errors are less critical. Since they do not have a full width agitator to turn, they require less effort to push. Rotary spreaders normally handle large particles well, but drift is a problem with fine particles when wind is excessive. Ground clearance in ornamental settings is usually a problem for rotary spreaders also. Since rotary patterns vary, more calibration time is needed. A major advantage of rotary spreaders is that they can be made of plastics and fiberglass and therefore are more resistant to corrosion. Rotary spreaders are also more durable in commercial use and less likely to be knocked out of calibration than some drop spreaders.

Experienced operators are familiar with proper use of granular applicators, but new operators should review the basic operating procedures.

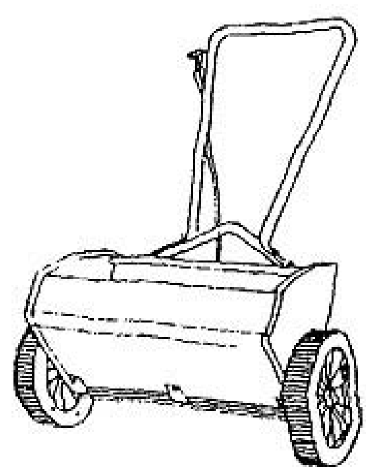


Figure 1.7.2. Drop spreader.

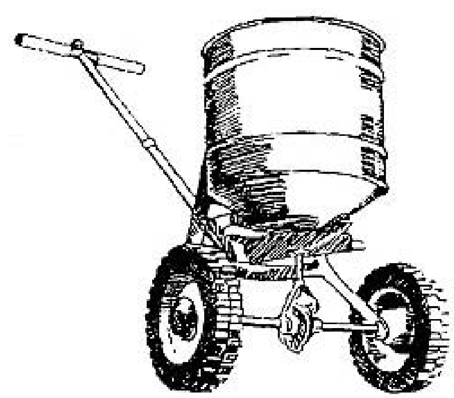


Figure 1.7.3. Centrifugal spreader.

Begin by reading the operator's manual or instruction booklet provided by the manufacturer and follow the manufacturer's instructions. The second obvious recommendation is to follow the instructions on the product label, modifying rate and pattern settings, if necessary, for specific conditions.

Header strips at each end of the ornamental area provide a place to turn around and realign the spreader and serve to make the border area more uniform. Operators should always get the spreader moving at rated speed (normally 3 miles per hour) on the header strip or on a driveway, sidewalk, etc., and then open the spreader as the spreader crosses into the area to be treated. At the other end, the spreader should be closed when moving into the header strip and turning. A spreader should be closed when stopped to prevent the product from being applied to a small area. Likewise, the end turns should be made with the spreader closed, since the application pattern would be very irregular while turning.

Occasionally, it may be impossible to obtain a completely acceptable pattern with a rotary spreader, and striping of the ornamental bed may result. A common approach to this problem is to reduce the setting to a half rate and go over the bed twice at right angles. This is not a valid solution to the problem. This approach will not average out the pattern, but will merely change stripes into a diagonal checkerboard. If pattern problems cannot be corrected, the proper procedure is to reduce the setting to a half rate and reduce the swath width in half, but still go back and forth in parallel swaths.

General Considerations

Normally, a spreader should not be operated backwards. It is obvious with most rotary spreaders that pulling the spreader backwards will deliver an unacceptable pattern. There is a problem also with reversing the direction of a drop spreader. Most drop spreaders will deliver granules at a considerably different rate at the same setting if reversed. In some cases such as in loose soil with new seedings, the spreader may be easier to pull than to push. If it is desired to operate a spreader backwards, a different setting must be determined.

Some rotary spreaders enable you to cut off one side of the pattern. This feature is desirable when edging along driveways, sidewalks, etc.

Fill the spreader on a paved surface rather than in the bed. If a spill occurs, a driveway is much easier to sweep clean than a bed.

There are two important aspects to the precise application of granular products. The first is the product application rate. This term refers to the overall average amount of product applied in pounds per thousand square feet. Overapplication is costly, increases the risk of plant injury and may be illegal if label recommendations are exceeded. Underapplication can reduce the product efficacy and cause customer dissatisfaction. Flow rate from granular applicators does not change proportionately with changes in speed. Therefore, uniform ground speed is necessary to maintain a uniform application rate, and constant speed is needed if predeveloped settings are to be accurate.

Equally important is uniform distribution. This aspect is different from the application rate. A pesticide might be labeled for application at 4 pounds per 1,000 square feet, If a spreader applies 20 pounds to a 5,000 square foot bed, the apparent rate of application is correct, but it is possible some areas of the bed will receive twice as much pesticide per square foot as other areas. It is impossible to achieve absolutely uniform distribution with any granular applicator, but the most uniform distribution possible is particularly important with ornamentals. Under certain conditions, small differences in rate on different areas may result in poor pest control.

With drop spreaders, the distribution pattern, whether good or bad, is normally the same within a fairly broad range, regardless of speed, product physical characteristics, the environment and other factors. Rotary spreader patterns, on the other hand, are sensitive to these variables, and severe pattern skewing can result if the operator neglects these variables. The pattern applied by a rotary spreader is dependent on impeller characteristics (height, angle, speed, shape and roughness), ground speed, drop point of the product on the impeller, product physical parameters (density, shape and roughness of particles) and environmental factors (temperature and humidity). Most of these factors are beyond the control of the spreader operator.

Spreader engineers normally try to design rotary spreaders to give an acceptable distribution pattern for a broad range of products and operating conditions. Small rotaries, particularly homeowner models, usually do not have any pattern adjustment and are designed to perform well with average products and to work acceptably well with a fairly wide range of products. This is possible because of the limited swath width. The wider pattern of the larger commercial rotary spreaders is more susceptible to skewing, thus a means of adjustment is usually provided for pattern distribution. This adjustment typically consists of blocking off part of the metering port(s) on smaller units and moving the metering point or changing the impeller geometry on larger units.

It is essential the operator be aware of the need for pattern adjustments and know how to make adjustments. The operator should first follow the manufacturer's recommendation on pattern adjustment. If the skewing cannot be fully corrected, there are other means that can be used, such as varying the speed or tilting the impeller. In extreme cases where a product is so heavy or so light that skewing cannot be eliminated, it may be necessary to use a wider swath width on one side than on the other.

How Do I Calibrate My Granular Applicator?

Because of many variables, it is highly recommended all spreaders be calibrated for proper delivery rate with the specific operator and product to be used. Many product suppliers furnish recommended settings and swath widths. These are as precise as the manufacturer can make them, but factors just mentioned can add up to a significant rate variation in some cases. Label settings should be used only as the initial setting for verification runs by the operator prior to large-scale use.

Calibration should be checked and corrected according to the manufacturer's directions at least once a week when the spreader is in regular use and more frequently if the spreader has suffered any abuse or mechanical damage.

The easiest way for an operator to check the delivery rate of a spreader is to spread a weighed amount of product on a measured area, preferably at least 1,000 square feet for a drop spreader and 5,000 for a rotary, and then weigh the product remaining to determine the rate actually delivered.

To avoid contamination of the ornamental area for initial calibration, the spreader can be supported above a floor and the drive wheel spun at the correct speed with the spreader remaining stationary. Granules can be collected and reused with this technique. Another method of rate verification that can be used with drop spreaders is to hang a catch pan under the spreader and push the spreader a measured distance at the proper speed. This method can be precise, but it is essential that the pan be hung on the spreader so that there is no interference with the shut-off bar or rate control linkage.

With rotary spreaders, it is also necessary to check and correct the distribution pattern. Again, the product label may give a recommended setting and width, but a custom applicator should check the setting and width before using. A quick pattern check can be made by operating the spreader over a paved area and observing the pattern. However, this method is not highly accurate, since even major distribution errors may not be visible because of particle bounce and scatter.

A preferred method is to lay out a row of shallow cardboard boxes on a line perpendicular to the directions of travel **(Figure 1.7.4)**. Boxes 1 to 2 inches high with an area of about 1 square foot and spaced on 1-foot centers are good for commercial push-type rotaries. The row of boxes should cover one and one-half to two times the anticipated effective swath width.

To conduct the test, pour some product into the spreader and set it at the label setting for rate and pattern. Make three passes over the boxes, operating in the same direction each time. The material caught in each box can be weighed and a distribution pattern plotted. However, a simpler procedure is to pour the material from

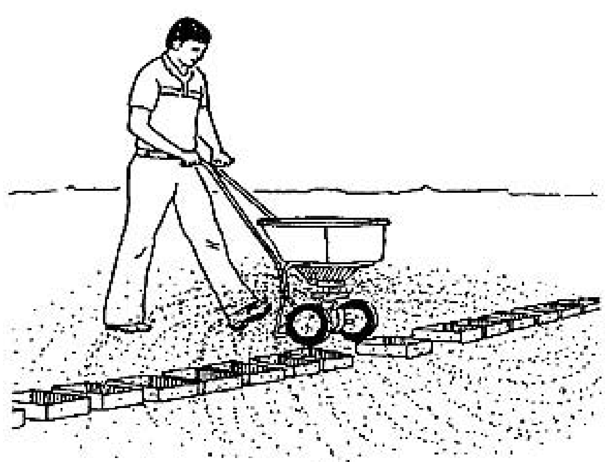


Figure 1.7.4. A row of shallow boxes can be used as a pattern check.

each box into a test tube, vial or small bottle. With the bottles standing side by side in order, a plot of the pattern is visible.

This method can be used to detect and correct skewing and to determine swath width. The effective swath width is twice the distance out to the point where the rate is one-half the average rate at the center. For example, if the center three to four bottles have material 2 inches deep, and the bottles from the 6-foot positions (6 feet left of the spreader center line and 6 feet right of the spreader center line) have material 1 inch deep, the effective swath width is 12 feet.

Shade Tree Sprayers

Spraying tall ornamentals and shade trees for insect and disease control requires thorough coverage of leaf, stem and trunk surface. Much more energy is required for trees than for ground spraying because of the greater distances the spray must be projected and the necessity for covering large surface areas.

Tree and ornamental spraying is normally accomplished with either high-pressure, high-volume hydraulic sprayers or air-carrier sprayers. Hydraulic sprayers use sufficient pressure in the liquid system to propel the spray droplets from the point of release to the point of application. Air-carrier sprayers use an airstream to transport and distribute the spray droplets. They may utilize either high- or low-pressure liquid systems.

How Is Uniform Coverage of Shade Trees Obtained With Hydraulic Sprayers?

Hydraulic sprayers used for spraying tall ornamentals generally have tanks, pumps and control systems that can handle high volumes of spray materials at high pressures. Sprayers are available with tank capacities up to 1,500 gallons and with pumps that can supply up to 60 gallons per minutes at pressures up to 800 psi. Hand-operated spray guns are used to direct the spray onto the ornamental.

Positive displacement piston pumps are generally used to produce the high pressures required. Abrasion-resistant cylinder linings are desirable to prevent damage to the pump when spraying wettable powders. However, piston pumps produce a pulsating flow that can damage gages, valves, hose fittings and even the pump itself. Therefore, a surge tank should be installed to absorb the pressure peaks. Air-chamber surge tanks are available for intermittent spraying at pressures up to 400 psi. Although the initial cost of a piston pump is high, its rugged construction, dependability and long life make it economical for continuous, hard usage.

A relief valve is necessary to protect the system from excessive pressure and to control the pressure applied to the spray gun. Tension on the spring in the relief valve is adjusted to maintain a constant pressure in the system by bypassing some of the liquid to the supply tank. When the line to the handgun is shut off, the entire output of the pump is bypassed to the tank. The relief valve must be sized to handle the desired flow rates of pressures. Some are available with two or more springs that make it possible to operate the spray system over a wide range of pressures. When the system is used at a low pressure, only the more responsive, low-pressure spring is energized.

When pressures of over 200 psi are to be used, the relief valve should be replaced with an unloader valve. This type of valve will decrease the pressure on the pump and the load on the engine when the spray valve is closed. Remember, if an unloader valve is used in a system having hydraulic agitation, the agitation flow may be insufficient when the valve is unloading.

A pressure gage, covering the range of pressures to be used, should be installed in the supply line to assist in adjusting and monitoring the sprayer's operation. A damper is needed to protect the gage from the pump pulsations. All components of the system must be designed to withstand the high pressures produced by the pump.

Nearly every hydraulic tree sprayer uses a hand-held gun. For short trees and shrubs, a multiple-outlet gun can be used, but the single-outlet gun with a pistol-grip valve is the most common. Many applicators use a variable discharge-angle gun. With a twist of the handle, the spray angle can be adjusted to a wide angle for short trees and shrubs and to a solid stream for tall trees.

Generally, coverage by a spray gun is relatively good with a high volume of water. If problems occur, they are usually with the tops of very tall trees. For optimum results, the correct combination of nozzle flow rate and pressure must be selected. **Figure 1.7.5** shows the effect of flow rate and pressure on the vertical reach of typical spray gun nozzles.

To reach the tops of trees, large drops are required, but the size of the drops emitted decreases with increasing pressure. Hence, there are limits to pressure increases to extend the vertical range of spray stream. Relatively large droplets are necessary to keep wind from dissipating or spreading the liquid stream. As can be seen in **Figure 1.7.5**, the vertical reach increases only slightly for pressures above 400 psi.

When vertical reach becomes a problem, better results will be obtained by selecting a nozzle of larger capacity than by increasing the pressure. The greater the nozzle capacity and the narrower its spray pattern, the higher it will reach. Guns and nozzle kits are available to spray trees up to 100 feet tall at pressures between 350 to 450 psi. Ladders, elevated truck-mounted platforms or gun extensions can also be used to gain the necessary height.

Disc-type nozzle orifices are usually numbered to represent the orifice diameter in 64ths of an inch. **Table 1.7.2** shows the relationship between flow rate, pressure and orifice size. At any given pressure, the flow rate will increase by a factor of four when the orifice diameter is doubled. Conversely, for any size orifice, the pressure must be increased by

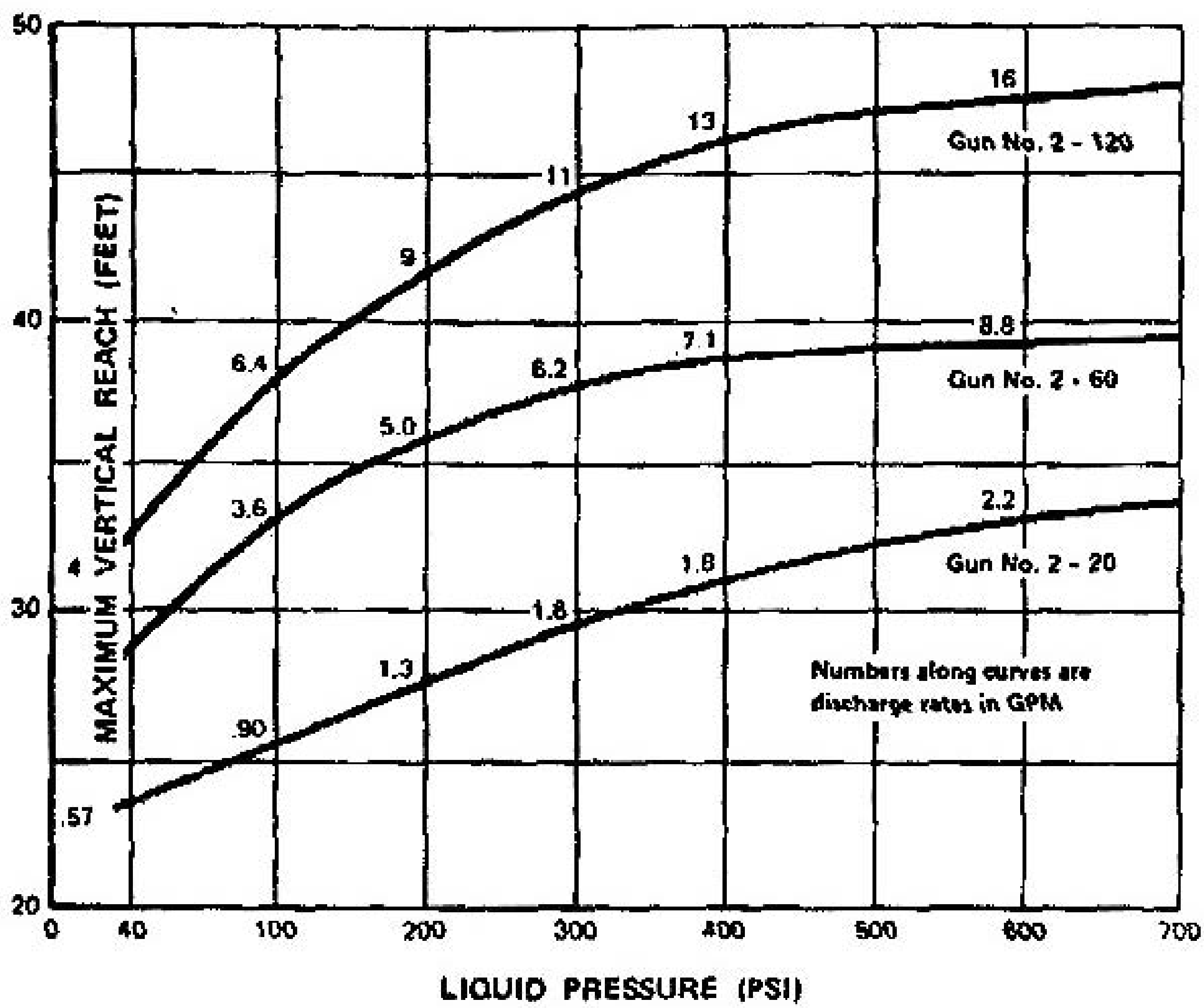


Figure 1.7.5. Maximizing vertical reach should be obtained by selecting a nozzle of larger capacity, rather than increasing the pressure.

Table 1.7.2. Spray gun flow rates, in gallons per minute, for various nozzle orifice sizes.

Orifice Disc. No.	Pressure (pounds per square inch)					
	50	100	200	300	600	800
2	.3	.4	.5	.7	.9	1.0
4	.6	.9	1.2	1.6	2.1	2.4
6	1.3	1.8	2.5	3.4	4.1	4.6
8	2.1	3.0	4.3	6.0	7.1	8.0
10	3.1	4.4	6.2	8.7	10.5	12.0
12	4.4	6.2	8.7	12.0	14.2	16.0
16	7.4	10.0	13.8	18.9	22.6	25.8

a factor of four to double the output. Nozzles wear with use, particularly when they are used to spray abrasive materials, such as wettable powders. As nozzles wear, the nozzle orifices become larger and nozzle output increases. Because of the high stress on the nozzles, hardened stainless steel, chrome-plated brass, or ceramic nozzle components should be used. Discs are available with hard center cores that can be replaced when worn.

Multiple nozzle arrangements with smaller nozzles may be used and tend to provide better coverage because they produce smaller droplets. However, drift increases and vertical reach decreases with smaller droplet sizes.

A major requirement for good application is to apply the pesticide uniformly to all surfaces of the tree. This requires a competent operator. To ensure adequate coverage, trees are usually sprayed to the point of runoff **(Figure 1.7.6)**.

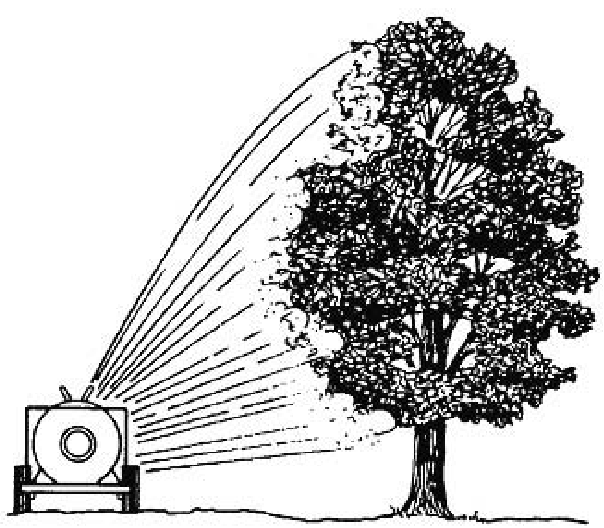


Figure 1.7.6. Air-carrier sprayer used on tall trees.

The amount of spray required to reach the point of runoff depends on the size and shape of the trees, density of the foliage and the application techniques used by the operator.

Often it is desirable to know the amount of spray required to wet a tree to the point of runoff. This is easily determined by measuring the flow rate of the spray gun and multiplying by the time required to spray the tree. For example, if a spray gun delivers 6 gallons per minute and a tree requires 3 minutes to spray, 18 gallons of spray mix are applied. Flow rate of a spray gun can be determined by collecting the output for a timed period. For example, if a gun fills a 3-gallon pail in 30 seconds, the flow rate is 6 gallons per minute.

Mixing is an important part of spraying ornamentals and trees. Most label rates are given as the amount of pesticide active ingredient, or product, to add to 100 gallons of water. If recommendations are given as active ingredients, then you must convert the amount of active ingredient into the amount of formulated product that is needed.

Can Air-Carrier Sprayers Be Used to Obtain Effective Pest Control in Shade Trees?

Sprayers that blow the spray into the trees with a blast of air are equipped with powerful fans to generate the required air current. Nozzles dispense the spray droplets into the high velocity air stream. Various combinations of air volume, air velocity, liquid volume and liquid pressure are used in air sprayers to obtain uniform spray distribution. Research has shown that more spray volume should be directed toward the top of the tree than to the lower portions to obtain uniform coverage, because the larger droplets containing most of the spray volume settle out of the air stream very rapidly.

Since air sprayers use both air and water as diluents, they give full coverage with less water than hydraulic sprayers. The use of a lower water-to-pesticide ratio with air sprayers is termed concentrate or low-volume spraying. With this technique, three, five or even 10 times the amount of pesticide is used per 100 gallons of spray, but only one-third, one-fifth or one-tenth as many gallons of spray are applied to the trees. In concentrate spraying, this rate is referred to as 3x, 5x or 10x application. The resulting deposit of pesticide on leaves should be the same as with the dilute method. **Table 1.7.3** shows the amount of spray required per tree for various degrees of concentrate spraying.

Basing the degree of concentration on the dilute application rate (spraying to the point of runoff) has caused considerable confusion. A 5x concentrate may mean 10 gallons per tree in one area, but 8 gallons per tree in another area. The difference is that different operators apply different amounts to obtain satisfactory coverage to treat the same tree. The quantity of foliage, amount of runoff, timing and spraying technique are all causes of variance.

The primary advantages of using concentrated sprays are that they require less labor, water and time than applying dilute mixtures. However, competent operation is essential when using air-blast sprayers, since the spray pattern is almost invisible. It is also impossible to determine the extent of coverage since there is no runoff.

Trees to be sprayed must be directly accessible to the sprayer unit because best coverage and distribution are obtained by spraying up through the canopy. If the distance from the tree to the sprayer is too great, the velocity will be insufficient to penetrate the canopy. Most airstreams lose 75 percent of their velocity in the first 25 feet after leaving the sprayer. Therefore, the sprayer should be immediately adjacent to the tree.

Two factors affecting the coverage obtained with air-carrier sprayers are airstream velocity and volume. In addition to canopy penetration, velocity is important in getting the spray to the top of tall trees. Spray material must be forced into the foliage with a turbulent force. To achieve this, air velocity is nearly 100 mph when leaving the sprayer and must be at least 15 mph at the tree surfaces.

Generally, increasing the volume of air applied improves the spray distribution. The blower must displace the volume of air in the tree with air from the sprayer containing spray droplets. When the available energy is fixed, the higher the ratio of air velocity to volume, the better the distribution.

Air-carrier sprayers are not trouble free. In addition to wind conditions, a potential problem

Table 1.7.3. Gallons of concentrate spray required per tree.*

Concentrate To Be Applied	Pressure (pounds per square inch)					
Dilute 1x	**5.0**	**8.0**	**10.0**	**15.0**	**20.0**	**50.0**
2x	2.5	4.0	5.0	7.5	10.0	25.0
3x	1.7	2.7	3.8	5.0	6.7	16.7
4x	1.3	2.0	2.5	3.8	5.0	12.5
5x	1.0	1.6	2.0	3.0	4.0	10.0
6x	0.8	1.3	1.7	2.5	3.3	8.3
8x	0.6	1.0	1.3	1.9	2.5	6.3
10x		0.8	1.0	1.5	2.0	5.0
15x		0.5	0.7	1.0	1.3	3.3
20x			0.5	0.8	1.0	2.5
30x				0.5	0.7	1.7

*The first line in the table is the amount of spray applied per tree to the point of runoff. From that basis, the amount of spray can be determined for the various concentrations.

during cold weather is freezing of the spray droplets, both on the nozzles and while airborne. Evaporative cooling may cause ice to accumulate on the nozzles. This can alter the droplet size as well as the distribution pattern. Also, after leaving the nozzle, sometimes droplets will form ice crystals and coverage is negligible. To avoid freezing problems, air-blast spraying should be done only when the temperature is above 45°F. Air-carrier sprayers often are difficult to use in Arkansas because of spray drift. The combination of fine spray particles and wind creates a situation for drift to occur. In urban landscapes, there is no room for allowing pesticide drift.

Although air sprayers can reach tall trees, their energy consumption far exceeds that of hydraulic sprayers. Since the energy needed is greater because air-blast sprayers must move both air and liquid, some air sprayers require a 140-HP engine. On the other hand, air sprayers cover trees faster and require less refilling than hydraulic sprayers. When spraying a large number of trees, timely application can result in pest control equal to hydraulic sprayers with lower overall costs.

Mixing and Loading Pesticides

How Much Pesticide Do I Add to My Spray Tank or Granular Applicator?

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

The recommended application rate of the pesticide is given on the label. The rate is usually indicated as pounds per acre for wettable powders, and pints, quarts or gallons per acre for liquids. Sometimes the recommendation is given as pounds of active ingredient (lb. a.i.) per acre, rather than the amount of total product per acre. The active ingredient must be converted to actual product.

Dry Formulation

Example 1. A carbaryl recommendation calls for two pounds of active ingredient (a.i.) per acre. You have purchased Sevin (80 percent wettable powder). Your sprayer has a 200-gallon tank and is calibrated to apply 20 gallons per acre. How much Sevin should be added to the spray tank?

Step 1. Determine the number of acres that you can spray with each tankful.

$$\frac{\text{Tank capacity (gallons/tank)}}{\text{Spray rate (gallons/acre)}} = \frac{200}{20} = 10 \text{ acres sprayed per tankful}$$

Step 2. Determine the pounds of pesticide product needed per acre. Because not all of the Sevin in the bag is an active ingredient, you will have to add more than 2 pounds of the product to each "acre's worth" of water in your tank. How much more? The calculation is simple: divide the percentage of active ingredient (80) into the total (100).

$$2 \text{ lb. a.i./acre} \times \frac{100\%}{80\%} = 2 \times 1.125 = 2.5 \text{ lb. of product/acre}$$

You will need 2.5 pounds of product for each "acre's worth" of water in the tank to apply 2 pounds of active ingredient per acre.

Step 3. Determine the amount of pesticide to add to each tankful. With each tankful, you will cover 10 acres (Step 1), and you want 2.5 pounds of product per acre (Step 2). Add 25 pounds (10 acres x 2.5 pounds per acre = 25 pounds) of Sevin to each tankful.

Example 2: The insecticide Diazinon recommendation calls for 4 pounds per acre. Your 5-gallon air compression sprayer applies 1.25 gallons per 1,000 square feet. How many ounces should you add to the spray tank?

Step 1. Convert the recommended rate to oz./1,000 square feet.

$$\text{oz./1,000 sq. ft.} = \frac{\text{recommended lb./A} \times \text{1,000 sq. ft.}}{2{,}722^*} =$$

$$\frac{4 \times 1{,}000}{2{,}722} = \frac{4{,}000}{2{,}722} = 1.5 \text{ oz./1,000 sq. ft.}$$

*2,722 = a constant arrived at by dividing the number of square feet in one acre (43,560) by the number of ounces in one pound (16).

Step 2. Determine the amount of pesticide to add to each tankful.

$$\text{oz. pest./tankful} = \frac{\text{gal./tank} \times \text{oz. pest./1,000 sq. ft.}}{\text{gal. applied/1,000 sq. ft.}} =$$

$$\frac{5 \times 1.5}{1.25} = 6 \text{ oz./tankful}$$

Liquid Formulation

Example 1: A trichlorfon recommendation calls for 1 pound of active ingredient (a.i.) per acre. You have purchased Dylox 4E (4-pounds-per-gallon formulation). You sprayer has a 150-gallon tank, and it is calibrated at 15 gallons per acre. How much Dylox should you add to the spray tank?

Step 1. Determine the number of acres that you can spray with each tankful. Your sprayer has a 150-gallon tank, and it is calibrated for 15 gallons per acre.

$$\text{Tank capacity (gallons/tank)} = \frac{150}{15}$$

$$= 10 \text{ acres sprayed with each tankful}$$

Step 2. Determine the amount of product needed per acre by dividing the recommended a.i. per acre by the concentration of the formulation.

1 lb. a.i. per acre =1/4 gallon per 4 lb. a.i. per gallon acre

One-fourth gallon or 1 quart of product is needed for each "acre's worth" of water in the tank to apply 1 pound of active ingredient (a.i.) per acre.

Step 3. Determine the amount of pesticide to add to each tankful. With each tankful, you will cover 10 acres (Step 1), and you want 1/4 gallon (1 quart) of product per acre (Step 2). Add 10 quarts (10 acres x 1 quart per acre = 10) of trichlorfon to each tankful.

Example 2: The recommendation for the insecticide malathion calls for 1 gallon of product per acre. You have a 4-gallon knapsack sprayer that has been calibrated to apply 1/2 gallon per 1,000 square feet. How many ounces should you add to the spray tank?

Step 1. Convert the recommended rate to pints/acre.

$$\text{pints/acre} = \frac{\text{1 gal.}}{\text{acre}} \times \frac{\text{8 pts.}}{\text{gal./acre}} = 1 \times 8 = 8 \text{ pts.}$$

Step 2. Convert the required pints/acre to oz./1,000 square feet.

$$\text{oz./1,000 sq. ft.} = \frac{\text{recommended pt./A} \times \text{1,000 sq. ft.}}{2{,}722}$$

$$= \frac{8 \times 1{,}000}{2{,}722} = 3 \text{ oz./1,000 sq. ft.}$$

Step 3. Determine the amount of pesticide to add to each tankful.

$$\text{oz./1,000 sq. ft.} = \frac{4 \times 3}{0.5} = 24 \text{ oz./1,000 sq. ft.}$$

Adjuvants

The manufacturer may recommend that you add a small amount of an adjuvant (spreader-sticker, surfactant, etc.) in addition to the regular chemical. This recommendation is often given as "percent concentration."

If you use an adjuvant at a 1/2 percent concentration by volume, how much should you add to a 300-gallon tank?

Solution 1:

1% of 100 gallons = 1 gallon (0.01 x 100 = 1)
1/2% of 100 gallons = 1/2 gallon

You will need 1/2 gallon per 100 gallons, or 1 1/2 gallons for 300 gallons (1/2 x 3 = 1 1/2).

Solution 2:

1/2% = 0.005
0.005 x 300 gallons = 1.5 gallons

Granules

Example: You are using a spinner granular spreader on a flowerbed 300 feet by 200 feet. The recommendation for Diazinon is 10 pounds a.i./acre. You have purchased Diazinon 14G. How many pounds of product will it take to cover this bed?

Step 1. Convert pounds active ingredient to pound product.

$$\text{Pounds product per acre} = \text{lb. a.i./acre} \times \frac{100\%}{\%\text{ a.i.}}$$

$$= 10 \text{ lb. a.i} \times \frac{100}{14} = 10 \times 7.14 = 71.4 \text{ lb.}$$

Step 2. Determine the number of ounces required to cover this bed.

$$\text{Ounces required} = \frac{\text{lb./A} \times \text{area treated (sq. ft.)}}{2{,}722}$$

$$\text{Ounces required} = \frac{\text{71.4 lb./A} \times \text{60,000 sq. ft.}}{2{,}722}$$

$$\frac{4{,}284{,}000}{2{,}722} = 1{,}573.8 \text{ oz. or 98 lb.}$$

Land Area Management

How Do I Measure Small Land Areas?

It is essential to know the amount of area you intend to cover when applying pesticides or fertilizer. Small ornamental areas, such as lawns, golf course greens and fairways, should be measured in square feet or acres, depending on the units needed.

Rectangular Areas

Area = l x w

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

Area = 980 ft. x 150 ft. = 147,000 sq. ft.

$$\text{Area in acres} = \frac{147{,}000 \text{ sq. ft.}}{*43{,}560 \text{ sq. ft./acre}} = 3.4 \text{ acres}$$

*1 acre = 43,560 sq. ft.

Triangular Areas

$$\text{Area} = \frac{b \times h}{2}$$

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

$$\text{Area} = \frac{500 \text{ ft.} \times 100 \text{ ft.}}{2} = 25{,}000 \text{ sq. ft.}$$

$$\text{Area in acres} = \frac{25{,}000 \text{ sq. ft.}}{43{,}560 \text{ sq. ft.}} = 0.6 \text{ acres}$$

Circular Areas

Area = Πr^2 where Π = 3.14 and r = the radius of the circle OR

$$\text{Area} = \frac{\Pi d^2}{4}$$ where Π = 3.14 and d = the diameter of the circle

Example: A ground cover underneath a tree has a diameter of 40 ft. What is the area?

$$\text{Area} = \frac{3.14 \times 40^2}{4} = \frac{5{,}024}{4} = 1{,}256 \text{ sq. ft.}$$

$$\text{Area in acres} = \frac{1{,}256 \text{ sq. ft.}}{43{,}560 \text{ sq. ft.}} = 0.03 \text{ acres}$$

Irregularly Shaped Areas

Any irregularly shaped ornamental area can generally be reduced to one or more of the geometric figures shown previously. The area of each is calculated and added together to obtain the total area.

Example: What is the total area of this ornamental area?

$$\text{Area 1 is a triangle} = \frac{b \times h}{2}$$

$$\frac{30 \text{ ft.} \times 20 \text{ ft.}}{2} = 300 \text{ sq. ft.}$$

Area 2 is a rectangle = L x w

500 ft. x 20 ft. = 10,000 sq. ft.

$$\text{Area 3 is a circle} = \frac{\Pi d^2}{4}$$

$$\frac{3.14 \times 40^2}{4} = 1{,}256 \text{ sq. ft.}$$

Total Area = Area 1 + Area 2 + Area 3

Total Area = 300 sq. ft. + 10,000 sq. ft. + 11,556 sq. ft.

Total Area = 21,856 sq. ft.

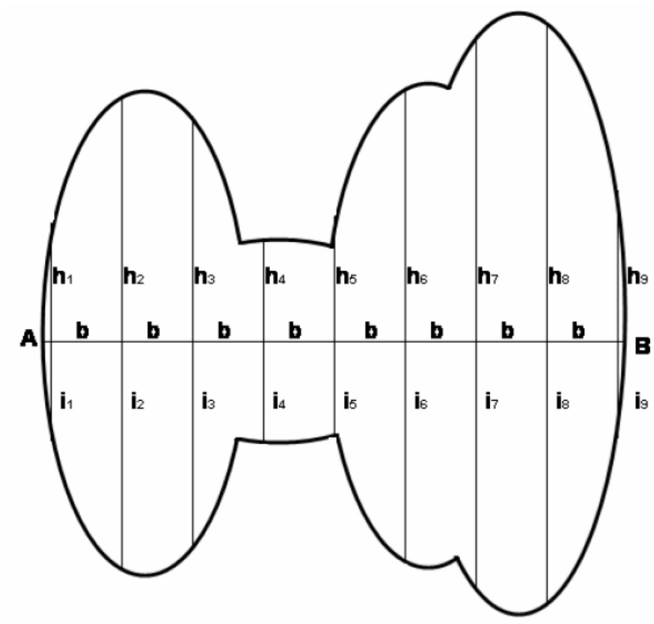
Irregular Boundaries

Irregular areas can be reduced to a series of trapezoids by right-angle offsets from points at regular intervals along a measured line AB. The area of this shape is determined by this formula:

$$\text{Area} = \left(b\left(\frac{h_1 + h_2}{2} + \frac{h_2 + h_3}{2} + \frac{h_3 + h_n}{2}\right)\right) + \left(b\left(\frac{i_1 + i_2}{2} + \frac{i_2 + i_3}{2} + \frac{i_3 + i_n}{2}\right)\right)$$

- b is the length of a common interval between the offsets.
- b must be the same for every interval.
- h_l, h_2, h_3,...h_n are the offsets measured perpendicularly from one side of line AB.
- i_l, i_2, i_3,...i_n are the offsets measured perpendicularly from the other side of line AB.

Example: In this flowerbed, the intervals, or b, are 10 feet. The offsets are measured out from line AB, which is a cord, stretched across the bed and marked in 10-foot intervals (h_l=5 feet, h_2=10, h_3=9, h_4=5, h_5=5, h_6=10, h_7=11, h_8=12, h_9=5, i_1=4 feet, i_2=10, i_3=9, i_4=5, i_5=5, i_6=10, i_7=11, i_8=12, i_9=3). What is the area of this bed?



$$\text{Area} = 10\left(\frac{5+10}{2} + \frac{10+9}{2} + \frac{9+5}{2} + \frac{5+5}{2} + \frac{5+10}{2} + \frac{10+11}{2} + \frac{11+12}{2} + \frac{12+5}{2}\right) +$$

$$10\left(\frac{4+10}{2} + \frac{10+9}{2} + \frac{9+5}{2} + \frac{5+5}{2} + \frac{5+10}{2} + \frac{10+11}{2} + \frac{11+12}{2} + \frac{12+3}{2}\right)$$

Area = $(10\,(7.5 + 9.5 + 7 + 5 + 7.5 + 10.5 + 11.5 + 8.5)) + (10\,(7 + 9.5 + 7 + 5 + 7.5 + 10.5 + 11.5 + 7.5))$

Area = $10\,(67) + 10\,(65.5)$

Area = $670 + 655 = 1{,}325$ sq. ft.

Suggestions

- A measuring wheel or device can save time over a tape.
- Once the area has been measured, record the measurements for future reference.
- If the area is new to you and you are relying on the figures of someone else, it would be advisable to check them.

Table 1.7.4. Measurement conversions.

Square Measure:		
144 square inches		1 square foot
9 square feet		1 square yard
30 1/4 square yards	1 square rod	272 1/4 square feet
43,560 square feet		1 acre
4,840 square yards		1 acre
160 square rods		1 acre
640 acres		1 square mile
Linear measure:		
1 inch	2 1/2 centimeters	25 1/2 millimeters
1 foot		12 inches
1 yard		3 feet
1 rod	5 1/2 yards	16 1/2 feet
1 mile .... 320 rods	1,760 yards	5,280 feet
Fluid Measure:		
1/6 fluid ounce		1 teaspoon (tsp.)
1/2 fluid ounce	1 tablespoon (Tbs.)	3 teaspoons
1 fluid ounce	2 tablespoons	1/8 cup
8 fluid ounces	1 cup	1/2 pint
16 fluid ounces	2 cups	1 pint
32 fluid ounces	4 cups	1 quart
128 fluid ounces	16 cups	1 gallons
Weights:		
1 ounce		23 1/3 grams
1 pound	16 ounces	453 1/2 grams
2 1/5 pounds	1 kilogram	1,000 grams
1 ton	2,000 pounds	907 kilograms
1 metric ton	1,000 kilograms	2,205 pounds
Approximate Rates of Application Equivalents:		
1 ounce per square foot		2,722.5 pounds per acre
1 ounce per square yard		302.5 pounds per acre
1 ounce per 100 square feet		27.2 pounds per acre
1 pound per 1,000 square feet	43.56 ounces per acre	2.72 pounds per acre
1 pound per acre	1 ounce per 2,733 square feet	8 1/2 grams per 1,000 square feet
100 pounds per acre		2.5 pounds per 1,000 square feet
5 gallons per acre		1 pint per 1,000 square feet
100 gallons per acre	2.5 gallons per 1,000 square feet	1 quart per 100 square feet

Minimizing Pesticide Hazards to the Consumer

Ornamental pesticides must often be applied in environments frequented by humans, pets and other domestic animals. The pesticide applicator must be constantly alert to the potential risks associated with this situation. Primarily, the problem is twofold – preventing hazardous amounts of pesticides from drifting into non-target areas and preventing humans, pets and other animals from contacting hazardous amounts of pesticides within the treated area. To avoid problems as much as possible, the following safety precautions should be followed:

- Double check to make sure you have the correct yard before spraying.
- Do not allow children or pets to remain in the area being sprayed. Check the neighbors' yards to make sure there are no children, pets or swimming pools which could come in contact with spray drift.
- Remove toys, pet food dishes and bird feeders.
- Be sure all clothing is removed from the area.
- Avoid fishponds and birdbaths.
- Avoid spraying lawn furniture and swimming pools.
- Make sure all house windows are closed.
- Observe pesticide label restrictions concerning tolerance for fruits and vegetables.

- Sweep or rinse away all spray puddles.
- Secure all pesticide containers or spray apparatus before moving to the next job.

Hazards to the Target Plant

Phytotoxicity

Probably the greatest hazard to the target plant is an adverse or "phytotoxic" reaction to the pesticide applied. Phytotoxicity, or pesticide damage to plants, results in such things as abnormal growth, leaf drop and discolored, curled and spotted leaves. If phytotoxicity is severe, the plant may die. Symptoms of phytotoxicity include leaf drop, stunting, overgrowth, discolored foliage, leaf curl and stem distortion.

Phytotoxicity often mimics such things as insect damage, plant disease and response to poor growing conditions, including insufficient moisture and improper fertilization. The following items are especially relevant to the phytotoxicity problem:

- A wide variety of plant material.
- Pesticide drift.
- Pesticide persistence beyond the intended period of pest control.
- Improper rate of application or improper technique.

The cause of phytotoxicity may be easy to determine or it may be subtle and hidden. Other causes that create similar symptoms are insects and disease agents, insufficient moisture, improper fertilization and other adverse growing conditions.

Factors that may contribute to pesticide phytotoxicity include:

- High air temperature during and immediately after pesticide application. Several pesticide labels warn of potential injury to plants if applied at or above certain temperatures.
- Excessive rates of pesticide application. Apply the pesticide at rates given on the label. Overdosing generally does not give any better control of the target pest and can injure the plant.
- Too little water. Insufficient dilution of the pesticide when mixing will result in a more concentrated spray. Plants under moisture stress can be more sensitive to chemical injury.
- Uneven distribution of pesticides. Inadequate mixing of pesticides in the spray tank may result in an uneven distribution of the chemical. Wettable powders in particular need agitation to keep them uniformly suspended in water.
- Formulation. Certain formulations may be more likely to cause injury than other types. Emulsifiable concentrates are more likely to cause injury than wettable powders, because the solvents in them may allow the chemical to come into direct contact with the plant tissue by dissolving the waxy protective layer on the leaves.
- Mixing liquids or emulsifiable concentrates with wettable powders.
- Variety and species differences. A wide range of ornamental plants exists. Variation in sensitivity to certain chemicals exists among varieties of the same kind of plant.
- Growing conditions. Weak plants in shallow soils, wet spots or under other types of stress are more sensitive to chemical injury. Young, tender, fast-growing plants with areas of new growth tend to be more susceptible to injury.

Finally, take special care to avoid injury to landscape plants and turfgrass when using herbicides. Some herbicides leave residues in spray tanks that will injure desirable plants. Use separate sprayers for herbicides and other pesticides to eliminate this source of injury.

Potential for Phytotoxicity

Ornamental plants vary from herbaceous to semi-woody and distinctly woody species. Generally, herbaceous plants (chrysanthemums, petunias, turfgrass, etc.) are more susceptible to pesticide damage than woody ones. Even the woody plants are more susceptible when growth is young and tender.

Plant damage is more likely to occur with herbicides. Fungicides tend to be less hazardous to plants than herbicides and insecticides. The pesticide label is the best guide for safe use on a specific ornamental plant. Since the registration status of pesticides is continuously being reviewed and is subject to change, read the product label before purchasing to make sure it is registered for your needs.

Where different plants are rotated in the same soil, a pesticide used to control some pests on one plant may leave residues in the soil that will damage or kill another plant. This is especially true of some herbicides. Also, shrubs and ground covers can be injured by herbicides applied to adjacent turf areas. Other examples of injuries that may be caused by careless spraying are as follows:

- Carbaryl injures Boston ivy.
- Bordeaux mixture may injure certain succulent plants and russet some apple varieties.
- Diazinon injures ferns, hibiscus, gardenias, stephanotis and African violet.
- Dimethoate causes defoliation of honey locust and elm. It may also injure flowering almond, dahlias, plum, peach, cherry, chrysanthemum and Chinese holly.
- Malathion injures Canaert, Sargent's and Burk junipers; Japanese holly; ferns; violets; petunias; and the rose varieties Caledonia and Talisman.
- Oil-sensitive plants include beech, black walnut, butternut, hickory, mountain ash, Japanese maple, red maple, sugar maple, yellow wood, Russian olive, Norway spruce, yews, hemlock, magnolias, redbud, broadleaved evergreens in general and junipers.
- Ovex is toxic to azaleas, beech, boxwood, barberry, deutzia, hollies, raspberry, oak, hawthorn, spruce and sycamore.
- Phorate distorts new growth of Eleyi crabapple trees.
- Sulfur is toxic to viburnums and forsythia.
- Tedion may injure some varieties of roses.
- Thiodan may injure geraniums.

Drift Problems

The proximity of different plants with varying susceptibility to pesticide damage requires commercial applicators in the ornamental and turf category to be especially aware of drift problems.

Two types of drift are associated with pesticides. The most common, drift of spray droplets or dust particles, is directly affected by such things as spray pressure, nozzle size, wind velocity and pesticide formulations. Drift of a pesticide with low vapor pressure is termed "vapor drift." Vapors or gases can drift in harmful concentrations, even in the absence of wind. Fumigants such as methyl bromide must be confined so they will not drift from the treated area. (Proper sealing with a plastic tarp is essential.) Some pesticide products are volatile or capable of vaporizing from soil and leaf surfaces in potentially harmful concentrations after application.

There are several steps that can be taken to prevent damage to nontarget plants. When several pesticides are available, the applicator should strongly consider the hazard and the toxicity of the active ingredient before making a choice. The applicator should use formulations and methods of application that will result in minimum drift. If possible, pesticides should be selected that are safe for both target and nontarget plants. This can be accomplished by reading the pesticide label and its MSDS. It may be necessary to place a barrier around the target plant or remove susceptible potted plants from the area.

Persistence Beyond Period of Control

The period of pesticide residual activity varies greatly from one class of pesticides to another. Persistence is directly related to chemical structure, rate of application, soil type or texture, temperature, moisture conditions, rainfall amounts and other factors. Commercial applicators must be familiar with persistence of each pesticide which may be applied to ornamentals, especially where adjacent areas may be affected, treated soil is used to grow other plants or where humans and pets frequent the area.

Persistence is an important part of pest control, since successful pest control requires knowledge of a pesticide's persistence to make subsequent applications. For example, herbicides used for preemergence weed control in turf generally persist for 60 to 90 days, and postemergence herbicides can last from 1 or 2 days to 3 or 4 weeks, depending upon the specific herbicide involved.

Persistence can be an advantage to the applicator for long-term control of the pest. The use of a long-lasting insecticide to control borers is a situation in which pesticide persistence is desired. However, problems can develop when applications are made too frequently, raising the level of the insecticide on the tree or in the soil to potentially phytotoxic amounts.

Combinations or Mixtures of Pesticides, Mixing and Compatibility

Mixing pesticides in the spray tank is an old and widely used practice. A mixture of an insecticide and fungicide or an insecticide and an acaracide is often used on fruit trees and ornamentals to save an additional application. Different herbicides are sometimes mixed to broaden the spectrum of activity – for example, combining a grass and a broadleaf herbicide. Many of the newer pesticide labels specifically list the mixtures that can or cannot be made with that pesticide.

In general, tank mixes of pesticides or pesticides with fertilizers are considered to be legal unless the label prohibits mixing with certain pesticides or fertilizers. A number of labels provide specific mixing instructions for certain pesticide combinations and fertilizer and pesticide combinations.

Even when pesticides are approved for use in a mixture, problems can still occur. Formulations of a particular pesticide may vary from one product to another, and incompatibility may result from the different wetting agents, solvents and other additives in them. Liquid formulations are particularly susceptible to incompatibility problems, due to the many additives they usually contain. Incompatibility is expressed in different ways, but a crystalline precipitate or a gelatinous mass is common, which would require time to clean out plugged nozzles, screens and regulators. Another common problem is a break in the emulsion in which the different ingredients separate out, as would oil and water. This is the result of the emulsifier being destroyed, and spray injury is likely to result. Sometimes, the addition of soluble salts to the spray tank will cause an emulsion to break. Separation can also take the form of clumping of particles together. Incompatibility can also result in lessened activity of the combination, although no visible problems can be seen. The combined materials inactivate one another, and the resulting mix will be less effective.

Hardness of water may also affect a pesticide or mixture of pesticides. Phosphate and carbamate materials are more susceptible to high alkalinity (high pH) than other pesticides. The addition of lime, lime sulfur, Bordeaux mixture or other highly alkaline materials may cause decomposition, loss of toxicity or phytotoxicity. *Bacillus thuringiensis* is often degraded when used with high alkaline fungicides such as Bordeaux or other fungicides containing copper.

Combinations of oil or petroleum solvents with organic chemicals frequently are injurious to plants. Many emulsifiable concentrates are formulated with petroleum solvents and fall into this category. Sometimes, one or both pesticides precipitate or fall out of the mixture, and spray injury to the crop is the frequent result. In other cases, mixing may cause excessive residues, although no precipitation is noticeable in the tank.

Most ornamental emulsifiable sprays are oil-in-water emulsions producing small particle sizes. When difficulties in emulsifying an oil- or pesticide-in-water spray are encountered, they can usually be corrected by starting with just enough water to cover the agitator, then starting the engine and running the agitator and the pump at full pressure to force the liquid through the by-pass return to the tank. If an additional or separate emulsifier is to be used, it should be added to the tank before adding the pesticide or oil. The pump should be allowed to run for 2 or 3 minutes. Once this emulsion is formed, add the rest of the water to fill the tank while the pump and agitator are running.

Although incompatibility may still be a problem, it can frequently be reduced to the minimum by:

1. Using formulations produced by the same manufacturer.
2. Keeping the equipment clean and well drained.
3. Never putting pesticides in an empty tank. The tank should always be partially filled before adding the pesticide.
4. Never combining concentrates without diluting them first.
5. Mixing wettable powders with water to form a slurry before they are added to the tank (unless you have an inductor system).
6. Adding wettable powders to the tank before the emulsifiable concentrates.

Mixtures of Pesticides and Fertilizers

Many of the principles for using tank mixtures of pesticides also apply to fertilizer-pesticide mixtures. The most important point to remember is that such mixtures, either wet or dry, should be handled as pesticides – not as fertilizers.

Pesticides are precision tools. The total quantity of a pesticide in the tank may be less than the accepted variation in fertilizer application, which may vary from a plus or minus of 10 to 15 pounds per acre. Timing, placement and distribution are frequently different for pesticides and fertilizers. Compromising one requirement may limit the usefulness and safety of the mixture.

Where tank mixtures are to be used, make sure that agitation is adequate to maintain the suspension. Suspensions also require about 1 to 2 gallons of spray carrier for each pound of product to be suspended. Some products are specifically formulated for use in fertilizer mixtures. Others specify the need to check emulsion stability and add a compatibility agent, if needed.

Adjuvants or Spray Additives

Pesticides, regardless of formulation, are formulated for general performance purposes under average conditions. For many jobs they perform satisfactorily, but there are also many situations where they fall short of the desired effect. For example, in very hard or soft waters, a formulation may have too little or too much emulsifier, with the consequent problems of difficulty in mixing or excessive foaming. A formulation may evenly distribute a pesticide on the leaves of plants that are not waxy. But on plants with waxy leaves, the spray may form small, round droplets instead of spreading as an even film over the leaf surface. The droplets then run off the plant and onto the ground, leaving no deposit to protect the plant. The addition of an appropriate surfactant to the spray tank will solve this problem.

A substance added to the spray mixture to aid or improve the performance of the main ingredient is an adjuvant.

Adjuvants can be added to the spray mixture to:

1. Improve the wetting of the foliage or the pest.
2. Change the evaporation rate of the spray.
3. Improve the ability of the spray deposit to resist weathering,
4. Improve the penetration, absorption and translocation of the pesticide.
5. Adjust or buffer the pH of the spray solution, increasing the effectiveness and longevity of alkaline-sensitive pesticides.
6. Improve the uniformity and amount of the deposit.
7. Improve the ease of mixing or compatibility of the spray mixture.
8. Increase the safety from spray injury to the crop.
9. Reduce the drift hazard to neighboring crops.
10. Improve physical properties of the mixture – for example, antifoaming agents.

Depending upon their intended use, adjuvants are called emulsifiers, wetters, stickers, extenders, spreaders, penetrants, foaming agents, antifoaming agents, etc.

Adjuvants are highly active materials. In most cases, a very small quantity will have great effect. Use only the amount recommended, since too much adjuvant may be just as bad as too little. It makes little difference whether the pesticide runs off the foliage because it balls up or because if forms too thin a film on the foliage. Many products contain adjuvants, and additional adjuvant may cause such problems as the loss of herbicide selectivity, which produces injury on normally tolerant plants. The label should be your guide on the addition of adjuvants.

Pesticide Use Problems (Ornamentals)

Before developing a pesticide management system, a commercial pesticide applicator must consider possible side effects on their own body, on other employees and on clients. Possible side effects include drift damage, phytotoxicity, reentry, residues and tolerances. Personal health and the prosperity of the business depend on knowledge and care in application.

The manual, *A Guide for Private and Commercial Applicators: Applying Pesticides Correctly*, addresses the acute hazards to man and other warm-blooded animals that are associated with the handling of pesticides.

Hazards to Applicator, Worker and Consumer

Dermal Toxicity

The greatest hazard from pesticides is absorption of pesticides through the skin. A survey conducted in a leading agricultural state found that more than 80 percent of the cases of poisoning in agricultural and industrial settings resulted from pesticides being absorbed through the skin. This can be caused by a splash, spill or drift when mixing or applying the chemical or from contact with a pesticide residue after application.

The hazards associated with skin absorption are increased by cuts, abrasions, scratches, scuffs or other damage to the skin. However, absorption can occur rapidly even through healthy skin. Absorption is high and rapid through the scrotum, armpit, ear canal, forehead and scalp. It is slower in the palm of the hand and the ball of the foot. However, even in these lower absorption areas, penetration can be great and will vary from pesticide to pesticide. For example, carbaryl (Sevin) is thought of as a relatively safe material, but it is absorbed through the skin of the forearm about seven times more rapidly than malathion or parathion. Studies show pesticides can be absorbed within a few minutes; therefore, waiting until the job is done to wash spills or splashes on the skin may be too late. Wash by rubbing hands together alone or with a piece of cloth, using detergent or soap. Do not scrub with a brush, since the outer, protective layer of skin could be scratched enough to permit more rapid absorption of any pesticide that is not removed.

Since dermal toxicity is a major concern, the EPA has specified that shoes and socks, a long-sleeved shirt and long-legged pants are the minimum personal protective equipment (PPE) required for any pesticide application.

Eyes

Eyes are particularly sensitive to harm by pesticides and should be protected with goggles or a face shield. If a pesticide is splashed into the eye, immediately flush the eye with a gentle stream of clean, running water or eye flushing solution for 15 minutes while holding the eyelid open. A few seconds delay could increase the extent of the injury. Do not use chemicals or drugs in the wash water. They may increase the injury. Convenient plastic eye wash bottles and holders are available. These useful bottles can be purchased from chemical laboratory suppliers and are called "eye wash stations." Whether clean water or commercial solutions are used, these need to be changed periodically to ensure their safety and freshness.

Lungs

Many applicators are not aware that inhalation of pesticides is a serious hazard. Inhalation is next in importance to skin contact in toxicity concerns. Since the lungs have such a large and highly absorptive surface area, even small amounts of a pesticide are hazardous because they are almost completely absorbed in the lungs. Vapors and extremely fine particles, 10 microns or smaller, are particularly hazardous. Spray particles of this size can move deep into the lungs and reach the area of the lungs where the blood vessels take in oxygen. This is an extremely critical area for absorption of materials into the blood stream.

Respirators should be worn when required by the label and when the applicator deems it necessary (regardless of label requirements), such as when small spray particles may be present. Occasional use of moderately toxic pesticides that do not require a respirator may not pose a risk. However, daily use of such pesticides could greatly increase exposure and may require use of a respirator to decrease the risk (exposure).

Feet

Foot protection is an important safety tool when using pesticides for controlling ornamental pests. During the mixing/loading, application and sprayer cleaning processes, the feet are potentially exposed to pesticide concentrate and spray mixture. By wearing chemical-resistant footwear, potential contamination to the feet can be avoided.

When selecting boots for PPE, there are several items to consider. First, check to see that the soles of the footwear are made of a durable substance that will not wear out quickly on rough surfaces such as concrete, asphalt or gravel. Next, make sure the soles have skid-resistant surfaces. Some footwear is extremely slippery when used on smooth concrete or metal surfaces that are wet. Be sure the footwear can withstand the use to which they will be subjected. Also, consider the comfort of the wearer. For example, footwear that is excessively hot will not be worn by applicators. Lastly, consider the ease of putting on and removing the footwear. Remember, boots are not needed when driving between jobs or during most of the day; rather, they are needed only when exposure to pesticides may occur. Therefore, the footwear must be easily put on and removed. Otherwise, they will not be used at all.

Hands

If pesticide applicators could choose only one PPE item, it would likely be gloves.

When selecting gloves, remember that they come in different sizes and not all hands are the same size. Therefore, it is likely you will need different sizes of gloves for your business.

Make sure the gloves will not interfere with other operations that must be done when worn. If this occurs, accidents are likely to follow. Dexterity is very important when selecting gloves. If dexterity is not considered, it is likely the glove selected will not perform as desired and will not be used. Also consider the durability of the gloves. If reel hoses are being used, for example, the gloves must withstand the friction from the hose. Chemicals can easily penetrate gloves if small holes are worn in them.

When many types of pesticides are being used, experiment to see how the gloves will react with the various pesticides. Switch to another type of glove material if the gloves are observed to "bubble" or "blister," because this is a chemical reaction and the glove material is being broken down.

Do not use latex gloves. Latex gloves will not provide the required protection. Use nitrile, butylene or a similar type of glove material. Do not use cloth or leather gloves for PPE. These gloves will absorb the pesticide and they cannot be cleaned. Only use these gloves as an outer glove with PPE underneath the cloth or leather gloves, When this is done, the cloth/leather gloves must not be used for other purposes, or they should be destroyed after each job.

Liners or gloves with liners are generally more comfortable to use and easier to remove. However, if the liner becomes contaminated with the pesticide, the hand becomes contaminated. Therefore, liners should only be used when one can ensure the liner will not become contaminated with the pesticide.

When repairing spray equipment, wear chemical-resistant gloves if the equipment has not been thoroughly washed.

Selection of Pesticide Protective Clothing

Selection can begin once you decide which pesticide to use and know how it affects humans. Without this information, selection is almost impossible. Once the pesticide has been selected, the label and Material Safety Data Sheet (MSDS) are to be consulted for toxicity and PPE information.

Personal Protective Equipment (PPE) Clothing

Minimum PPE clothing includes shoes and socks, long-legged pants and a long-sleeved shirt. These items are for all pesticide handling and application activities.

PPE comes in various forms and has different degrees of protection. The simplest is "normal" work clothing. Clothing should be of a closely woven fabric. The close weave "catches" more pesticide particles in the fabric, thus keeping them from directly contacting the skin. Generally, natural fabrics catch pesticide droplets better than synthetic fabrics. However, natural fabrics may be more difficult to clean. Natural fabrics are better at catching pesticide particles because the fibers are frayed. Multiple washings of synthetic fabrics before use will often fray the fibers, thus providing similar "catching" properties of natural fabrics. Synthetic fabrics are often somewhat water repellent which also increases their effectiveness. However, normal work clothing should be worn only when the pesticide label permits them and when small amounts of spray particles are expected to be deposited on the clothing by those pesticides. Other PPE clothing should be used if one expects to receive large amounts of spray particles on their clothing.

PPE Material

Disposable PPE clothing is either woven or spun. Woven material is made of closely woven synthetic fibers. These materials are water-repellent and tightly woven, thus they greatly limit the amount of spray that reaches the body. Woven fabrics "breathe" and are relatively comfortable. These fabrics are often treated with water-repellent materials. The water-repellent materials increase protection, but they also decrease the fabric's ability to breathe, making the clothing hotter and less comfortable. The other type of synthetic PPE is spun material. The fabric is extruded and does not have a weave. Since it lacks the "holes" woven materials contain, it is more protective because spray particles are much less likely to reach the skin. Spun materials are more repellent and hotter due to the decreased breathing of the fabric. There are newer fabrics with improved breathability. Treating spun materials with repellent materials will also increase its protecting ability, but it will decrease the materials breathability.

PPE Construction

It is important to know how PPE is constructed and the strong and weak points at critical areas of protective equipment.

Fabric

The choice of woven or spun fabric will partially depend on the pesticide applied. The other major consideration is comfort, which includes movement and breathability. If one is working in hot or warm conditions, the fabric's ability to breathe can become as important as the chemical protection provided. A woven fabric that has been treated with a repellent may breathe better than a spun fabric. The choice of fabrics will depend on the individual's circumstances and may have to be determined by trial and error.

Seams

Check the garment's seams. There are three types of seams. The simplest is a stitched seam. These can be effective or not, depending on the protection needed and strength of the seam. Stitching should be close (tight). Tight stitches help decrease the chance of spray particles passing through the seams. Double stitching is better than single because it adds protection and strength.

Fused seams are created by fusing or welding the fabric pieces together. A fused seam provides greater protection than a stitched seam, but its decreased breathing could create a comfort concern. Most fused seams are of sufficient strength, but they should be inspected before purchasing to ensure integrity.

The third type of seam is a combination of sewn and fused. This type of seam is the most protective because it provides all the benefits of the two; however, the breathability will be decreased.

Zippers, Buttons, Velcro, Drawstrings and Snaps

The fastening device can be very important. Buttons provide the least protection, because spray particles can pass through or around the loose closure. Velcro can provide a tighter closure; however, spray particles can build up on the velcro. Drawstrings on pants can create the tight fit needed but, like velcro, they can become contaminated over time. Metal zippers can become corroded by pesticide sprays. Plastic zippers can be dissolved if concentrated formulations are spilled on them. Zippers can form a tight or loose closure. Obviously, a tight closure is desired. One should consider the ease of operating the zipper with gloves. Snaps are similar to zippers and buttons. They have the same problems as buttons but are generally easier to fasten. Like zippers, they can be damaged by certain types of pesticide formulations. Snaps can also be damaged by being bent, thus they can be difficult to fasten. Often, closure devices can be improved by being inset with a covering flap.

How to Select PPE Clothing

First, determine the major formulations and requirements on the pesticide label and its MSDS. Regardless of whether woven or spun material is selected, be aware of a number of items pertaining to the construction of the PPE.

Once the type of PPE is know, the applicator must take into account the various aspects of the PPE to be worn. If heat is a concern, PPE which does not "breathe" may need to be avoided and another type used.

In selecting PPE, consideration of applicator requirements is paramount. PPE must not bind or restrict the applicator's movement such that the PPE becomes a greater hazard than the pesticide. Most PPE coveralls and sleeve protectors are bulky. When working around moving parts, such as reel hoses and sprayer pulleys, care must be taken to ensure clothing does not get caught in moving equipment.

Cleaning and Disposing of PPE

Boots and gloves should be washed with soap and water before removal. Disposable coveralls that received an excessive amount of spray residue should be rinsed with clean water before removal. These actions provide safety measures for the wearer during the changing and storage process of the PPE.

Once removed, gloves should be washed again in soap and clean water and air-dried in a location away from pesticides. Cloth coveralls should be washed, if possible, and air-dried. When washing, use 140ºF water, a full wash load cycle and a strong detergent. Wash the clothes in a load by themselves – do not wash PPE with other laundry. This helps avoid possible cross contamination of pesticide residues with other clothing. Air-dry the clothes. Run another complete cycle through the washer to clean the washer drum. Disposable coveralls may be laundered according to the manufacturer's instructions. An applicator has to make the decision whether to launder disposable coveralls or to use them a specified number of times and then destroy them. When disposable coveralls are laundered, they lose some of their protecting ability. Any PPE that is exposed to concentrate pesticides should be rinsed and disposed.

Respirators are to be washed and dried after each day's use. They may be washed in warm water with mild soap, wiped and hung up to air-dry. Do not use alcohol on respirators. Likewise, eye protection needs to be washed in the same manner after each day's use.

When PPE items are to be disposed of, shred and destroy them after cleaning so someone else cannot use them.

Cost of PPE

PPE costs do vary. The type and cost of PPE should be included in the selection of a pesticide.

Regulatory Matters

Reentry Into Treated Areas

Reentry requirements have been established for ornamental pesticides applications, as has been done for many agricultural pesticides. Ornamental pesticide labels do address reentry, usually by stating, "...Keep children and pets off treated areas until the sprays have dried." Some labels may provide a safe time for reentry, such as 12 or 24 hours after treatment. Such label statements are to be followed. They also must be considered when selecting a pesticide. Such requirements for pesticides to be used in parks and other high traffic areas can cause extreme management problems for the applicator.

Endangered Species Act

The Endangered Species Act (ESA) affects all federal programs and agencies. Since the EPA registers pesticides, pesticides are covered under the ESA. The act applies to all outdoor applications of pesticides.

Basically, no person is to take any action that may harm or kill a federally endangered or threatened species. This includes affecting the species habitat or food source. Ornamental pesticide applicators are responsible for determining whether or not their actions will harm an endangered species in the area to be treated. Your county Cooperative Extension educator, Extension pesticide coordinator, U.S. Fish and Wildlife Service representative and Arkansas State Plant Board inspector can provide information on location of endangered or threatened species.

Pesticides and Water

Arkansas has numerous lakes that provide drinking water. However, most of the fresh water in the United States is ground water. Rural residents and small communities usually receive drinking water from ground water sources. Pollution affects about 2 percent of ground water in the U.S. Unfortunately, an increasing amount of surface water is also becoming contaminated (EPA 1990).

Agriculture accounts for two-thirds of the more than 4.5 billion pounds of pesticides used in the U.S. yearly. This figure includes pesticides used in ornamental and turf and greenhouse production systems. The home and garden sector used 135 million pounds of pesticides in 1995 (EPA 1997).

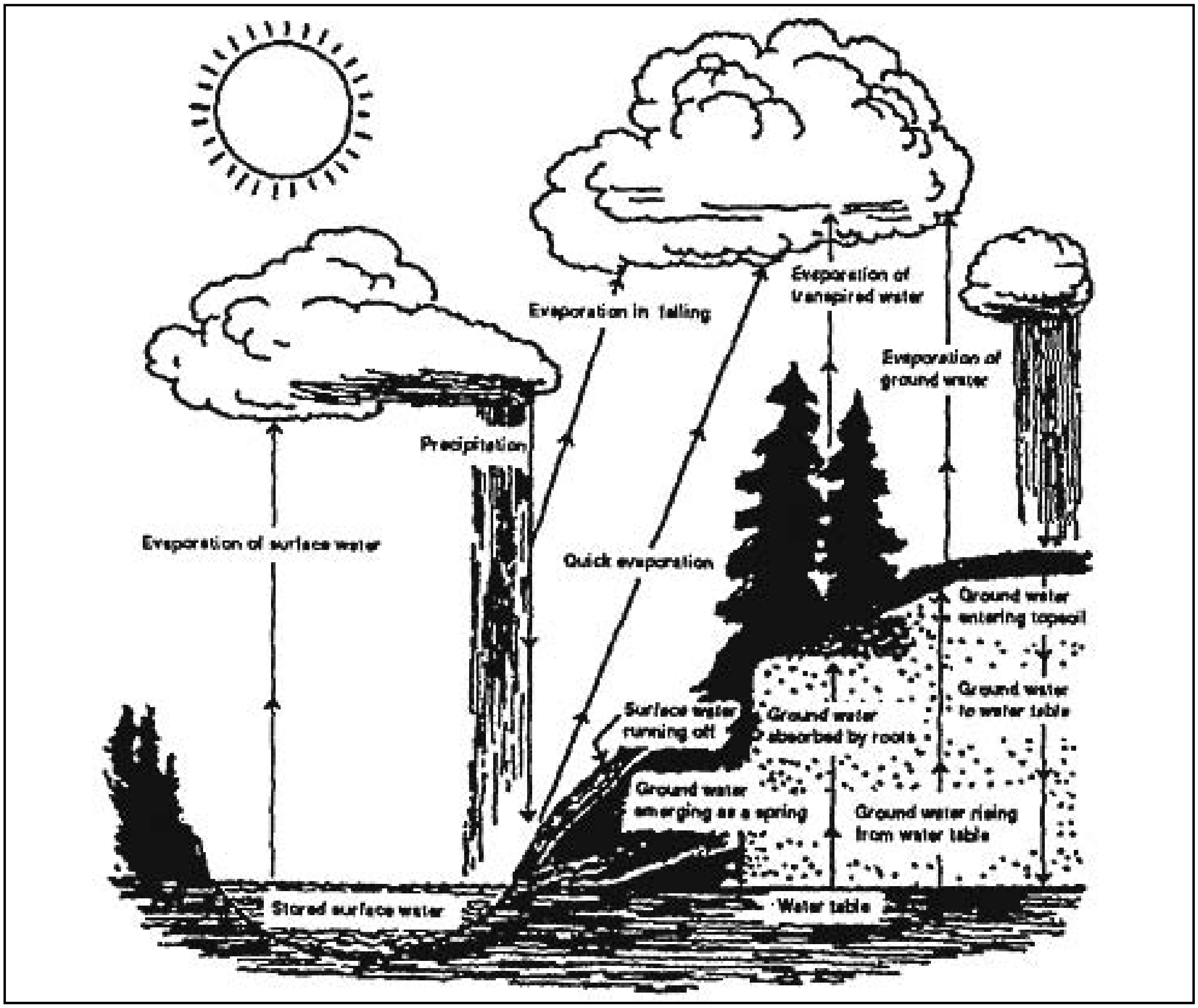


Figure 1.8.1. The hydrologic cycle.

Pesticides can contaminate water throughout the hydrologic cycle **(Figure 1.8.1)**. Water contamination is directly related to the degree of pollution in our environment. Rainwater flushes airborne pollution from the skies. Pollution is then washed over the land before running into rivers and lakes and seeping into underground aquifers. Since irrigation and drinking water come from surface and ground water, any chemical used may pollute our water supplies **(Figure 1.8.2)**.

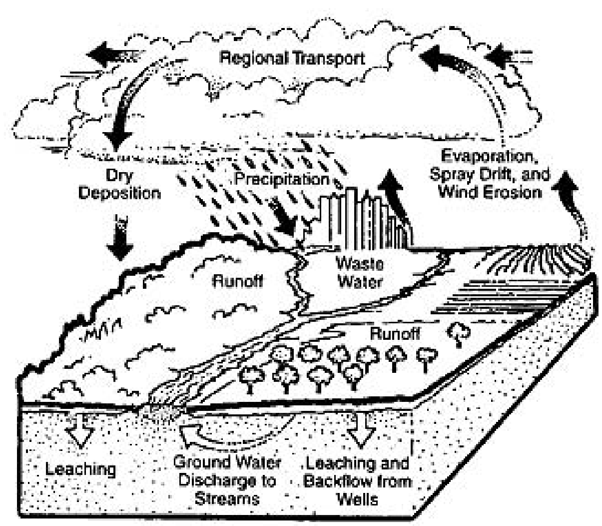


Figure 1.8.2. Pathways of pesticide movement in the hydrologic cycle.

While some substances that endanger water quality come from agriculture, most result from urban and industrial activity. Some also come from pesticide use on ornamentals. Whether in agricultural operations or in urban environments, the improper application, handling or disposal of pesticides can lead to water pollution. Therefore, it is important for ornamental operators to understand how to properly use pesticides to avoid human exposure and to protect water sources.

When selecting pesticides for use in ornamental settings, choose pesticides that will control the pest and have the least ability to runoff or leach into the soil. To achieve this balance, the applicator must be knowledgeable of a pesticide's efficacy and water solubility. Unfortunately, it is often difficult to determine if a pesticide has the potential to leach or run off into water sources. Water solubility information is available on the pesticide's label and the Material Safety Data Sheet (MSDS). However, many MSDS's do not provide water solubility or K_{oc} information. For specific product information, check reference sources and the company's technical sheets. Additional water data is often available from the University of Arkansas, Division of Agriculture, and the chemical company. **It is important to build your own file on pesticides and their potential for water contamination.**

Determining the soil type can be tricky for ornamental planting. Consider whether the planting is on natural soil in a relatively undisturbed area or on soil that was "developed" or "made." To assist with planting, contact the USDA – Natural Resources Conservation Service (NRCS) for soil maps to determine soil type, texture, organic matter content and depth to ground water. However, if the area experienced major soil movement and alteration, NRCS soil maps may not be useful.

Areas that are designed to drain require special consideration when selecting the appropriate pesticide. Determine if the planting has drain tiles or other drainage systems installed and know where these drainage systems empty. It is not good to move contaminated water from a treated area into any water system.

Determine the irrigation system to be used for the planting. During the planning process, consider the timing of pesticide application and the irrigation schedule. Pesticides should not be washed off the plants or through the soil too quickly.

Be prepared for accidents. Hoses sometimes break, drain plugs come out and sprayers can accidentally be overturned. Have the appropriate spill containment equipment in your vehicle.

Keep in mind that even if all the "numbers" indicate a pesticide has a high potential to leach or run off, this does not mean the pesticide will actually reach the water. There are many factors and situations that affect the risk of contamination.

Ways Pesticides Can Contaminate Water

Overapplication or misuse of pesticides can allow these materials to enter the surface and/or ground water. For some of the newer pesticides, drift from soil particles treated with the pesticide is a potential source of water contamination. Newer pesticides are often active at very low concentrations and, when bound to soil particles, the pesticide may be picked up by the wind and moved over surface water. When deposited in water, the soil particle with the pesticide attached can then move into the surface water. This is generally not a major problem unless large amounts of contaminated soil particles are moved and deposited in the same area or unless the pesticide is active on other target species.

Improperly cleaning pesticide containers and sprayers often leads to pesticide runoff or contamination of the soil at the mixing/loading site. Pesticide sprayers should be loaded and cleaned on an impervious pad. This eliminates concern about spills causing runoff or leaching problems, avoiding potential contamination of wells from constant small spillages at the same site.

When filling any sprayer, either an anti-back-siphoning device or an air gap should be used. This prevents the back siphoning of the pesticide mix into the water line if water pressure is lost. If using anti-back-siphoning devices, periodically inspect the device to ensure it is functioning correctly. Mechanical back-siphoning devices have been known to stick in the open position.

Pesticide containers should be pressure or triple rinsed immediately after emptying to rinse all the excess pesticide from the container. The rinsate is to be rinsed directly into the sprayer so the rinsate can be sprayed on the labeled site. This provides a clean container that can be recycled.

Pesticide Properties

It is extremely important to know the properties of the pesticide before its purchase and use. Know the pesticide's formulation, persistence, volatility, solubility in water and its soil adsorption.

Formulation – Pesticides come in several physical formulations. Common formulations include emulsifiable and flowable concentrates, wettable powders, granules and water dispersible granules.

Persistence – Persistence describes how long a pesticide remains active. Half-life is one measure of persistence. The half-life of a substance is the time required for that substance to degrade to one-half its original concentration. In other words, if a pesticide has a half-life of 10 days, half of the pesticide is broken down or lost 10 days after application. After this time, the pesticide continues to break down at the same rate.

The half-life of a pesticide is not an absolute factor. Soil moisture, temperature, organic matter, microbial activity, soil pH and sunlight all affect the breakdown of pesticides. In general, the longer a pesticide persists in the environment, the more likely it is to move from one place to another and be a potential water contaminant.

Volatility – Many pesticides, including several herbicides and soil fumigants, can escape from soils as gases. Some can distill from soils and enter the atmosphere with evaporating water. Pesticide particles in the atmosphere can come back to earth in rain or snow, which can leach into ground water or be carried by runoff into surface water.

Water Solubility – The water solubility of a pesticide determines how easily it goes into solution with water. When a pesticide goes into solution with water, the pesticide will move where the water goes. Solubilities are usually given in parts per million (ppm) or, in some cases, as milligrams per liter (mg/l). The solubility of a substance is the maximum number of milligrams that will dissolve in 1 liter of water.

Simply being water-soluble does not mean that a pesticide will leach into ground water or run off into surface water. However, solubility does mean that if a soluble pesticide somehow gets into water, it will probably stay there and go where the water goes.

Water solubility is one indicator of the pesticide's mobility in water. For most compounds, water solubility and adsorption to soil particles are inversely related. However, as with most rules, there are exceptions. Water solubility greater than 30 ppm indicates that significant mobility is possible if the K_{oc} value is low (less than 300-500). Pesticides with solubility greater than 30 ppm and K_{oc} values less than 100 are considered to be a concern in sandy soil, according to the EPA.

Pesticides with solubilities of 1 ppm or less are believed to have a higher likelihood of runoff. Likewise, pesticides with high K_{oc} values are more likely to run off than leach. Pesticides with K_{oc} values of 1,000 or higher have a strong soil attachment.

Soil Adsorption – Soil adsorption is the tendency of materials to attach to the surfaces of soil particles. If a substance is adsorbed by the soil, the substance stays on or in the soil and is less likely to move into the water system unless soil erosion occurs. A soil's texture, structure and organic matter content affect the soil's ability to adsorb chemicals.

The K_{oc} describes the relative affinity or attraction of the pesticide to soil material and, therefore, the pesticide's mobility in soil. Pesticides with small K_{oc} values are more likely to leach than those that have high K_{oc} values.

How Pesticides Enter Surface and Ground Water

Pesticides can enter water through surface runoff, leaching and erosion. Water that flows across the surface of a planting, whether from rainfall, irrigation or other sources, always flows downhill until it meets a barrier, joins a body of water or begins to percolate into the soil.

Wind and water can erode soil that contains pesticide residues and carry them into nearby bodies of water. Even comparatively insoluble pesticides and pesticides with high soil adsorption properties can move with eroding soil. A number of the sulfonylurea herbicides have warning statements regarding movement of treated soil.

With increasing frequency, soil-applied pesticides are being found in ground water where the water table is close to the soil surface and/or where the soil is sandy. As a result, ornamental applicators need to ensure that irrigation systems are not operated too long after pesticides have been applied. This will avoid the irrigation water washing the pesticide off the planting and into the storm drain.

Pesticides that enter water supplies can come either from point sources or from nonpoint sources. Pollution from point sources originates from small, easily identified causes or areas of high pesticide concentration, such as tanks, mixing/loading sites at wellheads, containers or spills. Nonpoint sources are diffuse, undefined areas in which pesticide residues are present, such as fields or city streets.

Water Quality Protection

Most pesticide contamination does not come from the normal, correct usage. Problems arise from misuse or careless handling. A checklist is provided to use when applying any pesticide. Use these guidelines to help safeguard water sources near your ornamental operation:

- Read and follow pesticide label directions.
- Consider the susceptibility of the site. Be sure that weather and irrigation will not increase the risk of water contamination.
- Evaluate the location of water sources, including storm drains.
- Use IPM practices.
- Make sure pesticide containers do not leak.
- When possible, use pesticides with the least potential for surface runoff and leaching.
- Prevent backflow during mixing operations by using a mechanical anti-back-siphoning device or an air gap.
- Always mix, handle and store pesticides down slope and at least 50 feet from water wells.
- Do not apply pesticides when conditions are most likely to promote runoff or excessive leaching.
- Do not spray pesticides on windy days (winds in excess of 10 mph).
- Calibrate all pesticide application equipment at least after every third use.
- Prevent pesticide spills and leaks from application equipment.
- Leave buffer zones around sensitive areas, such as wells, gardens, water gardens, streams, drainage ditches, septic tanks and other areas that lead to ground or surface water.
- Do not water pesticide-treated areas immediately after application unless indicated on label instructions.
- Triple or pressure rinse pesticide containers upon emptying and pour rinsate into the spray tank.
- Store pesticides properly.
- Dispose of excess pesticides by using on labeled sites.

Tables 1.8.1, 1.8.2 and 1.8.3 are provided at the end of this chapter to give examples of information needed for making decisions to avoid surface or ground water contamination. Ornamental applicators should develop a database for the pesticides they apply to ornamentals.

Worker Protection Standard

Although the EPA's Worker Protection Standard (WPS) does not include applicators treating household/urban ornamentals, it does include those making applications to greenhouse, nursery and Christmas tree sites. We would expect many of the requirements for WPS to eventually include ornamental applicators. In that respect, applicators should carefully read the pesticide labels for PPE requirements.

Table 1.8.1. Insecticide Water Quality Data.

Common Name	Solubility (ppm)	Toxicity (LD_{50}) (rat) in mg/kg	Half-Life in Days	Persistence in the Soil	Soil Adsorption
Abamectin	.001	650	>30	Low	High
Acephate	650,000	1,447	3	Low	Medium
Bendiocarb	280	179	5	Low	
Carbofuran	351	4	40	Medium	Medium
Carbaryl	120	283	10		High
Chlorpyrifos	1.4	270	30		High
Cyfluthrin	.025	826	30	Low	
Diazinon	60	300	30		High
Dicofol	.8	595	60		Large
Dimethoate	23.3	235	7		Medium
Disulfoton	25		2	Medium	Medium
Endosulfan	.32	160	150	High	
Fluvalinate	.001	16,800	50		
Imidacloprid	610	5,000	<1	Low	Medium
Lindane	7.3	125		High	
Malathion	145	2,800	1		
Oxamyl	280,000	4	10	Medium	Low
Permethrin	.2	4,000	<40		
Propargite	632	119	56		

Table 1.8.2. Herbicide Water Quality Data.

Common Name	Solubility (ppm)	Toxicity (LD_{50}) (rat) in mg/kg	Half-Life in Days	Persistence in the Soil	Soil Adsorption
Fluazifop-P-butyl		2,712	<21		
Glyphosate		5,000	60	Low	High
Metolachlor	530	2,780			High*
Napropamide	73	>500	25	Low	High
Oxadiaxon	0.7	>5,000	>90		High
Oxyfluoren	0.1	>5,000	30		High
Oryzalin	2.6	>10,000	>30		
Oxadiazon	0.0007	4,100			High
Pendimethalin	0.275	3,956	>90	High	High
Sethoxydim	4.8	3,125	4-11	Low	Low
Simazine	3.5	>5,000	50		High*
Trifluralin	0.3	>10,000	>60	Medium	High

*Is readily absorbed by 2% or greater organic matter and clay soils.

Figure 1.8.3. Fungicide Water Quality Data.

Common Name	Solubility (ppm)	Toxicity (LD_{50}) (rat) in mg/kg	Half-Life in Days
Captan	3.3	9,000	3
Chlorothalonil	.81	>10,000	30
Copper	2.9	4,500	
Etridiazole	117	1,077	10
Fenarimol	13.7	3	360
Ferbam	130	>17,000	17
Fosetyl-Al	12,000	5,800	<1
Iprodione	13	>4,400	
Mancozeb	6.2	11,200	15
Metalaxyl	7,100	669	30
Myclobutanil	142	i,600	66
Propiconazole	100	1,517	100
Thiophanate-methyl		7,500	21
Triadimefon	64	1,000	26
Triflumizole	12,500	715	14
Triforine	9	>16,000	21
Vinclozolin	2.6	>5,000	20
Ziram	1.58	320	1

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Ornamental Glossary

Abdomen: The posterior of the three main body divisions of insects.

Abiotic: Without life or ever being alive.

Absorption: The process by which an herbicide passes from one system into another, e.g., from the soil solution into a plant root cell or from the leaf surface into the leaf cells.

Acid equivalent (ae): The theoretical yield of parent acid from a pesticide active ingredient that has been formulated as a derivative. For example, Roundup Pro contains 4 pounds per gallon of the isopropylamine salt form of glyphosate but 3 pounds per gallon of the parent acid.

Acid soil: Soil with a pH value less than 7.0.

Activation: The process by which a surface-applied herbicide is moved into the soil where it can be absorbed by emerging seedlings. This is normally accomplished by rainfall, irrigation, or tillage. Activation does not imply any chemical change in the active ingredient.

Active ingredient (ai): The chemical in an herbicide formulation primarily responsible for its phytotoxicity and which is identified as the active ingredient on the product label.

Adjuvant: Any substance in an herbicide formulation or added to the spray tank to modify herbicidal activity or application characteristics.

Adsorption: The process by which an herbicide associates with a surface, e.g., a soil colloidal surface.

Adsorption characteristics (K_{oc}): The K_{oc} describes the relative affinity or attraction of the pesticide to soil material and, therefore, its mobility in soil. Pesticides with small K_{oc} values are more likely to leach than those with high K_{oc} values.

Aestivation: Period of insect inactivity (dormancy) during the summer months.

Alkaline soil: Soil with a pH greater than 7.0.

Allelopathy: The adverse effect on the growth of plants or microorganisms caused by the action of chemicals produced by other living or decaying plants.

Alternate host: A plant used by the pest to complete its life cycle other than the primary host. Example: One of two kinds of plants on which a parasitic fungus (e.g., rust) must develop to complete its life cycle.

Antagonism: An interaction of two or more chemicals such that the effect when combined is less than the predicted effect based on the activity of each chemical applied separately.

Anthracnose: A disease that appears as irregular dead areas on leaves and is caused by a fungus.

Asexual: Reproducing without mating (no union of sperm and egg).

Bactericide: A chemical compound that kills or inhibits bacteria.

Band treatment: Applied to a linear restricted strip on or along crop rows rather than continuous over the field area.

Bioaccumulation: The storage or accumulation of materials in the tissues of living organisms.

Bioassay: Quantitative or qualitative determination of herbicide by use of sensitive indicator plants or other biological organisms.

Biological control of weeds: Control or suppression of weeds by the action of one or more organisms, through natural means or by manipulation of the weed, organism or environment.

Biological control: Suppression or destruction of pest populations by other living organisms (e.g., parasites, predators, microorganisms) other than the host or man.

Biotic: Relating to living things.

Biotype: A population within a species that has a distinct genetic variation.

Blight: A disease characterized by general and rapid killing of leaves, flowers, and stems.

Blotch: A disease characterized by large, irregular-shaped spots or blots on leaves, shoots, and stems.

Boot or Booting: A growth stage of grasses (including cereal crops) when the upper leaf sheath swells due to the growth of the developing spike or panicle.

Broadcast treatment: Applied as a continuous sheet over the entire field.

Brood: Individuals that hatch from the eggs laid by one mother (or the individuals that hatch and mature about the same time).

Canker: A necrotic, often sunken lesion on a stem, branch, or twig of a plant.

Carcinogenic: A property that makes a material more likely to cause cancer in humans or animals that are exposed to that property.

Carrier: A gas, liquid, or solid substance used to dilute or suspend an herbicide during its application.

Caterpillar: The larvae of a butterfly or moth.

Chemical name: The systematic name of a chemical compound according to the rules of nomenclature of the International Union of Pure and Applied Chemistry (IUPAC), Chemical Abstracts Service, or other organization.

Chlorosis: Yellowing of normally green tissue due to chlorophyll destruction or failure of chlorophyll formation.

Cocoon: The silken case in which a pupa develops.

Common name: A generic name for a chemical compound. Glyphosate is the common name for Roundup.

Compatibility: The characteristic of a substance, especially a pesticide, of being mixable in a formulation or in the spray tank for application in the same carrier without undesirably altering the characteristics or effects of the individual components.

Competition: The active acquisition of limited resources by an organism that results in a reduced supply and consequently reduced growth of other organisms in a common environment.

Concentration: For herbicides, the quantity of active ingredient or parent compound equivalent expressed as weight per unit volume (such as pounds per gallon for liquids). Dry herbicide concentrations are expressed as percent by weight.

Contact herbicide: An herbicide that causes injury to only the plant tissue to which it is applied, or an herbicide that is not appreciably translocated within plants.

Contact pesticide: A pesticide that kills on contact.

Cornicles: Projections (tailpipelike appendages) on the posterior part of the abdomen of certain aphids.

Crawlers: The immature, active-moving stage of scale insects.

Degradation: Degradation occurs due to sunlight, soil microorganisms, and chemical reactions in the soil. Soil temperature and moisture can greatly affect degradation. Degradation rate is quantified in terms of degradation half-life, the time required for 50 percent of the pesticide to decompose to products other than the original pesticide. The EPA considers a pesticide with a soil half-life of greater than 21 days as having a potential for causing ground water concerns due to the pesticide's longevity.

Diapause: Similar to hibernation or the period of rest in the life of an insect (no growth and suspended activity) during the winter or colder months.

Dicot: Abbreviated term for dicotyledon; preferred in scientific literature over broadleaf to describe plants.

Dicotyledon (dicot): A member of the Dicotyledoneae; one of two classes of angiosperms usually characterized by having two seed leaves (cotyledons), leaves with net venation and root systems with tap roots.

Dieback: Progressive death of shoots, twigs, branches, terminal growth, and/or roots generally starting at the tip.

Diluent: Any gas, liquid, or solid material used to reduce the concentration of an active ingredient in a formulation.

Directed application: Precise application to a specific area or plant organ such as to a row or bed or to the leaves or stems of plants.

Disease: Any malfunctioning of host cells and tissues that results from continuous irritation by a pathogenic agent or environmental factor and leads to development of symptoms.

Dispersible granule: A dry granular formulation that will separate or disperse to form a suspension when added to water.

Dormancy: The state of inhibited seed germination or growth of a plant organ when in an environment normally conducive to growth.

Ecotype: A population within a species that has developed a distinct morphological or physiological characteristic (e.g., herbicide resistance) in response to a specific environment and that persists when individuals are moved to a different environment.

Emergence: The event in seedling establishment when a shoot becomes visible by pushing through the soil surface.

Emulsifiable concentrate (EC): A single-phase liquid formulation that forms an emulsion when added to water.

Encapsulated formulation: Herbicide enclosed in capsule or beads of material to control the rate of release of active ingredient and thereby extend the period of activity.

Epidermis: The outermost layer of cells of the leaf and of young stems and roots.

Epinasty: That state in which more rapid growth on the upper part of a plant organ or part (especially leaf) causes it to bend downward.

Exoskeleton: The external skeleton (hard shell covering) of insects and other arthropods.

Exuviae: The cast-off skin (or molt residue) of insects or other arthropods.

Flowable: A two-phase formulation containing solid herbicide suspended in liquid and that forms a suspension when added to water.

Formulation: (1) A pesticide preparation supplied by a manufacturer for practical use. (2) The process, carried out by manufacturers, of preparing pesticides for practical use.

Frass: Insect excrement (fecal material) typically mixed with plant fragments (often associated with boring insects).

Fruiting body: A complex fungal structure containing spores.

Fungicide: A compound toxic to fungi.

Gall: The abnormal growth of plant tissues caused by the stimulus of an insect, mite, nematode, or microorganism/pathogen.

Generation: The period from the beginning of one life cycle (birth) until the end of that life cycle (death).

Granular: A dry formulation consisting of discrete particles generally $<10\ mm^3$ and designed to be applied without a liquid carrier.

Ground water: A region within the earth that is wholly saturated with water.

Head or heading: A growth stage of grasses (including cereal crops) when the spike or panicle is emerging or has emerged from the sheath.

Herbaceous plant: A vascular plant that does not develop persistent woody tissue above ground.

Herbicide: A chemical substance or cultured biological organism used to kill or suppress the growth of plants.

Herbicide resistance: The trait or quality of a population of plants within a species or plant cells in tissue culture of having a tolerance for a particular herbicide that is substantially greater than the average for the species and that has developed because of selection for naturally occurring tolerance by exposure to the herbicide through several reproductive cycles.

Honeydew: A sweet, sticky, shiny secretion of aphids, whiteflies, scales, and mealybugs. It is a favorable medium for the growth of black, sooty mold (fungi).

Host range: The various kinds of host organisms that may be attacked by a parasite.

Host: An organism that is invaded by another organism and from which the invading organism obtains its nutrients.

Hypha: A single thread of fungus mycelium.

Incorporate: To mix or blend an herbicide into the soil.

Infection: The establishment of a parasite within a host plant.

Infectious disease: A disease that is caused by a pathogen that can spread from a diseased to a healthy plant.

Inoculum: The pathogen or its parts that can cause infection. That portion of individual pathogens that are brought into contact with the host.

Instar: The stage of an insect between molts.

Interference: For plants, the total adverse effect that plants exert on each other when growing in a common ecosystem. The term includes competition, allelopathy, biotic interference, and other detrimental modifications in the community or environment.

Label: The directions for using a pesticide approved as a result of the registration process.

Larva(e): The active, immature stage of an insect with complete metamorphosis (four life stages – egg, larva, pupa and adult), e.g., caterpillars, maggots and grubs.

Latent infection: The state in which a host is infected with a pathogen but does not show any symptoms.

Lateral movement: Movement of an herbicide through soil, generally in a horizontal plane, from the original site of application.

Leaching: (1) The removal of materials in solution from the soil. (2) The downward movement of material(s) into a soil profile with soil water (material may or may not be in true solution and may or may not move from soil).

Leaf spot: A self-limiting lesion on a leaf.

Lesion: A localized area of discolored, diseased tissue.

Life cycle: The changes in the form of an insect, beginning with the egg and ending with the adult reproductive stage (one complete life cycle equals one generation).

Metamorphosis: Changes in form as insects grow and develop.

Mildew: A fungal disease of plants in which the mycelium and spores of the fungus are seen as a whitish growth on the host surface.

Molt: The shedding of the exoskeleton (resulting in an exuviae) by an insect as it grows and develops.

Monocot: Abbreviated term for monocotyledon; preferred in scientific literature over grass to describe plants.

Monocotyledon (monocot): A member of Monocotyledoneae; one of two classes of angiosperms, usually characterized by the following: one seed leaf (cotyledon), leaves with parallel venation, root systems arising adventitiously and usually diffuse (fibrous).

Mosaic: Symptom of certain viral diseases of plants characterized by intermingled patches of normal and light green or yellowish color.

Mottle: An irregular pattern of indistinct light and dark areas.

Mycelium: The hypha or mass of hyphae that make up the body of a fungus.

Mycoplasmalike organisms: Microorganisms found in the phloem and phloem parenchyma of diseased plants and assumed to be the causes of the disease; they resemble mycoplasmas in all respects except that they cannot yet be grown on artificial nutrient media.

Necrosis: Death of tissue (characterized in plants by browning and desiccation).

Necrotic: Dead and discolored.

Nematicide: A chemical compound or physical agent that kills or inhibits nematodes.

Nematode: Microscopic, wormlike animals that live saprophytically in water or soil, or as parasites of plants and animals.

Noninfectious disease: A disease that is caused by an environmental factor, not by a pathogen.

Nonselective herbicide: An herbicide that is generally toxic to all plants treated. Some selective herbicides may become nonselective if used at very high rates.

Nontarget species: A species not intentionally affected by a pesticide.

Nymph: The immature stage (resembling the adult) of an insect that develops through three stages (egg, nymph, adult) or the term for the young insects with gradual metamorphosis.

Overtop application: A broadcast or banded application applied over the canopy of crops such as by airplane or a raised spray boom of ground equipment.

Overwintering stage: The life stage/form of an insect that diapauses to survive winter weather.

Ovipositor: The egg laying apparatus/structure of a female insect.

Parasite: An organism living on or in another living organism (host) and obtaining its food from the latter.

Pathogen: An entity that can incite disease.

Pathogenicity: The capability of a pathogen to cause disease symptoms.

Pelleted formulation: A dry formulation consisting of discrete particles usually larger than 10 cubic millimeters and designed to be applied without a liquid carrier.

Persistence: The ability of a substance to remain in its original form without breaking down.

Persistent herbicide: A herbicide that, when applied at the recommended rate, will harm susceptible crops planted in normal rotation after harvesting the treated crop, or that interferes with regrowth of native vegetation in noncrop sites for an extended period of time. See residual herbicides.

Pesticide interaction: The action or influence of one pesticide upon another and the combined effect of the pesticide(s) on the pest(s) or crop system.

Pheromone: A biochemical substance produced by insects to communicate with the same species through the sense of smell. An insect sex pheromone is a chemical produced by the females to attract males.

Phloem: The living tissue in plants that functions primarily to transport metabolic compounds from the site of synthesis or storage to the site of use.

Phytotoxic: Injurious or lethal to plants.

Plant growth regulator: A substance used for controlling or modifying plant growth processes without severe phytotoxicity.

Postemergence (POST): (1) Applied after emergence of the specified weed or crop. (2) Ability to control established weeds.

Predaceous: Feeding on another organism, usually killing it.

Preemergence (PRE): (l) Applied to the soil before emergence of the specified weed or crop. (2) Ability to control weeds before or soon after they emerge.

Preplant application: Applied before planting or transplanting a crop, either as a foliar application to control existing vegetation or as a soil application.

Preplant incorporated (PPI): Applied and blended into the soil before seeding or transplanting, usually by tillage.

Prolegs: The fleshy abdominal legs of caterpillars and sawfly larvae.

Pupa(e): The resting/transformation stage between the larva and adult in insects with complete metamorphosis.

Pustule: Small, blister-like elevation of epidermis created as spores form underneath and push outward.

Rate: For herbicides, the quantity of active ingredient expressed as weight per unit area of treated surface or per unit volume of the treated environment for aquatic applications.

Registration: The process designated by the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) and carried out by the Environmental Protection Agency (EPA) by which a pesticide is legally approved for use in the U.S.

Residual herbicide: An herbicide that persists in the soil and injures or kills germinating weed seedlings for a relatively short period of time after application. See persistent herbicide.

Residual: A pesticide persisting for several days, weeks, or longer after application in amounts sufficient to kill.

Residue: That quantity of an herbicide or metabolite remaining in or on the soil, plant parts, animal tissues, whole organisms and surfaces.

Resistance: Chemical, structural or other mechanisms that retard, degrade or render a pesticide ineffective to an organism, or the possession of qualities that hinder the development of a given pathogen, resulting in little or no infection. **Note: (1)** Resistance in insects or mites where a pesticide does not kill the pests is not immunity. Insecticide resistance is the ability of some individuals of a pest population to survive exposure to an insecticide that would be fatal to others because of some genetic (inheritable) difference between them and the other individuals. It tends to occur in pest populations where they are regularly exposed to an insecticide. Pests with high reproductive rates and short life cycles (resulting in more generations produced in the shortest period of time) provide the greatest potential for the occurrence of resistance. **(2)** There is no general agreement as to the distinction between herbicide tolerance and herbicide resistance in plants.

Resting spore: A sexual or other thick-walled spore of a fungus that is resistant to extremes in temperature and moisture and which often germinates only after a period of time from its formation.

Ringspot: A circular area of chlorosis with a green center; a symptom of many virus diseases.

Rot: The softening, discoloration, and often disintegration of a succulent plant tissue as a result of fungal or bacterial infection.

Rust: A disease giving a "rusty" appearance to a plant and caused by one of the Uredinales (rust fungi).

Safener: A substance that reduces toxicity of herbicides to crop plants by a physiological mechanism.

Scab: A roughened, crustlike diseased area on the surface of a plant organ. A disease in which such areas form.

Scorch: "Burning" of leaf margins as a result of infection or unfavorable environmental conditions.

Selective herbicide: A chemical that is more toxic to some plant species than to others.

Senescent: The growing old and dying back of plant tissue.

Sessile: Term describing certain stages of an insect that are normally immobile (as stationary to an area and feeding), e.g., scale insects after the crawler stage.

Seta(e): Hairlike sensory structures found on the exoskeleton of insects and other arthropods.

Shot-hole: A symptom in which small disease fragments of leaves fall out and leave small holes in their place.

Sign: The pathogen or its parts or products seen on a host plant.

Skeletonize: Describing the feeding pattern of certain leaf-feeding insects that remove the tissue from leaves except for the veins.

Slope and landscape: Areas with high runoff capability will have less of an impact on water infiltration than areas that are flat or have a concave slope. Landscape that encourages runoff will minimize leaching. Landscape that holds water may increase leaching potential or may provide organic matter which assists in "holding" the pesticide.

Soil organic matter: Soil organic matter helps to bind pesticides, especially those with high K_{oc} values, and promotes degradation.

Soil permeability: Permeability is a function of soil texture, structure, and pore space. Highly permeable, coarse, sandy soils have large pores that allow water and pesticides to move rapidly between soil particles during rainfall or irrigation. In medium- and fine-textured soils, water moves more slowly, allowing more time for pesticide adsorption and degradation. Each layer of soil can have a different permeability, but the most restrictive layer determines the overall permeability. Soil permeability can be enhanced by the presence of macropores – large channels produced by plant roots, earthworms, soil cracks, and the burrowing of smaller animals.

Soil pH: The pH of the soil is a measure of its degree of acidity or alkalinity. The pH affects the degradation rate of pesticides and the adsorption characteristics and mobility of ionic pesticides.

Soil texture: Texture is determined by the reactive proportion of sand, silt, and clay. Permeability and chemical adsorption are both affected by soil texture.

Soluble concentrate (SC): A liquid formulation that forms a solution when added to water.

Soluble granule (SG): A dry granular formulation that forms a solution when added to water.

Soluble powder: A dry formulation that forms a solution when added to water.

Solution: A homogeneous or single-phase mixture of two or more substances.

Spore: The reproductive unit of fungi consisting of one or more cells; it is analogous to the seed of green plants.

Sporulate: To produce spores.

Spot treatment: An herbicide applied to restricted area(s) of a whole unit; i.e., treatment of spots or patches of weeds within a larger field.

Spray drift: Movement of airborne spray from the intended area of application.

Surfactant: A material that improves the emulsifying, dispersing, spreading, wetting or other properties of a liquid by modifying its surface characteristics.

Susceptibility: (1) The sensitivity to or degree to which a plant is injured by an herbicide treatment. **(2)** The inability of a plant to resist the effect of a pathogen or other damaging factor.

Susceptible: Lacking the inherent ability to resist disease or attack by a given pathogen; nonimmune.

Suspension: A mixture containing finely divided particles dispersed in a solid, liquid, or gas.

Symptom: The external and internal reactions or alterations of a plant as a result of a disease.

Systemic: Synonymous with translocated herbicide, but more correctly used to describe the property of insecticides or fungicides that are absorbed into a plant (through roots or leaves) and translocated to other tissue.

Tank-mix combination: Mixing of two or more pesticides or agricultural chemicals in the spray tank at the time of application.

Thorax: The middle body region of an insect (where the legs and wings are attached).

Tiller or Tillering: A growth stage of grasses when additional shoots are developing from the crown.

Tolerance: (1) Ability to continue normal growth or function when exposed to a potentially harmful agent (there is no general agreement as to the distinction between herbicide tolerance and herbicide resistance in plants). (2) The concentration of a pesticide residue that is allowed in or on raw agricultural commodities as established by the Environmental Protection Agency.

Toxicity: The quality or potential of a substance to cause injury, illness, or other undesirable effects.

Toxicology: The study of the principles or mechanisms of toxicity.

Trade name: A trademark or other designation by which a commercial product is identified.

Translocated herbicide: An herbicide that is moved within the plant. Translocated herbicides may be either phloem mobile or xylem mobile. However, the term frequently is used in a more restrictive sense to refer to herbicides that are applied to the foliage and move downward through the phloem to underground parts.

Vapor drift: The movement of pesticides as vapor from the area of application after the spray droplets have landed on the target.

Vascular: Term applied to a plant tissue or region consisting of conductive tissue; also refers to a pathogen that grows primarily in the conductive tissues of a plant.

Virulence: The degree of pathogenicity of a given pathogen.

Virulent: Capable of causing a severe disease; strongly pathogenic.

Virus: A submicroscopic obligate parasite consisting of nucleic acid and protein.

Volatilization: Volatilization or evaporation reduces the total amount of pesticide available for movement to water. Volatilization increases with air temperature and the vapor pressure of the pesticide formulation. It occurs more rapidly in wet than in dry soils.

Water solubility: A pesticide's water solubility is often viewed as an indicator of its mobility in water. Water solubility and adsorption to soil particles, for most compounds, are inversely related. However, as with most rules, there are exceptions. Water solubility greater than 30 ppm indicates that significant mobility is possible if the K_{oc} value is low (less than 300 -500). The EPA considers pesticides with solubility greater than 30 ppm and K_{oc} values less than 100 to be a concern in sandy soils. Pesticides with solubilities of 1 ppm or less are believed to have a higher likelihood of runoff. Likewise, pesticides with high K_{oc} values have a higher likelihood of runoff than leaching. Pesticides with K_{oc} values of 1,000 or higher have a strong attachment to soil. Solubility is measured in mg/l of the pesticide in water at room temperature (20 or 25ºC). It is generally the solubility of the pure (active ingredient) that is measured, not the formulated product.

Water table: The upper limit of the saturated level of the soil.

Weed: Any plant that is objectionable or interferes with the activities or welfare of man.

Weed control: The process of reducing weed growth and/or infestation to an acceptable level.

Weed eradication: The elimination of all vegetative plant parts and viable seeds of a weed from a site.

Wettable powder (WP): A finely divided dry formulation that can be readily suspended in water.

Wetting agent: (1) A substance that serves to reduce the interfacial tensions and causes spray solutions or suspensions to make better contact with treated surfaces (see surfactant). (2) A substance in a wettable powder formulation that causes it to wet readily when added to water.

Wilt: Loss of rigidity and drooping of plant parts generally caused by insufficient water in the plant.

Xylem: The nonliving tissue in plants that functions primarily to conduct water and mineral nutrients from roots to the shoot.

Zoospore: A spore bearing flagella and capable of moving in water.

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Turfgrass Pest Management

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Introduction to Turfgrass Pest Management

A turfgrass pest is any organism causing deterioration in the aesthetic or functional value of turfgrass. Pests include weeds, insects and mites, nematodes, diseases and vertebrate mammals.

When pests are mentioned, pesticides are considered as important means for achieving control. Pesticides are valuable components of a turfgrass management program, but pest management includes more than selecting and applying the appropriate pesticide. The concept of integrated pest management (IPM) begins with selection of a well-adapted turfgrass, following proper establishment procedures and implementing cultural practices that favor healthy turfgrass growth. Therefore, IPM is the proper use of pesticides, in conjunction with a sound cultural program that ensures high quality turfgrass.

Weeds and diseases are often indicative of unfavorable growing conditions for specific turfgrasses; their incidence can be prevented, or at least substantially reduced, where favorable turfgrass growth conditions prevail. Damage from insects and mites, nematodes and other animals are often greater where the turfgrass is also subjected to other stresses. Many pests can be effectively controlled as long as vigorous turfgrass growth is favored. As often as not, pest activity is the result of underlying cultural problems rather than the problem pest itself.

Symptoms associated with various pests and cultural problems are often similar and easily confused. As a result, pests can inflict extensive damage before proper control measures can be started. Therefore, the first step toward the alleviation of any turfgrass pest problem must be proper identification.

The following chapters in this manual are designed to help turfgrass managers understand cultural practices that promote a healthy turf, properly identify pest problems, understand conditions which favor these pests and review the principles of safe and proper pesticide application.

Turfgrass Management

Preventing pests from invading a turf area starts with maintaining a healthy, vigorously growing stand of turfgrass plants. Pests usually take advantage of a turfgrass that is exposed to long periods of environmental stress, improper cultural practices or selection of the wrong turfgrass for the area. Pesticides alone will not guarantee a successful pest management program.

Turfgrass maintenance requires timely implementation and use of cultural practices and pesticides. Simply stated, it is the "how to" and "when to" of maintaining turfgrasses. Turfgrass maintenance requires a year-round commitment of care from the turf manager and a monetary commitment to provide the necessary funds for equipment and supplies from club, community or school organizations.

Turfgrass Selection

Turfgrass selection should be based on the environment, the intended use and expected management intensity. Check with a turfgrass specialist or extension agent to find out which grasses perform best in a given area. Blends and mixtures should be used whenever possible to insure good performance over a wide range of conditions. Cool-season grasses (bentgrass, bluegrass, ryegrass, fescue) are best established in the fall, whereas warm-season grasses (bermudagrass, zoysiagrass, centipedegrass, St. Augustinegrass) are best planted in late spring or early summer.

Use of improved, adapted, turf-type grasses, free of objectionable weed and crop content, is one of the best means of preventing pest activity. A number of cultivars have been released with improved tolerance to certain diseases such as leaf spot, rust, dollar spot and others. Several cultivars are also being marketed which claim resistance to certain insects. Insist on certified seed or sod to assure high genetic purity. Uncertified seed or sods frequently produce plants of low quality that are very difficult to manage.

Cultural Practices

Mowing

Mowing schedules should be based on the desired cutting height and amount of plant growth allowed between mowings. The growth rate will depend on the level of soil moisture, nutrients, temperature and sunlight. Since these factors fluctuate from week to week, it follows that plant growth also fluctuates. Therefore, the time to cut turfgrasses is at a point so that no more than 1/3 of the leaf area is removed at any one mowing. This means to maintain a turf at 1 inch, it should be cut when it reaches 1 1/2 inches **(Table 2.2.1)**. Scalping or removing too much of the leaf area in a single mowing can cause plant stress and reduces the aesthetic value of the area.

Table 2.2.1. Cutting height and amount of growth allowed so no more than 1/3 of the leaf area is removed.

Cutting height	Growth allowed	Maximum height allowed*
1/2	1/4	3/4
5/8	1/4	7/8
3/4	3/8	1 1/8
7/8	1/2	1 3/8
1	1/2	1 1/2
1 1/2	3/4	2 1/4
2	1	3
2 1/2	1 1/4	3 3/4
3	1 1/4	4 1/4

*Please note that these values are to be used as guidelines and illustrate how the growth allowed is a direct function of the desired cutting height (i.e., maximum height allowed = 3/2 x desired cutting height).

Reel-type mowers provide the best mowing quality if properly maintained and operated. Rotary mowers are more versatile but may not cut as "clean" as a reel-type mower. Flail mowers are generally not used for fine turf because they are not designed to provide a quality cut at 1 inch or below. They are best suited for roadsides and utility turfgrass areas that are infrequently mowed at cutting heights of 2 to 3 inches or more. Regardless of the type of mower used, it is essential that mowing equipment be kept sharp and in good operating condition. Dull, improperly adjusted equipment bruises leaf tips, induces plant stress and destroys the aesthetic value of the area.

Irrigation

Irrigation is required to maintain soil moisture levels that support optimal turfgrass growth during periods of low or uneven rainfall. However, watering is one of the most often abused and misunderstood aspects of turfgrass culture. Frequent, shallow watering encourages shallow rooting, soil compaction, thatch accumulation, weed seed germination and disease development.

Irrigation frequency should be determined by the moisture needs of the turfgrass. It is difficult to schedule a definite irrigation frequency because of (1) dissimilar water holding capacities of different soil types, (2) weekly fluctuations in temperature, humidity and wind, and (3) the influence of management practices such as mowing and fertilization on turfgrass water consumption. Sandy coarse-textured soils absorb water faster but retain less water than fine-textured clay soils **(Figure 2.2.1)**. Therefore, more frequent applications of less water are required for turfgrass areas constructed on a sandy soil than those on a clay soil. Close mowing and increased applications of fertilizer accelerate growth and therefore increase the amount of water necessary for optimal turfgrass growth.

Turfgrasses should be irrigated when they show the first visual symptoms of wilt that is characterized by "foot printing" and a blue-gray appearance. Water constitutes approximately 80 percent of the fresh weight of turfgrasses. When turfgrasses experience moisture stress, their leaves begin to curl and wilt. Thus, the leaves are slower to bounce back when stepped or driven on. Enough water should be applied to wet the soil to a 6-inch depth. This can be checked with a soil probe. If the turf area begins to puddle, stop irrigating and allow the water to soak into the soil. It may be necessary to repeat this cycle several times before irrigation to the proper depth is complete.

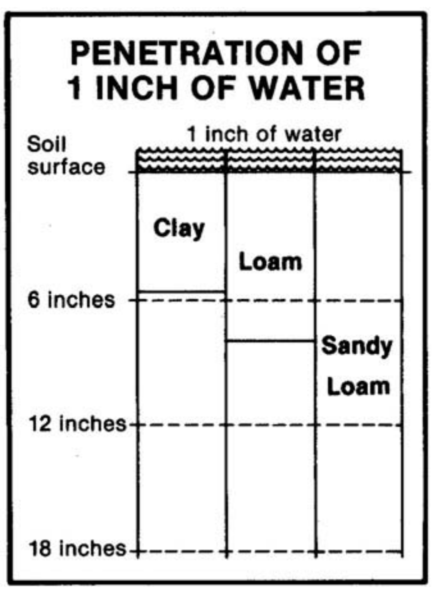


Figure 2.2.1. One inch of water will penetrate approximately 6 inches into clay soil and 18 inches into sandy loam soil.

Fertilization

Turfgrass plants require nitrogen (N), phosphorus (P), potassium (K) and 10 other mineral elements in available forms within the soil root-zone. Nitrogen fertilizers are particularly important because it is the nutrient required in greatest amounts by turfgrass (a healthy turfgrass plant is approximately 4% N, 0.5% P and 2% K, by dry weight).

Nitrogen applications are necessary because available nitrogen is negligible in most topsoils of Arkansas. The level of nitrogen within a turfgrass plant is correlated with plant color and vigor. However, excessive levels of nitrogen can lead to poor rooting, higher disease incidence and reduced tolerance to environmental stress, so it is best to maintain turfgrasses "just on the lean side." Phosphorus and potassium are also required in relatively large quantities for healthy plant growth. Applications of phosphorus and potassium are not needed as frequently as nitrogen because lower levels are required.

Sources of nitrogen that are quickly available, such as ammonium nitrate, ammonium sulfate or urea, are highly water soluble, cause a rapid but short-term growth response, have a high burn potential and have a low cost per unit nitrogen. Sources of nitrogen that are slowly available, such as ureaformaldehyde (UF, Nitroform), isobutylidine diurea (IBDU), sulfur-coated urea (SCU) and activated sewage sludge (Milorganite), generally produce a gradual long-term turfgrass response, have a low burn potential and have a moderate to high cost per unit nitrogen.

A complete fertilizer (one that contains nitrogen, phosphorus and potassium) may be necessary only once or twice a year, with the remaining applications consisting of a nitrogen-only source. Fertilizer formulations having a grade similar to 12-4-8 or 24-8-16 provide mineral elements closer to actual plant needs than fertilizer formulations such as 10-10-10 or 10-20-10. Apply no more than 1 to 1 1/2 pounds of quickly available nitrogen per 1,000 square feet in a single application. Higher rates cause increased shoot growth without corresponding increases in turfgrass quality. Slowly available fertilizers have a longer residual response. Nutrients are released for a duration that is two to three times longer than quickly available fertilizers. Therefore, fewer applications at higher rates are needed for slowly available fertilizers.

The availability of plant nutrient elements in the soil is influenced by soil pH. These nutrient elements are available at specific pH levels **(Figure 2.2.2)**. Between pH 6.5 and 7.0, all essential elements are adequately available for optimal turfgrass growth. To economically maintain optimum soil fertility, a soil test determining pH and levels of available phosphorus and potassium is beneficial. Lime (to increase pH) or sulfur (to reduce pH) **should only** be applied when recommended by a soil test.

Preventing Thatch

Thatch is a layer of undecayed grass found between the soil and green leaves of the turf plant. Thatch occurs because as old turf plants age and die, they decompose into fine textured humus that becomes part of the soil surface. Some factors that favor thatch buildup are:

- Excessive growth from over fertilization.
- Overgrowth followed by severe cutting.
- Fungus disease.
- Conditions unfavorable to microorganisms that decompose dead turf plants.

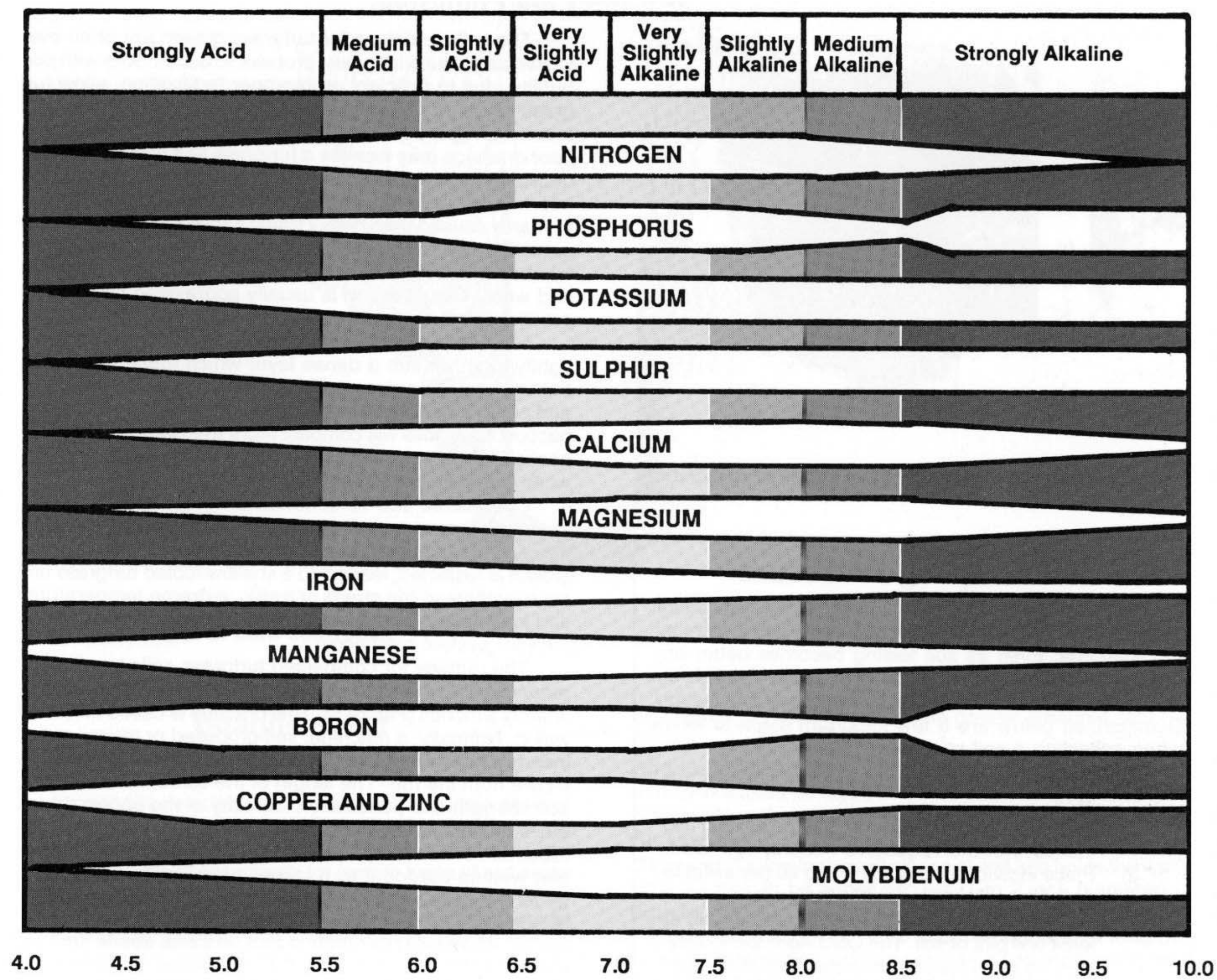


Figure 2.2.2. Nutrient availability as influenced by soil pH.

Rapid and excessive growth is the major cause of thatch because plant material is produced at a faster rate than decomposition can occur. Good cultural practices may not prevent thatch indefinitely but can retard its formation. Some of these practices include:

- Moderate and regular fertilization of the soil to maintain turf vigor without excessive growth.
- Regular mowing at the proper height to avoid plant stress.
- Deep, soaking irrigations during dry periods to encourage deep rooting.
- Vertical mowing annually before a new flush of growth.
- Aerification to improve water penetration and reduce compaction.

To determine if thatch is a problem, cut and lift several plugs two to three inches deep. Examine the profile of the plug. If thatch is present, it will appear as a distinct layer of felt-like material that is partially decomposed **(Figure 2.2.3)**.

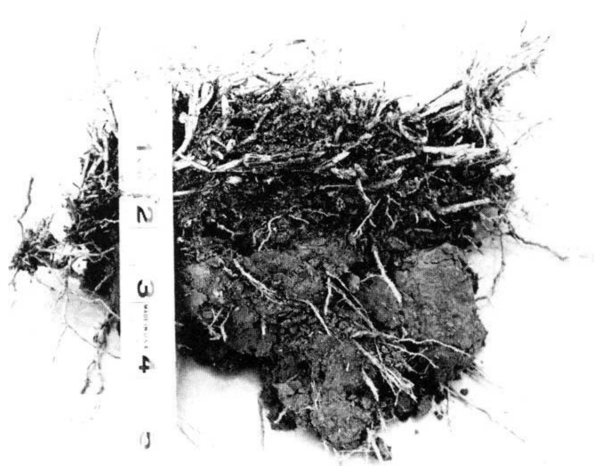


Figure 2.2.3. A bermuda turf with heavy thatch accumulation.

A thatch layer in excess of 1/3 inch should be removed by a verticutter, power rake or dethatching machine. Cool-season species should have thatch removed in the fall and spring months. Warm-season species can be lightly dethatched before greenup in the late winter or early spring (before March 15) or heavily dethatched after the turf is completely green in late spring or early summer (May or June).

In severe situations, removal of thatch by mechanical means will also remove most of the green living grass. Moderate treatments over 2 to 3 years are more desirable than complete removal in a single operation.

Soil Sampling Procedure

The use of soil testing as a guide to the application of agricultural chemicals on turfgrass continues to increase in Arkansas. Even as soil testing becomes better and more widely used, getting a good soil sample stands out as a major factor affecting the usefulness of soil testing. Summarized below are a few important steps to follow when collecting a soil sample:

1. Follow a random pattern when sampling a turf area.
2. Individual sample depths should be at least 2 inches with the vegetative material removed.
3. Place individual samples (15 to 20 per area) in a clean container and mix thoroughly.
4. The test sample for the area should contain at least 1 pint of soil. Soil sample containers are provided free-of-charge through your county Extension office.

Core Cultivation

The soil conditions for turfgrass growth are often overlooked as a cause for a pest problem to occur. Soils with poor fertility due to deficient or improper fertilization allow turfgrass pests to invade an area. Even though the area is mowed, irrigated and fertilized properly, soil compaction or poor drainage may weaken a turfgrass and increase its susceptibility to turfgrass pests. Soil compaction causes poor internal soil aeration and water drainage **(Figure 2.2.4)**. It is primarily caused from heavy traffic and is more likely in soils containing clay. The end result is a turf area characterized by shallow-rooted plants that cannot withstand heavy use and wear. This situation is usually aggravated by irrigation practices that are too frequent and too light.

Soil compaction occurs when soil particles are pressed tightly together into a dense layer that impairs soil aeration and water movement. The centers of most football fields, and along sidewalks or cart paths, are areas prone to compaction. Clay soils will compact more than sandy soils. Compaction can occur quickly any time a turfgrass area is used when it is wet, particularly those constructed of clay.

Compacted soil is detrimental to the growth of turfgrasses because it impedes the

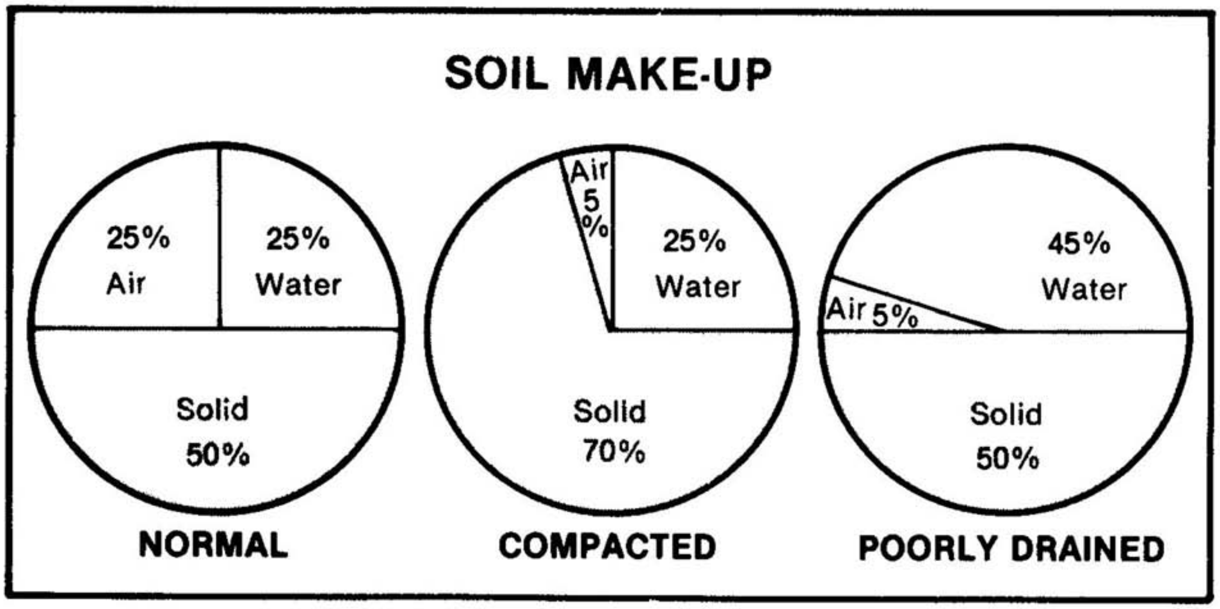


Figure 2.2.4. "Normal soil" contains 50 percent soil material, 25 percent air and 25 percent water. Compacted soil has too little air space, and poor drainage occurs when the soil holds too much water.

entry and movement of air, water and nutrients into and within the root-zone soil. Root growth is restricted, leading to a shallow-rooted turfgrass unable to withstand the stress of traffic, extreme temperatures and low moisture. In severe cases of compaction, death of the root system may occur.

The remedy for compacted turfgrass soils involves the removal of 1/4- to 3/4-inch diameter cores to a depth of approximately 3 inches **(Figure 2.2.5)**. This practice is called core cultivation. Normally, a machine, self-propelled or tractor-pulled, inserts a hollow metal tine or spoon into the soil and extracts a core from the turf. The length of the cores will vary due to soil strength and penetration capacity of the coring device, but they should be at least 2 inches in length for effective reduction of soil compaction. Adding weight to the machine and wetting the top 4 to 6 inches of soil 1 to 2 days prior to core cultivation will aid in the penetration of metal tines or spoons.

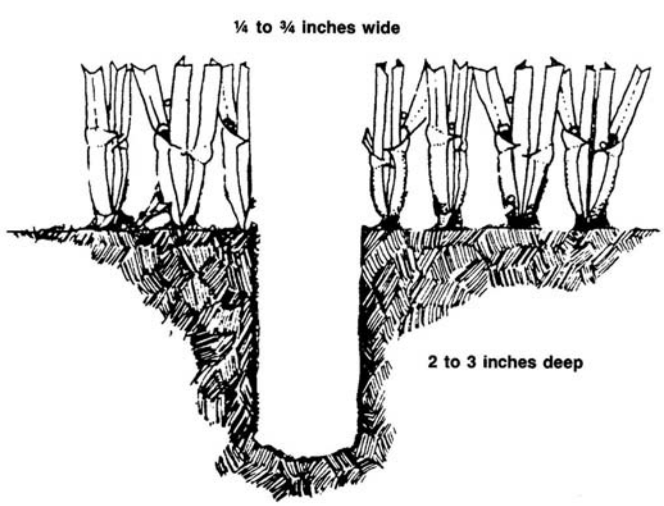


Figure 2.2.5. Example of core cultivation.

Establishment

Site Selection and Preparation

Proper site selection and preparation can help prevent the development of future problems. Good soil and surface drainage can help reduce disease and weed problems. Soil mixtures developed specifically for certain types of turf areas can aid soil drainage, prevent soil compaction and provide an environment favorable for good growth. Wise tree removal can limit shade and tree root competition as well as reduce environmental conditions favorable for pest development. Certain diseases such as Pythium blight are more likely to occur where trees or dense undergrowth impedes air movement.

Soil amendments (sand, organic matter, etc.) to improve drainage as well as fertilizer and lime are best incorporated prior to seeding. The type and quantity of amendments should be determined from chemical and physical soil tests. Soil test results are only as good as the sample submitted; therefore, care should be taken to insure that each sample is representative of each site. Amendments should be evenly spread and thoroughly incorporated to be most effective and to eliminate a future nonuniform appearance of the turf.

Methods

Depending on the cultivar and species, turfgrasses can be seeded or vegetatively propagated by sodding, plugging, sprigging or stolonizing.

The methods of turfgrass establishment are briefly described below.

Seeding: Broadcasting clean, pest-free seed uniformly across an area is an important first step. The seed should be gently incorporated into the surface soil (1/8 to 1/4 inch) and rolled and pressed into the soil to establish good seed/soil contact. Keep area moist for at least the first 10 to 14 days by frequent, gentle, daily waterings. One week after the seedlings have emerged, start watering with greater amounts, less frequently.

Sodding: The turf area is established with slabs or rolls of sod. Sod should be layed in a brickwork arrangement. Roll the area to make good sod/soil contact. Keep the area moist for several weeks until grass is well rooted.

Plugging: Transplant small pieces of sod into holes the same size. Plugs can be either circular (1- to 2-inch diameter) or square (1- to 2- inch square) and are usually planted on 6- to 12-inch centers. Roll the area after planting with a weighted roller to establish good soil contact. Keep area moist until the plugs are well rooted and beginning to spread.

Sprigging: Fresh sprigs are runners with two to four nodes (joints). Plant the sprigs on 6-inch centers or in rows that are 12 inches apart with 4 to 8 inches between each sprig. Leave about one-quarter of each sprig above ground after planting. Roll the area to make good sod/soil contact. Keep area moist until the sprigs are well rooted and beginning to spread.

Stolonizing (broadcast sprigging): Broadcast stolons over the area to be established. Press them into the ground with a light disc and/or cover them with one-quarter inch of soil or similar material. Roll the area to make good sod/soil contact. Keep area moist until the stolons are well rooted and beginning to spread.

Summary

A pest problem often results from improper selection or management of turfgrasses. The following is a brief checklist of cultural practices that affect turf vigor and pest invasion.

Seed and sod: Insect-, disease- and weed-free seed or sod is one of the first steps in pest control. Many turf areas have pest problems because the pests were present in the seed or sod or were not removed from the planting bed before seeding, sprigging or sodding.

Improper mowing: Mowing too short and not mowing often enough thins the turf, allowing weeds to get started. Mowing with a dull or improperly sharpened blade will damage and weaken a turfgrass. Mowing at the recommended height and proper frequency will encourage vigorous, dense, competitive turf.

Improper watering: Frequent and shallow watering encourages weed seed germination, disease, thatch and a shallow-rooted turf that is unable to compete with pests. Watering helps a turfgrass survive drought periods and maintain vigorous growth. Water turfgrasses when they show signs of wilt and then water to wet the soil to a depth of 6 inches or more.

Improper fertilizing: Fertilizing too much, too little or at the wrong time may benefit pests more than the grass. Fertilization programs that furnish turfgrasses with essential elements throughout the growing season tend to discourage pests through competition by a vigorous, healthy turf.

Compacted soil: Soil compaction is a hidden stress on the turfgrass root system. The reduction in available oxygen lowers the ability of the turfgrass to compete effectively with pests. Clay and silt soils are especially prone to compaction.

Poor drainage: The oxygen supply is depleted in poorly drained areas. Pests become a problem in these areas, especially those that thrive in waterlogged soils.

Wrong turfgrass: The wrong turfgrass for the location will gradually decline and be invaded by pests. Turfgrasses that are poorly adapted to the intended area or use cannot be expected to adequately compete with pests.

Environmental stress: Pests often take over a lawn after it has been weakened and thinned from stress caused by the weather. Allowing a turf to become stressed for extended periods is an open invitation for pest problems.

Thatch: Excessive thatch causes shallow-rooted grass and contributes to insect and disease problems, which are followed by weed invasion. Thatch also reduces the effectiveness of some soil-applied pesticides.

Turfgrass Diseases

Plant Diseases – An Introduction

A plant disease can be defined as an abnormal alteration in the structure and/or physiological function of a plant. This alteration often leads to the development of symptoms, which is the visible expression of a disease. Some diseases produce specific symptoms that are used in diagnosing the disease. The causes of plant diseases may be broadly divided into two basic groups, those that are abiotic (nonliving agent) and those that are biotic (living agent). Abiotic diseases are those that are caused by an unfavorable growing environment. Examples of environmental stress include water stress, temperature extremes, nutrient imbalances and plant injury (chemical or mechanical). Biotic plant diseases are most commonly caused by living microscopic organisms called pathogens. These diseases are often referred to as parasitic diseases. A parasitic disease is the end result of three very important factors that makeup the **"Disease Triangle" (Figure 1.3.1)**. This triangle consists of a **susceptible host plant**, a **favorable environment** and a **pathogen** (causal agent) capable of infecting the host plant. There is a very close relationship between these three factors. If one of these factors is incompatible with the other two at a specific time, there will be no disease development. The most common plant disease pathogens consist of fungi, bacteria, viruses and nematodes. Biotic diseases usually develop over an extended period of time, whereas abiotic diseases are usually over a short time period.

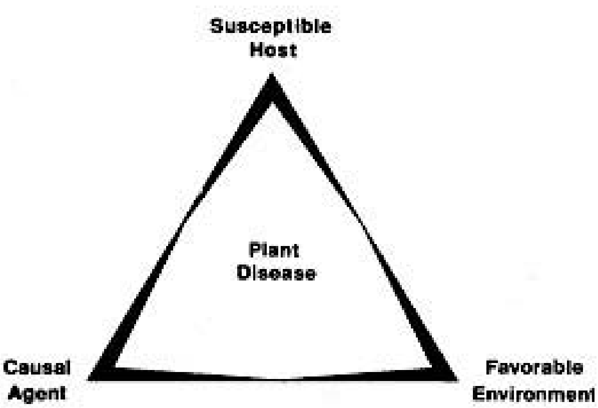


Figure 1.3.1. Disease Triangle.

Fungi cause the majority of severe diseases on plants. The thread-like body (hyphae) of a fungus usually reproduces by forming microscopic seedlike structures called spores that are commonly spread from one plant to another by wind, splashing water, equipment, animals and infected plant parts. The fungi may enter the plant by natural openings (stomata, lenticels and nectarines), wounds and direct penetration. Fungi cannot manufacture their own food, thus they rely on a host plant for nourishment. They can live off of dead or living plant or animal matter. Spores land on a leaf surface, germinate and penetrate the leaf tissue. This is called the infection process, after which disease symptoms appear. Use of protectant fungicides interrupts this process and prevents disease from developing. Understanding the preventive nature of this process helps an applicator understand the importance of proper spray intervals and adequate coverage of foliage. Not all fungi are detrimental to plants. Some fungi are beneficial because they break down organic matter and are extremely important in the food-making process and the production of some antibiotics. Significant plant diseases caused by fungi include late blight of potato, downy mildew on grapes, powdery mildew on many field-grown ornamentals, cereal rusts and smuts, chestnut blight, daylily rust, Dutch elm disease, brown patch of turf, brown spot of rice and soybean rust.

Bacteria are single-celled microorganisms that reproduce by dividing themselves. Most plant pathogenic bacteria are rod-shaped microorganisms that divide rapidly. Under optimum conditions, bacteria may divide every 20-50 minutes, one bacterial cell becoming two, two becoming four, four becoming eight and so on. Bacteria enter plants through wounds created on the plant or through natural openings such as the stomata on the leaf, nectarines of the flower and lenticels on the stems. Bacteria are spread by splashing water, wind, equipment, animals and soil. Some insects are important vectors of bacterial diseases. Most bacterial diseases are related to moist environments where plants are grown. The bacteria commonly infect plants by being splashed onto wet plant foliage from the soil. Water-soaked or greasy areas are common symptoms on plants. Important diseases caused by bacteria include fire blight on apples and pears, bacterial leaf spots and wilt on many ornamental foliage plants, crown gall on a variety of field-grown ornamentals, bacterial leaf scorch on shade trees and citrus canker on citrus.

Viruses are much smaller than bacteria and can exist and multiply only inside living cells. Viruses enter the plant only by wounds made mechanically or by vectors, or occasionally by infected pollen grains. These agents do not divide and do not produce any kind of a reproductive structure like spores of a fungus. They multiply by inducing the cells of the living host plant to form more virus particles. They are spread mainly by contact between plants, sucking insects (leafhoppers, whiteflies and aphids), propagation of infected plants and contaminated equipment. Mosaic (a mixture of dark and light green areas), flecking and ringspotting are foliar symptoms typical of viruses. Viruses can also cause stunting and other growth disorders. The disease symptoms of some virus infections often resemble other plant problems such as herbicide injury and nutritional imbalances. Viruses may remain from season to season in perennial weeds, insects, nematodes and seeds. Once a plant is infected with a virus, no practical treatment for complete removal of the pathogen exists. Plant removal is often recommended to prevent spread of the virus to healthy plants. Infected plants may serve as a reservoir for additional infections when there is an insect or other vector present that can transmit viruses. Chemical control for virus diseases is not effective. Diseases caused by viruses include rose mosaic, tobacco mosaic, tomato spotted wilt, impatiens necrotic spot, barley yellow dwarf of wheat and plum pox of stone fruits.

Mycoplasmas are ultramicroscopic organisms that lack a true cell wall but are bounded by a "unit" membrane. They grow to various shapes and sizes. These organisms reproduce by budding and binary fission. They do not produce spores like the fungi often do. Spiroplasmas and phytoplasmas are related organisms and cause diseases including corn stunt, aster yellows and elm yellows. These organisms may be found in the food-conducting tissues of the plant.

Nematodes constitute a serious problem with many plants. Nematodes are microscopic round worms approximately 1/50-inch long. If they have a satisfactory food source, they reproduce rapidly. A single female nematode may lay up to 500 eggs at a time. Once the eggs hatch, the immature nematodes will undergo several morphological changes as they mature into adults. Nematodes can be found in all types of soil, but tend to be most numerous in sandy or light-textured soils. Nematodes are usually spread from one locale to another by soil movement or irrigation water. Many types of plant parasitic nematodes exist, but the most common one is the root-knot nematode. This nematode may attack many species of economically important plants. Most of the damage inflicted by nematodes is a result of direct feeding on the roots. The nematode inserts a sophisticated feeding tube (stylet) into the cells of the root. Although the majority of plant parasitic nematodes feed on the roots of plants, some feed on the leaves. Plants with knotted or galled root systems cannot absorb enough water and nutrients to adequately supply the plant. The tops of plants may appear wilted or inadequately fertilized. Once the soil becomes infested with nematodes, it is difficult to eradicate them completely from the soil by conventional means. Damage to the plant may not become apparent until the nematode population increases beyond an economic threshold for the host plant. Chemical treatment is often used to reduce the population so that a reasonable crop can be grown. Important nematode problems include root knot on many ornamentals and vegetables, lesion nematode, cyst nematode on soybean, reniform nematode on cotton, foliar nematode on ornamental foliage plants and pinewood nematode.

Parasitic higher plants such as dodder, mistletoe and witchweed obtain all or part of their nutrition from a host plant. The dodder produces a yellow, small-diameter vine that attacks plants intertwining around the host plant. With the aid of a specialized absorbing organ (haustoria), it drains nutrients and water from its host. The mistletoes can be found on a number of woody plants. These parasitic plants have chlorophyll and produce sticky seed that are often dispersed by birds that eat them. Control is difficult to achieve. Witchweed, another parasite, is not common in North America. It is a parasite on corn, rice, sugarcane and a few small grain crops. Heavily infected plants will die as a result of the roots being parasitized by witchweed.

Abiotic plant disorders constitute a vast majority of problems with ornamentals in the landscape. Among the most common problems are moisture and temperature stress, improper planting and maintenance, improper site, improper fertilization and pesticide application and string trimmer injury. When plants are stressed, they are more vulnerable to the effects of attack by disease-causing pathogens and insects. Although some pathogens will attack vigorously growing and healthy plants, many attack and infect only plants that are stressed. A weakened tree or shrub, for example, is much more susceptible to cankers, wood decay, root rot and certain wilt diseases than a vigorously growing ornamental.

Accurate disease identification is the first important step in planning an effective and efficient disease control program. An understanding of the pathogen's life cycle and mode of action is crucial in developing control strategies. Literally thousands of specific diseases exist. As growers, we may encounter only a few during a particular season, but we must be able to distinguish significant and potentially serious diseases from those of lesser importance.

Turfgrass Disease Descriptions

Lawns constitute a significant place in home landscapes. For a landscape to be healthy and attractive, the lawn must be healthy. Turfgrass diseases can seriously damage the appearance of a home lawn, athletic field or golf course. With few exceptions, fungi are more damaging to turfgrass plants during wet weather or when moisture from rain, irrigation or dew remains on the leaves for a long time, than they are during dry weather. In Arkansas, the fungi are responsible for most of the infectious (biotic) diseases of turf. The bacteria and virus diseases are considered minor problems in turfgrasses. The fungi that cause turfgrass diseases have specific temperature ranges and thus are active during different times of the year. Thus, some diseases are more prevalent than others, depending on the season.

Brown patch (*Rhizoctonia* spp.) is caused by a fungus that affects grasses when night temperatures are cool in the fall and spring. Rhizoctonia affects both warm- and cool-season turfgrasses in Arkansas. Disease symptoms depend on whether it is a cool- or warm-season grass, cultural practices and environmental conditions. Brown patch develops most rapidly during periods of warm temperatures (75 to 85 degrees F) and moist or wet conditions. On warm-season grasses, the disease can be a problem during the fall, winter and spring when grasses are entering or emerging from dormancy. Infected turfgrass usually exhibits irregular or circular patches of blighted grass ranging from several inches to many feet in diameter **(Figure 2.3.2)**. The bases of infected leaves become rotted and can easily be pulled from the bottom of the grass plant. The fungus primarily attacks the shoots rather than the roots. Roots of affected grass generally will not be discolored, and green grass will occasionally be present in the middle of diseased patches, giving a "smoke ring" appearance.

Figure 2.3.2. Brown patch symptoms on zoysia.

To reduce the severity of brown patch, irrigate only when needed and do so early in the morning. Although several fungicides are labeled for control of brown patch, effectiveness is much greater when they are applied before the disease becomes well established. Brown patch severity is directly related to the fertility status of the turfgrass. High nitrogen tends to increase disease severity.

SAD (St. Augustine Decline) is the most significant virus disease of turfgrass in Arkansas. SAD is caused by panicum mosaic virus. This disease occurs only on St. Augustine and centipedegrass. Leaves appear mottled. Do not confuse this with iron chlorosis, which causes a striped appearance. In iron chlorosis, the veins remain green and the chlorotic areas occur between the veins. If the virus is present, however, a mottled or speckled condition occurs in the leaf tissue. Another distinguishing factor is that iron chlorosis appears first in the new or young leaves, whereas SAD causes yellowing in both old and young leaves **(Figure 2.3.3)**. SAD is spread by lawn mowers and cannot be controlled with chemicals. The best control of this disease is to plant one of the commercially available resistant St. Augustinegrass varieties.

Fairy ring is a condition caused by fungal development in the soil. Several fungi can cause

Figure 2.3.3. SAD on St. Augustinegrass.

fairy ring. Most are growing in association with organic material buried in the soil such as decomposing stumps, branches or building materials. All turfgrasses can be affected by fairy ring. The fungi can be located at varying depths in the soil, making it virtually impossible to remove by digging infested soil out of the area. Fungi that typically produce mushrooms invade organic matter in the soil **(Figure 2.3.4)**. It then produces mushrooms on the edge of this organic matter, and a ring effect is often noted. The disease becomes noticeable during spring and summer months when a ring of dark green grass or brown circular bands appear. The dark green grass is a result of nitrogen released after fungi decompose organic matter in the soil. The brown ring of dead or dying grass appears as a result of a hydrophobic (water repelling) effect from the spreading fungi. Mushrooms can be removed by mowing, and proper irrigation and fertilization will suppress or mask the green or brown rings associated with this disease.

Managing fairy ring involves forcing water into the hydrophobic or dry areas and using

Figure 2.3.4. Mushrooms of fairy ring.

fungicides specifically labeled for this disease. Wetting agents added to the water may help penetration. This disease is considered more of a cosmetic problem in the home lawn, whereas it may be significant in a golf course situation. Fungicides are available that suppress disease development; however, multiple applications will be necessary to maintain suppression of this disease.

Take-all patch (*Gaeumannomyces graminis* var. *graminis*) is a serious fungal problem in St. Augustinegrass and bermudagrass. This disease is most active during fall, winter and spring when soil is moister and temperatures are moderate. Take-all patch can destroy large areas of grass if not controlled. The first symptom of take-all patch is yellowing of leaves, usually in large circular or irregular shaped patches **(Figure 2.3.5)**. The grass gradually thins within the patch. The roots of infected plants are frequently rotted, but the leaves cannot be easily pulled from the plant, as is the case with brown patch. Because the fungus that causes take-all patch survives on plant debris, use practices that prevent thatch build-up. Take-all patch tends to be more severe on soils with a high pH. Although there are fungicides labeled for control of this disease, these chemicals should be applied on a preventive basis, generally in the fall. On an already established take-all patch, fungicides may be ineffective.

Figure 2.3.5. Take-all patch.

Gray leaf spot (*Pyricularia grisea*) is a disease of St. Augustinegrass in Arkansas. This disease can be a problem in the spring and early summer, especially in shaded areas. Symptoms include tan lesions with purple or brown borders on the leaf blades **(Figure 2.3.6)**. Eliminating the use of soluble nitrogen fertilizers during summer months on shaded lawns can reduce the severity of the disease. Water early in the

Figure 2.3.6. Gray leaf spot on St. Augustinegrass.

morning and remove grass clippings from infected lawns to slow the spread of gray leaf spot. Several fungicides are labeled for control of this disease.

Dollar spot (*Sclerotinia homeocarpa*) is a fungal disease that attacks most turfgrasses grown in the South. Hybrid bermudagrass, zoysiagrass and bentgrass are particularly sensitive to this disease. Generally occurring in the spring through the fall, it prefers low soil moisture. 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. Not to be confused with brown patch, grass blades affected by dollar spot exhibit light tan lesions with reddish-brown bands **(Figure 2.3.7)**. Dollar spot is often associated with poor turf maintenance. Dry soils, thatch buildup and inadequate amounts of nitrogen and potassium favor this fungus. Control dollar spot by removing thatch, fertilizing properly and avoiding shallow, frequent watering. Several fungicides are recommended to prevent dollar spot.

Figure 2.3.7. Dollar spot on bermudagrass.

Spring dead spot (SDS) is a very destructive disease in bermudagrass lawns. Two fungi (*Leptosphaeria korrae* and *Ophiosphaerella herpotricha*) are associated with the disease in North America. Bermudagrass is the most significant host to this disease. The causal organisms grow most actively during the fall and spring when temperatures are cool and soils are moist. Bermudagrass varieties that have poor cold hardiness tend to have more severe SDS. SDS-infected lawns exhibit small, circular dead areas from less than one to several feet across in the spring **(Figure 2.3.8)**. This disease becomes noticeable during greenup in the spring. Other symptoms include dark and rotted roots and a slow recovery of bermudagrass into the affected areas, usually about mid summer. SDS does not affect newly planted lawns but becomes a problem on lawns 3 to 4 years old. It may be connected to an accumulation of thatch. In some locations, SDS has been controlled with repeated applications of systemic fungicides in the early fall.

Figure 2.3.8. Spring dead spot.

Rust (*Puccinia* spp.) can be found on a number of turfgrass species but is most frequently a problem on zoysiagrass, fescue and bermudagrass. Grass that is under stress during warm, humid conditions is most susceptible to the disease. Rust is identified by orange to reddish-brown flecks on grass blades that develop into pustules and eventually turn brown to black **(Figure 2.3.9)**. Ryegrass can be very susceptible to rust in the spring, especially when nitrogen levels are low. Severely infected turf looks reddish brown, yellowish or orange. The turfgrass often thins and becomes chlorotic. Cool to moderately warm, moist weather favors rust development. Condensed moisture, even dew, for 10 to 12 hours is sufficient for rust spores to infect plants. Cultural practices such as proper fertilization, avoiding moisture stress and selecting resistant varieties can help prevent rust. Removal of grass clippings from affected areas is helpful. Spores on the mowed leaves die out rapidly. The rust over-seasons in infected grasses. The overwintering rust produces short black streaks on the leaves. If cultural practices are inadequate, there are a number of fungicides recommended for rust control.

Figure 2.3.9. Zoysia leaf rust.

Pythium blight (*Pythium* spp.) is caused by several species of *Pythium* fungi. The infection process, symptom development, spread of the pathogen and destruction of turf is often very rapid. This disease is most prevalent on highly maintained turf such as golf course greens. This disease is often associated with waterlogged soils and a moist thatch layer, along with high relative humidity and daytime temperatures in the 80s and 90s with warm nights (above 70°F). These conditions are ideal for warm weather pythium blight. There are cool weather pythiums also. The disease often appears as elongated streaks, following water drainage or mowing patterns. Large areas of turf can be destroyed within 24 to 48 hours after disease onset. Excessive nitrogen favors this disease. Wet turfgrass and poor soil drainage are the two most important criteria for disease development. For control, both surface and subsurface drainage needs to be improved. Avoid over-watering, thick thatch, excessive nitrogen fertilization and compacted soil profiles. Systemic fungicides when applied as part of a preventative program before the onset of hot, humid conditions is recommended for high value turfgrass.

Nematodes are probably the most abundant form of animal life in the soil. Most species that occur in soil feed on fungi, bacteria or small invertebrate animals, but many are parasites of higher plants, including turfgrass. Nematodes have distinctive life cycles very similar to those of insects. Females lay eggs, which hatch into larvae. The larvae mature through a series of four molts to become adults. Nematodes typically survive adverse conditions in the egg or larval stages and feed most actively when the turfgrass is also actively growing. Nematodes are mobile within the soil, but long distance spread usually requires their movement in surface water runoff, in soil on equipment or in sod. All turfgrasses are susceptible to nematode damage. In Arkansas, nematodes can cause significant damage and need to be controlled on bentgrass golf greens and sod farms. Plant parasitic nematodes feed on turfgrass roots and on other organs by puncturing the plant cells with a hollow, needlelike structure called a stylet **(Figure 2.3.10)**. Nematodes cause direct impairment of root functions, and nematode-weakened plants are susceptible to infection by various pathogenic fungi and bacteria. The above ground symptoms of a nematode infestation include chlorosis (yellowing) of the leaves, slow growth, gradual thinning, poor response to adequate fertilization and irrigation, rapid wilting during dry weather and weed invasion. Nematodes are

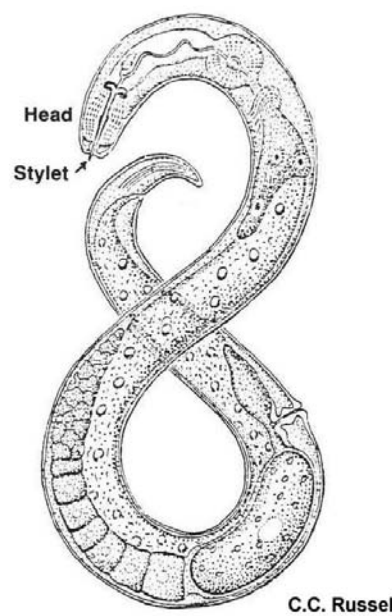


Figure 2.3.10. Schematic drawing of a plant parasitic nematode.

most damaging in light, sandy soils which are low in nutrients and water-holding capacity. Increased fertilization and irrigation practices can often overcome the effects of some types of nematodes. Highly compacted and heavy-textured soils are less favorable to nematodes because they restrict nematode movement and prevent good turfgrass growth. Nematodes are usually most active and most numerous on warm-season grasses during the summer and autumn, on cool-season grasses in mid to late spring and again in autumn. These times correspond with and follow active growth of turfgrass roots. However, the result of nematode feeding generally becomes most apparent when conditions become unfavorable for the turfgrass. For high maintenance turfgrass, such as golf greens and sod farms, chemical control of nematodes may be necessary. Because of their distribution in the soil profile and their position on or in the roots, complete chemical control is impossible, but reductions of large populations to manageable levels can be achieved with chemical nematicides. The only way to determine if nematodes are involved is to have soil samples assayed for nematodes. They seldom, if ever, are controlled in home or recreational turfgrass.

Slime molds are harmless but unsightly fungi that seem to suddenly appear over the grass surface during warm weather following heavy rains or watering. These fungi may be black, bluish-gray, cream to yellow or white in color and grow over the grass blades in round to irregular patches **(Figure 2.3.11)**. These organisms are not parasitic on turf, but rather feed on decaying organic matter, other fungi and bacteria in the thatch layer and soil. Slime molds usually disappear when dry conditions are present. Raking, brushing or hosing down the area with water is helpful in speeding their disappearance.

Figure 2.3.11. Slime mold on Zoysiagrass leaves.

Turfgrass Disease Summary

Diseases, whether abiotic or biotic, can be destructive to all plants. It is very helpful to become familiar with the way healthy plants look in the landscape. Proper placement and maintenance are of the utmost importance in overall plant health. We have discussed the interactions of the “disease triangle” and its role in disease development. Infectious disease development is an ever-changing and dynamic process in which a series of events occurring in succession leads to the development and perpetuation of the disease and a pathogen.

In order to diagnose a plant disease, it is important to determine if the disease is caused by a pathogen (fungus, bacteria, virus, etc) or if the problem is a result of an unfavorable growing environment. Accurate identification is the first and most important step in designing an effective disease control program. Details of the symptom expression on individual plants are very important in the diagnosis of plant disease. Each causal agent, biotic or abiotic, will produce some specific symptoms. These symptoms may vary, depending on the plant, growth stage, exposure time, etc. The ability to anticipate and react appropriately to common problems and implement preventive solutions can be quite valuable in maintaining a healthy lawn grass and landscape planting.

The aim of this information is to help with the diagnosis and understanding of disease mechanisms of ornamentals and turfgrasses. It describes many common diseases that have distinctive symptoms. This information offers comments on controlling these various diseases.

For further information and assistance with plant disease identification and control, consult you local Extension office.

Turfgrass Insects

Introduction

Insect and mite damage to turf is often mistaken for a disease, drought or fertility problem. The symptoms are often similar: chlorosis, wilting, dieback, stunting or distortions of growth. As a result, it is not uncommon for pests to inflict extensive damage before their presence is realized. Early detection of such symptoms may prevent the rapid buildup of pest populations that can occur when conditions are right.

Good control depends on correct identification of the pest and some knowledge of its behavior and biology as well as the environmental factors, such as temperature, moisture, soil type and location, which affect population buildup. This information also helps determine the appropriate insecticide to use and the rate and method of application that will control a pest. Some pests thrive in warm, dry conditions; others prefer wet, moist conditions. Some locations in turf may be more susceptible to infestation than others. Often, pests are first found in isolated spots rather than distributed evenly throughout the turf. Also, conditions of shade or sun, slope and soil type can influence pest establishment.

Serious insect and related pest infestations are sporadic and generally unpredictable. Therefore, the application of pesticides to turf should not be preventive in nature. It is wiser economically and ecologically to treat damaging infestations only as they occur. In this way, the development of resistance to pesticides will be delayed, the buildup of harmful residues will be unlikely, populations of beneficial organisms can be maintained, and costs will be reduced.

Detection and Survey Techniques

Selecting the proper pesticide depends on proper diagnosis of the pest problem. Insects must often be disturbed or trapped in order to properly identity them. Some of the sampling procedures are described below.

Flotation – Flotation is a method whereby water is used to detect the presence of insects such as the chinch bug. Select a large can, such as a 2-pound coffee can or one with a diameter of at least 6 inches, from which both ends are removed. Push the can into the turf, through the thatch into the soil surface in an area suspected of being infested with chinch bugs. Then fill the cylinder with water. If the water recedes, more should be added. Chinch bug adults and nymphs present in the thatch soon float to the surface, and within 5 to 10 minutes the entire population present within the cylinder will have surfaced.

Use of Irritants – Irritation is another effective method of detecting certain insects. It involves sprinkling a gallon of water containing an irritant over a square yard of turf to bring pests to the surface. This method is primarily effective in detecting caterpillar-type insects such as sod webworms and cutworms, although it has been used successfully for billbug adults and mole crickets. One readily available irritant is household detergent. Add 1/4 cup of dry or 1 ounce of liquid detergent to 1 gallon of water in a sprinkling can and apply the solution to 1 square yard of turfgrass where infestation is suspected. One tablespoon of a commercial garden insecticide containing 1 to 2 percent pyrethrin in 1 gallon of water is also very effective. Larvae usually come to the surface within 10 minutes. If the thatch is dry, irrigation before the test is advisable. This method does not bring soil-inhabiting insects such as grubs or billbug larvae to the surface.

Pitfall Traps – This trap can be made with three plastic cups, with the upper interior cup modified to act as a funnel to direct captured specimens into the collection cup below. A hole the size of the cup is made in the turfgrass and the cup placed in the hole so the lip is at the thatch-soil level. Alcohol or water is placed in the collection cup. Insects crawling through the turf fall into the cup, through the funnel and into the collection cup containing alcohol/water. Trap contents should be emptied daily. These traps can be used to monitor and detect the presence of chinch bugs, adult billbugs and many other arthropods.

Soil Sampling – The techniques required to sample the soil underlying turfgrass areas are not only the most arduous but also the most disruptive of the turf's appearance, especially when soil samples must be as large as 1 square foot because the population is likely to be scattered.

Because turf-damaging insects remain strictly in the soil, disruption of the soil is necessary to obtain accurate counts. The least disruptive method of examining 1 square foot of sod is to cut three sides and turn back the cut area as if it were a flap. This procedure allows many of the plants to keep their root systems intact.

The motorized sod cutter provides another convenient means of checking for soil pests. For example, setting a cutter for a depth of 2 inches would allow for easy inspection for grubs during the most active feeding periods in the spring and fall.

A standard golf cup cutter that takes a sample of sod and soil 4.25 inches in diameter is a very useful tool for sampling smaller soil-inhabiting pests. Once removed, samples can be examined on the spot with soil and turf being placed back in the hole made by the sampler. To convert the number of insects found per sample to the number per square foot, multiply by a factor of 10.15.

In the case of white grubs, it is extremely important that the soil be at least moist when shallow samples are made. Grubs will tend to move down during dry periods. In suspected grub damaged areas where it is extremely dry, do not give up on grub presence until you have sampled the soil 6 inches to 10 inches below the turf.

Visual Observation – Observation and a keen sense of awareness are of paramount importance in detecting developing or potential insect problems. Examples of situations and conditions to watch for include:

1. The potential for turf-damaging populations of grubs can be estimated by observing the density of adults on some of their favorite host plants, e.g., May or June beetles frequently feed on the young tender leaves of oaks, persimmon, hickory, walnut and elm.
2. Be watchful for billbug adults on sidewalks and driveways adjacent to turf; this can signal the potential for larval infestation in adjacent turf.
3. Small moths flying erratically over turf at dusk can indicate possible sod webworm problems.
4. Sod torn up in small or large areas may be from skunks, raccoons or armadillos searching for grubs.
5. Birds frequenting turf often signal infestations of sod webworms, cutworms or grubs. Also, numerous circular holes in turf are often probes made by birds searching for cutworms or webworms.
6. Ball-mark type injuries on golf greens that have holes in the center and the grass eaten off below the cutting level of green mowers may indicate cutworm or armyworm activity.
7. A generally droughty looking turf where water should not be a problem may signal a chinch bug infestation.

Management Practices

As noted above, diseases, unfavorable soil conditions or poor cultural practices may cause similar symptoms. These possibilities should be investigated before pest control measures are taken. In fact, the first line of defense against turfgrass pests is a program of good cultural practices. Poorly kept turf shows pest injury sooner and recovers more slowly than vigorous, well-kept turf.

Good fertilization, watering and aeration programs cannot be overemphasized. The vigor of a turfgrass directly influences its ability to withstand insect population pressures, even though maintenance may be entirely independent of any consideration of turfgrass insects. Since injury by turfgrass insects is caused mainly by their feeding, a vigorous, steadily growing stand can be one of the strongest deterrents to permanent turf damage because of the plant's active regenerative capacity.

Thatch, allowed to accumulate and develop a thick layer of organic matter on the soil surface, can greatly influence the amount of damage an insect pest causes. Initially, it provides a haven for insects. Also, thatch buildup results in poor water penetration and aeration, which weakens the grass and may make it more susceptible to insect damage. While damage occurs where thatch is not a factor, many cases of severe damage are associated with it.

Thatch, when it is thick or tight, greatly limits the effectiveness of insecticides in the control of soil-inhabiting turfgrass insects. Insecticides applied to the sod surface may be absorbed by the thatch, preventing their movement even to the surface soil. When long residual chlorinated cyclodiene insecticides, such as chlordane and dieldrin, were used for grub control, these materials eventually moved to and penetrated the soil through various actions of weather.

The organophosphate (OP) and carbamate insecticides to be effective must move through the thatch into the surface soil rapidly because of their short residual activity. Some are degraded completely in less than a month. The most effective medium for percolation through the thatch and into the soil is water, either natural rainfall or irrigation. As a general rule of thumb, there is often less thatch tie-up with OP's that have high water solubilities and, conversely, more tie-up with the less water-soluble materials.

Insecticides

Specific insecticide recommendations have purposely been omitted. Label changes, regulatory actions, new product development and budgetary restraints make it virtually impossible to insure that a publication of this nature is reprinted on a timely enough basis to be current. There are fact sheets and other current control information publications for turfgrass pests available through the county offices of the Cooperative Extension Service.

It is worthy of mentioning that there is the possibility of insecticidal resistance developing in the turfgrass pest complex. In this regard, we suggest using a preventive strategy of rotating products used for control. Continued use of one insecticide or one class of insecticide places a definite selection pressure on certain genes for resistance. Alternation between insecticides of different structure and class is suggested in the hope that it will help prevent or retard the development of resistance. Also, it is extremely helpful to water the area to be treated (at times both before and after treatment), but rely on label indications for this possibility (e.g., when it is extremely dry, heavy watering or rainfall will be needed to bring white grubs up closer to the root zone so the chemical will have a chance to work).

Insect Identification

The following pages provide descriptions (pests and damage), as well as pictures of turf pests, and pests' life cycles and occurrence information. The most prevalent and recurring turf pest (encountered on turf farms and golf courses) is the white grub. The other pests described in the following tables may be found in turf in isolated areas of Arkansas each year; however, the more common situation is to find only one or two of these pests during any one growing season with the remainder only occurring sporadically or not at your location.

Figure 2.4.1. White grub (larva).

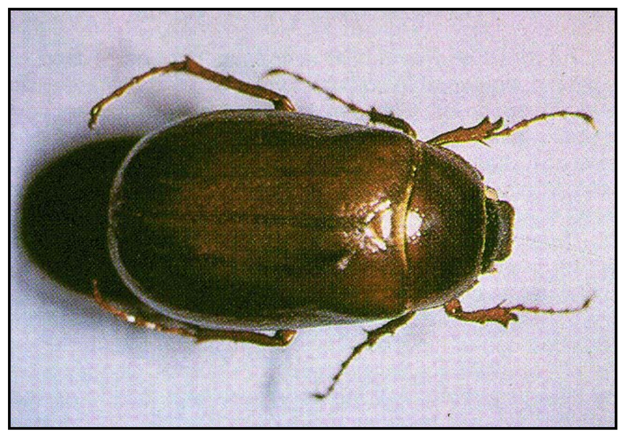


Figure 2.4.2. May/June beetle (Phyllophaga **spp.).**

Figure 2.4.3. Annual white grub adult (Cyclocephala **spp.).**

Figure 2.4.4. White grub damage.

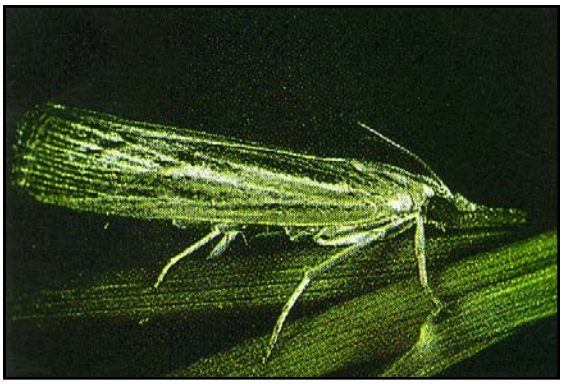


Figure 2.4.5. Sod webworm (adult moth).

Figure 2.4.6. Sod webworm (larva).

Figure 2.4.7. Sod webworm damage.

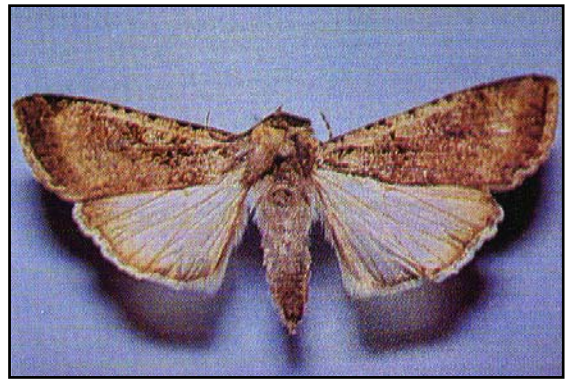


Figure 2.4.8. Variegated cutworm (adult moth).

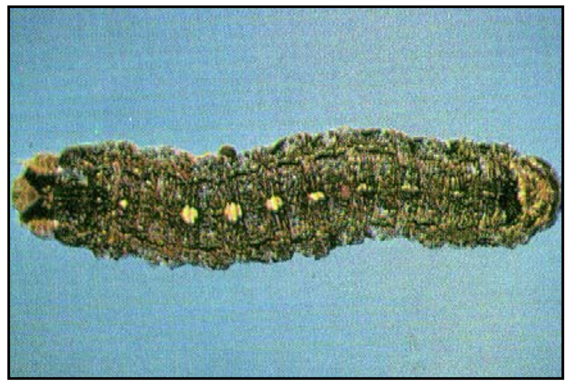


Figure 2.4.9. Variegated cutworm (larva).

Figure 2.4.10. Black cutworm (larva).

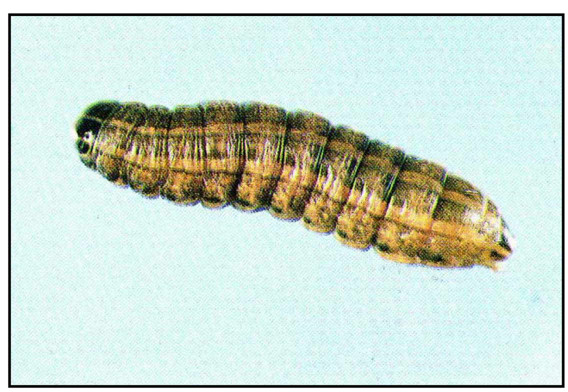


Figure 2.4.11. Bronzed cutworm (larva).

Figure 2.4.12. Granulate cutworm (larvae).

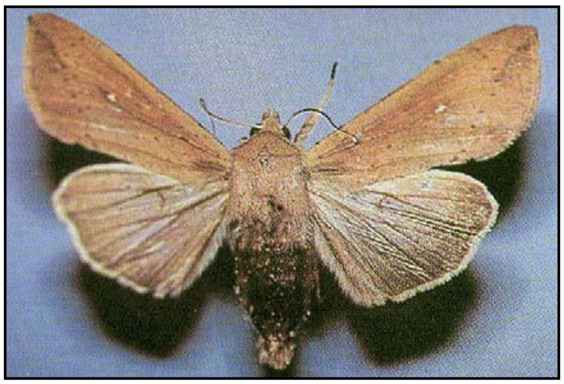


Figure 2.4.13. Armyworm (adult moth).

Figure 2.4.14. Armyworm (larva).

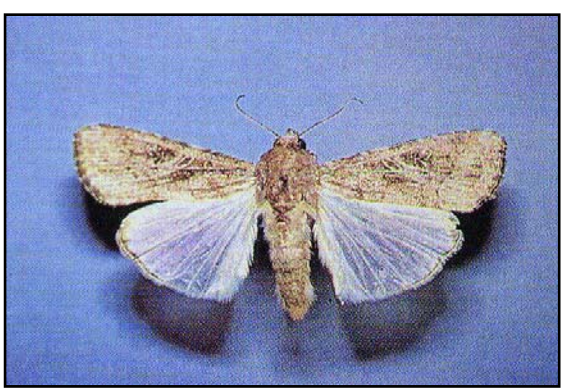


Figure 2.4.15. Fall armyworm (adult moth).

Figure 2.4.16. Fall armyworm (larva).

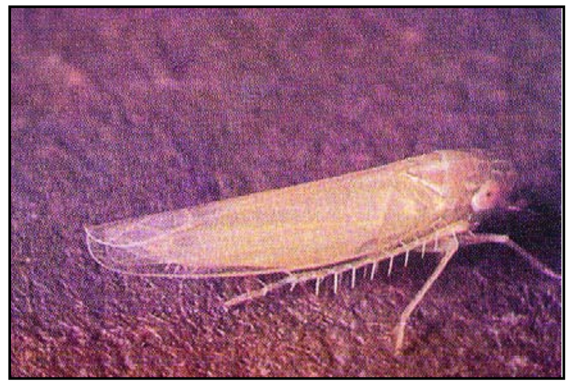


Figure 2.4.17. Leafhopper (side view).

Figure 2.4.18. Leafhopper (top view).

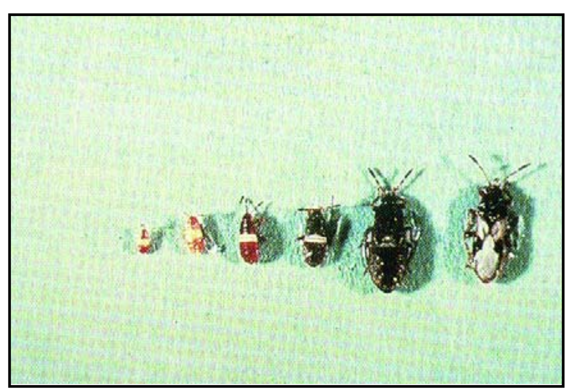


Figure 2.4.19. Chinch bug (growth stages).

Figure 2.4.20. Chinch bug damage (St. Augustinegrass.)

Figure 2.4.21. Clover mite.

Figure 2.4.22. Bermudagrass mites (close-up).

Figure 2.4.23. Bermudagrass mites.

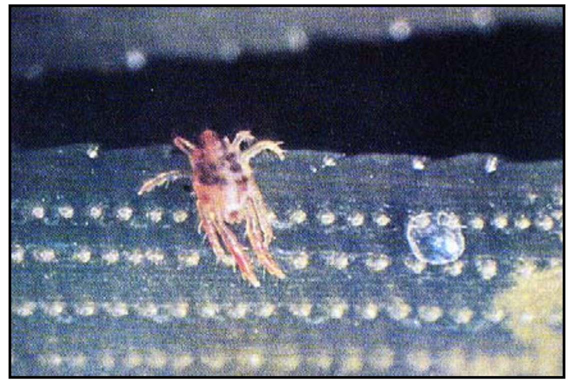


Figure 2.4.24. Spider mite.

Figure 2.4.25. Damage from Banks grass mites.

Figure 2.4.26. Billbug (adult).

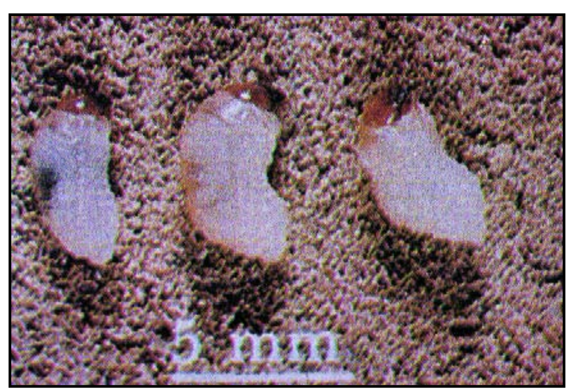


Figure 2.4.27. Billbug (larvae).

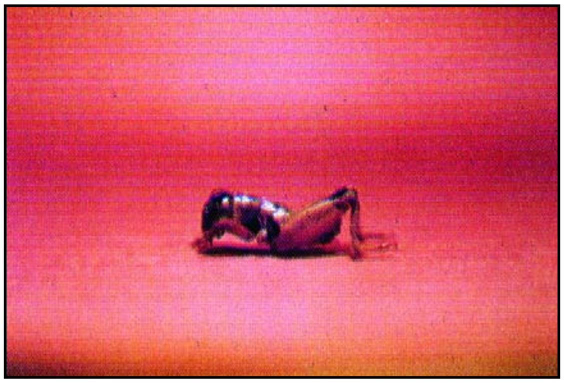


Figure 2.4.28. Shorttailed cricket.


Figure 2.4.29. Frit fly (adult).

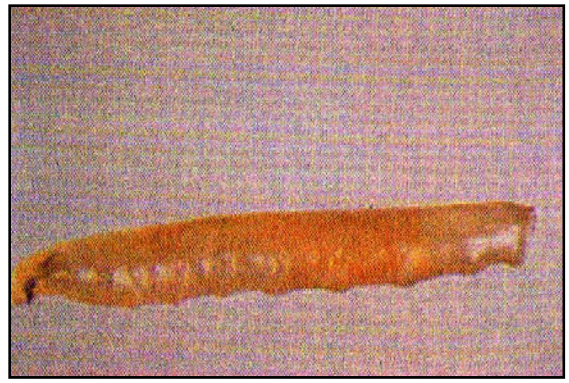


Figure 2.4.30. Frit fly (larva).


Figure 2.4.31. Ground pearls.

Turfgrass Insects

Insect and Description	Life History and Habits	Susceptible Plants	Damage Caused	Method of Detection
White grubs, Cyclocaphala and Phyllophaga spp. Larvae or grubs about 1 to 1 1/2 inches long when fully grown, C-shaped when at rest with many folds or wrinkles in front half of body. Rear end of body often slightly larger in diameter than rest and may be bluish or blackish in color. White grubs have a brown head capsule and three pair of conspicuous legs. (Grubs of the billbug are legless). Adults of white grubs are commonly called May beetles, June beetles or June bugs. They are a little over 1/2 inch long and yellowish-brown with a reddish head.	The common species of Cyclocaphala attacking turf in Arkansas have a 1-year life cycle while most of the Phyllophaga spp. have 2-year life cycles. Few recordings of 3-year life cycle grubs have been made in Arkansas. The larvae approach maturity about October. The Phyllophaga adults emerge from the ground from April to August depending on species. The adults of the annuals emerge from the soil from June through July. Little feeding appears to take place during the winter or early spring.	All grasses.	White grubs feed beneath the soil surface on the roots of grasses. Aboveground symptoms are a browning and dying of the grass in localized spots or in large irregular shaped areas. Where infestations are heavy, the grass roots may be entirely eaten away as well as the grass blades and the turf may be rolled back like a carpet. Damage may be severe in September and October when the grubs are reaching maturity and the growth of bermudagrass is slowing down.	Examine the soil around the grass roots. Dig in brown areas near the edge of green, healthy areas of grass. If more than 1 grub per square foot of area is found, the lawn should be treated. If the soil is dry, you may need to dig 6 to 10 inches deep to find larvae.
Sod webworms, Crambus spp. Larvae slender, grayish, black-spotted caterpillars about 3/4 inch long when full-grown, rather sluggish in their activity. Moths whitish or buff-colored. Wing span slightly over 1 inch. One species with white or silver stripe along margin of forewing, others without stripe. Wings folded close to body when at rest giving slender appearance.	Moths hide during day in grass and shrubbery, fly over grass at dusk. Eggs are laid on the leaves and crown. Larva hatch in a few days and begin to feed. They feed at night and hide during the day in shelters constructed of bits of grass and debris. Moths begin flying in April or May in warm areas and breeding continues through October. There may be 3 or 4 generations per year with broods overlapping.	All grasses. Bent and blue grasses most susceptible to injury, especially new lawns.	Larvae feed on grass blades, growing tips and greener portions of crown, but not on the roots. Damaged areas appear as scattered irregular brown patches in turf.	Pyrethrum test. Treat when 16 or more larvae are found per square yard. Preventive treatments are suggested for newly planted lawns.
Cutworms, Nephelodes minians Guenee, Feltia subterranea (Fab.), Peridroma saucia (Hubner), Agrotis ipsilon (Hufn.). Thick-bodied caterpillars from 1 to 2 inches long when full grown. Usually dull-colored, greenish, gray, brown or blackish; often with spots or longitudinal stripes. Adults are night-flying moths, dull or somber colored and with a wingspan of 1 1/4 to 1 1/2 inches.	Moths fly at night and lay eggs on leaves of grasses or nearby plants. Larvae feed at night and hide in holes, under debris or in mat of organic matter at the surface of the ground during the day. Breeding continues throughout the warm months of the year, and there may be several generations per season with overlapping broods.	All grasses.	Cutworms feed on the leaves and crown and may cut off plants near the soil line. Only the larvae are injurious.	Pyrethrum test. Treat when 5 or more cutworms are found per square yard.

Turfgrass Insects (cont.)

Insect and Description	Life History and Habits	Susceptible Plants	Damage Caused	Method of Detection
Armyworm, Pseudaletia unipuncta (Haw.), and **fall armyworm**, Spodoptera frugiperda (J.E. Smith). Large, active caterpillars up to 1 1/2 inches long when full grown. Both species have longitudinal stripes on the body. Adults are dull colored, night-flying moths with a wingspan of 1 1/4 to 1 1/2 inches.	Larvae may feed day and night but are more active after dark. They may migrate into lawns from nearby fields or pastures. The true army-worm has 3 or 4 genera-tions per year but is usually found in turf only in the spring, Fall army-worms have several generations from July to November and may damage turf in the fall.	All grasses.	Armyworms feed on the leaves and crown of grasses. Only the larvae are injurious.	Pyrethrum test. Treatment may be needed when 5 or more armyworms are found per square yard.
Leafhoppers, many species. Small active insects 1/8 to 1/4 inch long. Adults whitish-green, yellow or brownish-gray. May be speckled or mottled. Adults fly or jump short distances when disturbed. Nymphs are various colors as adults, but with-out wings. Nymphs have characteristic habit of moving sideways or back-wards when disturbed.	Adult females insert eggs into tissues of the host plant. Eggs hatch in a few days in warm temperature. Several generations may occur in a season.	All grasses.	Both adults and nymphs suck juices from the leaves and stems of grasses. Symptoms are a bleaching or drying out of the grass.	Examine areas in the lawn that looked bleached or dry, also the surrounding green areas. Look closely for the small, wedged-shaped, jumping or flying adults as you walk. Also look closely on the leaves and stems for the nymphs that move sideways or backwards when disturbed.
Chinch bug, Blissus spp. Adults are about 1/5 inch long, black with nearly all white wings that are folded flat over the body. There are both long- and short-winged forms. The young are bright red but turn black as they approach the adult stage.	There appear to be at least three generations a year, with all stages present in any month. The highest populations occur during the summer, and at this time development from egg to adult takes about 6 weeks.	Only St. Augustine-grass is seriously damaged.	Yellowish to brownish patched in lawn.	Close examination of damaged and adja-cent areas. Flotation, as described earlier under detection and survey techniques, can be used to find chinch bug.
Clover mite, Bryobia praetiosa Koch, is about 1/30 inch in length with long front legs. Its body is somewhat depressed and is reddish-brown to greenish in color. The legs are amber to orange colored.	This mite is often concentrated in turf next to the foundation of a building. They are active during spring and fall when daytime tempera-tures are below 70ºF. They oversummer as eggs in the turf. Damage is not often serious, but they can become a nuisance pest by entering homes.	Grasses and various weeds.	Damage may occur from 1 to 3 feet out from buildings. Feeding causes the turf to become silvery because of the extrac-tion of plant sap and the drying of cells.	Close examination of the leaves for stippling, speckling, silvering and drying, plus the presence of miles and mite eggs. Also check nearby tree trunks and walls.

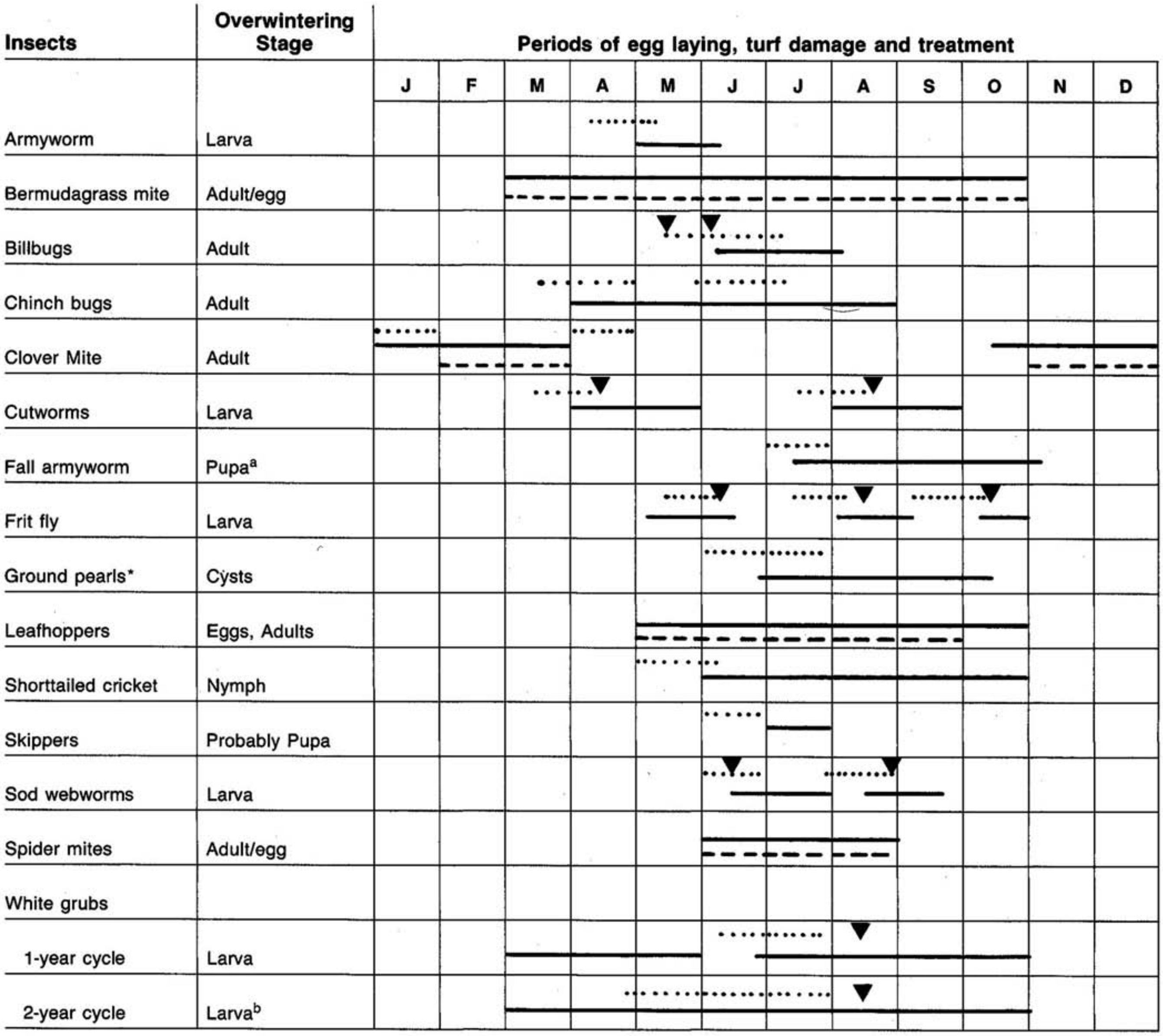
Turfgrass Insects (cont.)

Insect and Description	Life History and Habits	Susceptible Plants	Damage Caused	Method of Detection
Bermudagrass mite, Eriophyes cynodoniensis Sayed. Extremely small (can barely be seen with a 10X hand lens), white, wormlike mites. Have two pairs of legs near head end. Females lay spherical, transparent eggs singly or in groups. Also called Eriophyid mite.	Little is known of the life history of this pest, but it is thought to overwinter beneath the leaf sheaths in the crowns of the bermudagrass plants. The females begin laying eggs beneath the leaf sheaths of the new growth in the spring. Breeding continues during the warm part of the year, and several generations occur during the season. The mites suck juices from the stems and inside of the leaf sheaths.	Common and hybrid bermudagrasses.	Shortening of stem internodes resulting in a stunted, rosetted or tufted appearance of the plants. With heavy infestations, the grass turns brown and dies. When infestations are allowed to persist, the grass may be thinned out allowing the growth of weeds.	Look for plants with a stunted, rosetted or tufted appearance. Pull leaf sheaths away from stems. Examine inside of leaf sheaths and exposed stems with 10X to 20X hand lens or dissecting microscope. Look for mites and spherical, transparent eggs.
Spider mites of the Family Tetranychidae are about 1/50 inch long, globular in shape and reddish, yellowish or greenish in color. The two-spotted mite has a pronounced dark spot on each side of the body. The Banks grass mite can also damage lawns in Arkansas.	Spider mites lay eggs on grasses, oxalis or other plants in lawns. Some species spin fine webbing that may entirely cover the grass in spots, especially in protected areas near curbs, walls or planter boxes. Spider mites breed throughout the warm months of the year, producing several generations per season.	All grasses, clovers, oxalis.	Mites feed by puncturing the leaves and sucking out the juices. First symptoms of this injury appear as a speckling or stippling of the leaves. This is followed by a yellowing, bronzing or bleaching and drying of the leaves.	Close examination of the leaves for stippling, speckling, yellowing, bronzing, bleaching, drying, webbing, plus the presence of mites and mite eggs. (A hand lens or low power microscope may be necessary to see the mites and eggs.)
Billbugs, Sphenophorus parvulus (Gyll.) and S. venatus vestitus (Chitt.). The larvae of billbugs are white, legless grubs from 1/4 to 3/8 inch long when full-grown. The adults are small black or brown weevils, or “snout” beetles.	Little is known of the billbug life history. Adults can be found throughout the year, and in many areas larvae can also be found.	All grasses, but mainly bermudagrass.	Billbug larvae or grubs feed beneath the ground on the roots of grasses. Aboveground symptoms include the browning and dying of grass in spots or sometimes large areas.	Examine the soil around the grass roots. Dig in the edges of brown areas near green, healthy grass. If more than 1 grub per square foot is found, the lawn should be treated.
Shorttailed cricket, Anurogryllus arboreus Walker. Adults are brown and about 3/4 inch long and resemble pale field crickets except for the short ovipositor. Nymphs resemble adults but are smaller and lack wings.	This cricket overwinters as large nymphs and becomes adults in the spring. Mating and egg laying occurs in late spring or early summer. Young nymphs stay in the burrow in which they hatch but larger nymphs leave and construct their own burrows. There is one generation per year. Most activity occurs at night.	Grasses and weeds.	Crickets feed on grass blades but damage is usually negligible. Burrow construction produces unsightly mounds of small soil pellets in lawns. These are especially noticeable in the fall as they reappear after each rain.	Observation of mounds of small soil pellets or soil deposits “similar” to crayfish activity. Treatment provides only partial control. Control is seldom needed unless large numbers of mounds are encountered.

Turfgrass Insects (cont.)

Insect and Description	Life History and Habits	Susceptible Plants	Damage Caused	Method of Detection
Frit fly, Oscinella frit (L.). Adult frit flies are slightly more than 1/16 inch long, shining black with small yellow markings on the legs. The eggs are pure white, 1/32 inch long, with a finely ridged surface. Mature larvae are 1/8 inch long, yellow, with black, curved mouth hooks. Pupae are yellow at first, then turn dark brown and are slightly less than 1/8 inch long.	The winter is passed in the larval stage in the stems of grasses. Pupation takes place in the spring, and the first adults emerge about March. Eggs are laid on the leaves and leaf sheaths of grasses. Several larvae may occur in one plant. There are at least three broods, the activity of the last extending into October in warmer areas.	All grasses. Bent and bluegrasses are most susceptible to injury.	The larvae tunnel in the stems near the surface of the soil causing the upper portion of the plants to turn brown and die. Damage is most common on golf greens. Injury appears first on the collars of greens and moves in toward the center. The high or upper sections are usually the first to show the symptoms. Greens with high organic matter content appear most susceptible.	Look for small, black adult flies hovering close to the grass from mid to late morning. Look for the larvae in the stems near ground level. A hand lens or dissecting microscope is useful in finding the very small larvae.
Ground pearls, Margarodes spp. Females are wingless, pinkish scale insects with well-developed forelegs and claws, about 1.6 mm long. Males, considered rare, are gnatlike and vary from 1 mm to 8 mm in length. Clusters of pinkish white eggs are enclosed in a white waxy sac. Nymphs, called ground pearls, have a globular, yellowish purple shell. Most cysts are 0.5-2.0 mm in diameter.	The life cycle is not completely understood. They overwinter in the cysts. Females mature in May, emerge from the cysts, and after a short mobility period, secrete a waxy filament that covers the body. They remain about 2-3 inches deep in the soil and deposit eggs within the waxy coat. Egg laying begins in June and continues into July, with the hatch extending into August. Young crawlers start feeding on grass roots and develop the globular appearance. There is usually one generation per year, but under unfavorable conditions 2-3 years may be required to complete a life cycle.	All turfgrasses.	Nymphs extract sap from the roots. The damage appears as irregular patches. During summer dry spells, the grass yellows, browns and usually dies by fall. Cysts are present in larger numbers at the interface between damaged and healthy grass.	Examine the soil around the grass roots. Dig in the areas near green, healthy grass. Ground pearls can be found as deep as 10 inches in the soil (a depth that reduces the possibility of developing practical means of control).
Skipper, Atalopedes campestris. Larvae about 1 inch long and brownish-yellow in color. First 2 body segments behind head smaller than rest, giving appearance of a "neck." Adults are small butterflies with wingspan of a little more than 1 inch. Males have orange-yellow wings spotted with black; wings of the female are dark brown, with orange-yellow spots.	Female butterflies lay eggs on turfgrass leaves and on other ornamental plants during the warm months. Adults feed on nectar from various flowers. Lantana is a favorite. There may be several generations per year.	All grasses, especially bentgrasses. (Note: not extremely common to find damaging populations of this pest).	Larvae feed on leaves and crown.	Pyrethrum test. Treat when 10 or more larvae are found per square yard.

Turfgrass Insect Occurrence in Arkansas



[a]Infestations from migrating moths from the South.
[b]Several spp. involved thus extending egg laying.
*No effective chemical control available.

. . . . Period of egg laying
_______ Period of damage by immatures
------------ Period of damage by adults

▼ Probable Treatment period for damaging stage. Some activity periods are not marked with a treatment indicator because damaging population may occur anytime throughout the period.

Turfgrass Weeds

If there were no humans, there wouldn't be any weeds. There are no weeds in nature. Good or bad, we decide which plants are weeds. Opinions as to what is a weed vary widely. Divergent viewpoints on this matter have given rise to the observation that one person's weed is another's wildflower. Typically, a weed is a plant growing where someone doesn't want it. Violets may be desirable in an ornamental bed but are often considered a weed when growing in a lawn. Bermudagrass in a pure stand is a turfgrass but is considered a weed when growing in a zoysiagrass turf. Turfgrass weed control is usually concerned with maintaining the uniformity of the stand. But there are other reasons to control turfgrass weeds: competition with turfgrass, hard to mow plants, spiny plants and that clump of goosegrass that ruins your birdie putt on No. 17.

Sources of Turfgrass Weeds

Most turfgrass weeds result from seeds found in the soil. The number of weed seeds in the soil seed bank varies widely. Documented counts of viable seed from 1 square yard and a 10-inch depth range from a low of 250 to a high of 130,000. The old saying, "One year's seeding – seven years' weeding," is pretty accurate. Some seeds may remain inactive for several years and then emerge under favorable temperature, light and moisture conditions. These weeds generally germinate and mature when bare spots develop or if the soil is disturbed. Topsoils, manures and composts usually contain an abundance of weed seed. A new crop of weeds can be expected whenever these amendments are used.

Weed seeds may be transported from place to place by a variety of methods. Dandelion seeds are carried many miles by the wind. The tacky seeds of plantain are transported by clothing, equipment and animals. Ripe seedpods of yellow wood sorrel can explode and throw their seeds many feet. Moving weeds on sod is a common means of introducing weeds. Turfgrass managers should inspect sod prior to purchase to make sure it is free of problem weeds. Three difficult to control weeds that are commonly moved with sod are bermudagrass, Virginia buttonweed and nutsedge. The introduction of weeds from ornamental plantings is also common. Ornamental containers are an excellent way to transport weeds over long distances. Chamberbitter made its way to Arkansas in container ornamentals. Other species such as yellow nutsedge, oxalis and bittercress are commonly found in containers.

Reasons for Weed Invasion

Weed invasion is often the result of weakened turf rather than being the cause of it. Weed encroachment occurs in bare spots or areas of thin turf. There are a multitude of reasons for weak turfgrass including (1) turf species not adapted to the environmental conditions, (2) damage from turfgrass pests such as insects, diseases, nematodes and animals, (3) environmental stresses such as excessive shade, drought, heat and cold, (4) poor turf management practices such as misuse of chemicals and fertilizer, improper mowing height, frequency and incorrect soil aeration, and (5) physical damage and compaction from concentrated traffic. Unless these fundamental causes of weed problems are corrected, weed invasion will continue. The presence of certain weed species may be an indicator of specific environmental conditions.

Weeds as Indicators of Specific Conditions

Condition	Indicator Weed(s)
Low pH	red sorrel
Soil compaction	goosegrass, knotweed, Poa annua, path rush
Low nitrogen	legumes: clover, lespedeza
Poor (sandy) soils	sandbur, poorjoe
Poor drainage	sedges, rushes
Surface moisture	algae
High pH	plantains
High nematode populations	prostrate spurge, knotweed
Low mowing	algae

Developing a Weed Control Program

There are several important considerations when developing a weed control program.

1. Know what kinds of turfgrass you have and the total area of each different type.

2. Identify the problem weeds and note what time of the year they occur.
3. Determine why the weeds invaded the turf area and correct the conditions or cultural practices that caused the problem.
4. When an herbicide is needed:
   - Select a chemical that is effective for the weeds and safe for the turfgrass.
   - Follow all label directions.
   - Apply the herbicide at the correct time and rate.
   - Apply the herbicide uniformly over the turf area without skips or overlapping.
   - Repeat the herbicide application when specified on the label.
5. Follow a good turf management program along with the weed control program. An integrated approach that includes enhancing turfgrass competition, mechanical control and chemical control methods will be the most successful weed control program.

Weed Identification Is a Fundamental Skill

The importance of weed identification skills is obvious. It is impossible to look for control information until the weed has been identified. The ability to identify weeds is important from more than a control standpoint. Often, the first question a client is going to ask is, "what is that weed?" So, weed identification is also useful in establishing your credibility as a professional.

Weed identification should begin with classifying weeds by type. The four most common weed types are grasses, broadleaves, sedges and rushes.

Grasses are monocotyledonous plants, which means they have only one seed cotyledon (leaf) present when a grass seedling emerges from the soil. Grasses have joints (nodes) and hollow, rounded stems. The true leaves (as opposed to seed or cotyledon leaves) have parallel veins and are several times longer than they are wide. Crabgrass, goose-grass, dallisgrass and annual bluegrass are typical grass weeds found in turf.

Broadleaf weeds are dicotyledonous, which means they have two cotyledons at emergence and have netlike veins in their true leaves. Broadleaves often have colorful flowers compared to the inconspicuous flowers found on grasses. Chickweed, henbit, lespedeza, clover, dandelion and dock are typical broadleaf weeds.

Sedges have solid, triangular stems (in most species) which bear leaves extending in three directions (3-ranked). Sedges lack ligules and auricles, and the leaf sheath is continuous around the stem. Yellow and purple nutsedge, rice flatsedge and globe sedge are examples.

Rushes have round, solid stems and favor a moist habitat. Path rush is an example of the rush family. Path rush is often found on golf cart routes, sports fields and other compacted areas.

Not all turfgrass weeds fall into these categories. Some turfgrass weeds are monocotyledonous plants but are not sedges or grasses. Some examples are wild garlic, false garlic and star-of-Bethlehem, which are members of the **lily family**.

Weed Life Cycles

The previously listed weed classifications may be further divided into annuals, biennials and perennials. **Annuals** germinate from seed, grow, mature and die in less than 12 months. Annuals may be further classified as winter and summer annuals. **Winter annuals** germinate in the fall, grow during cool periods, mature in the spring and then die during the summer. **Summer annuals** germinate in the spring, grow actively during the summer and die in the fall. Crabgrass and goosegrass are examples of summer annual grasses. Annual bluegrass is our most common winter annual grass weed in turf. Prostrate knotweed is an example of a summer annual broadleaf, while henbit and chickweed are representative of winter annual broadleaves.

Biennials reproduce from seed and complete their life cycle in two years. Biennials form rosettes and store food in their fleshy roots the first year and then flower the second year. Many thistle species in Arkansas are biennials.

Perennial weeds live more than two years. Perennials may reproduce from seed or from vegetative structures such as roots, rhizomes, stolons, tubers or bulbs. The ability to reproduce vegetatively makes perennials more difficult to control. Some perennials such as dandelion, dock and wild garlic are actively growing during cool weather, while others like dallisgrass and nutsedge grow rapidly during the summer months. Perennials are further subdivided as simple perennials and creeping perennials. **Simple perennials**, such as dock and dandelion, overwinter by means of a vegetative structure such as a perennial root with a crown, but they reproduce almost entirely by seed. **Creeping perennials** can both overwinter and produce new independent plants from vegetative reproductive structures. Vegetative reproductive structures include creeping roots, stolons (bermudagrass), rhizomes (johnsongrass), tubers (nutsedge) and bulbs (wild garlic). Most perennials can also reproduce from seeds.

If you are serious about turfgrass weed control, a guide to weed identification is a very useful tool. Some recommended publications may be found in the section "Selected Turfgrass References and Study Material."

Principles of Herbicide Use

Before selecting any herbicide, determine whether or not the desirable turfgrass is tolerant of the chemical being considered. The majority of turfgrass herbicide failures result not from the weakness of the herbicide but from (1) choosing the wrong herbicide, (2) applying at the wrong time, (3) treating a turfgrass species that is susceptible to the herbicide, (4) poor calibration, (5) lack of uniform application, (6) unsuitable application equipment, (7) insufficient agitation, (8) wrong growth stage of the target weed, and (9) undesirable environmental conditions at the time of application.

Herbicide Names

Herbicide labels contain three names: trade name, common name and chemical name. The nomenclature for Roundup Pro would is: **Trade Name**: Roundup Pro, **Common Name**: glyphosate, **Chemical Name**: N-(phosphonomethyl)glycine. The trade name is used by the chemical company to market the product and is often the most recognizable name. The common name is a generic name that is given to a specific chemical. Only one common name exists for each herbicide. It is useful to be familiar with common names when comparing products. The chemical name describes the chemistry of the herbicide. To make things confusing, the same or different chemical companies often sell the same herbicide under different trade names. For example, DuPont markets metsulfuron for pasture use as Cimarron and for forestry use as Escort. Metsulfuron is sold for use in turfgrass by Riverdale as Manor and by PBI Gordon as Blade.

Herbicide Terminology

Selective. A selective herbicide controls or suppresses some plant species without seriously affecting the growth of another plant species. Selectivity may be due to differential absorption, translocation, morphological and/or physiological differences between turfgrasses and weeds. Most turfgrass herbicides are selective. 2,4-D is an example of a selective herbicide that controls many broadleaf weeds without causing significant injury to grasses. Selective is a relative term that depends of many factors that include herbicide rate, environmental conditions, timing of application and the desirable species and variety being treated.

Nonselective. Nonselective herbicides control or suppress plants regardless of species. Glyphosate (Roundup), glufosinate (Finale) and diquat (Reward) are examples of nonselective herbicides. These products are often used for trimming along sidewalks and fences and as Preplant treatments when renovating or establishing turfgrass. It is important to note that the selectivity of some herbicides is based on rate. Increasing the rate of a selective herbicide such as atrazine will move it into the nonselective category.

Mode of action refers to the sequence of events that includes herbicide absorption, translocation to the site(s) of action, inhibition of a specific biochemical reaction, the degradation or breakdown of the herbicide in the plant and the effect of the herbicide on plant growth and structure.

Herbicide Movement in the Plant

Systemic (sometimes referred to as translocated) herbicides are extensively translocated in the vascular system of the plant. The vascular system consists of the xylem and phloem. The xylem transports water and various nutrients in solution upward from the roots where they entered the plant, through the stems and into leaves, flowers and fruits. The phloem conducts food materials from their principal sites of synthesis in leaves to other locations, such as fruits and developing roots, for storage and use. Systemic herbicides are slower acting than contact herbicides because they require from several days to a few weeks to move throughout the vascular system of a treated plant. Systemic herbicides may be selective or nonselective. Glyphosate (Roundup) is an example of a nonselective systemic herbicide, while 2,4-D, dicamba (Vanquish), imazaquin (Image) and sethoxydim (Vantage) are examples of selective systemic herbicides.

Contact herbicides affect only the green plant tissue that comes in contact with the herbicide spray. Thus, thorough coverage of the weed foliage is needed to achieve optimum control. These herbicides are either not translocated or only move to a limited extent within the vascular system of plants. For this reason, underground vegetative reproductive structures such as roots, rhizomes and tubers are not affected. Multiple applications of contact herbicides are needed for long-term control because plants regrow from these unaffected plant parts. Contact herbicides are fast acting. Symptoms are often visible within a few hours of application. 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 by when the chemical is applied relative to turfgrass and/or weed seed germination. The majority of herbicides may be classified into one of three timing categories: preplant, preemergence or postemergence. However, atrazine (Aatrex), simazine (Princep), dithiopyr (Dimension) and pronamide (Kerb) are exceptions. They are used as preemergence and postemergence herbicides.

Preplant Herbicides

These herbicides are applied before turfgrass is established to make the site as weed-free as possible. Glyphosate (Roundup) is often used as a preplant herbicide. On high-value sites such as putting greens, soil fumigants such as methyl bromide, metam-sodium or dazomet are used as preplant herbicides.

Preemergence Herbicides

Preemergence herbicides are the foundation of a turfgrass weed management program. Preemergence herbicides are applied to the site before weed seed germination. After being activated by rainfall or irrigation, these herbicides form an herbicide barrier at or just below 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 are cell division inhibitors affecting the emerging root and shoot, which are sites of rapid cell division. Weeds that have already emerged (visible) are not consistently controlled because their growing point has escaped contact with the herbicide. The primary target of preemergence herbicides is annual grass, but some small-seeded annual broadleaves will be controlled.

A variety of factors affect the performance of preemergence herbicides. These include timing of application in relation to weed seed germination, soil type, environmental conditions (primarily temperature and rainfall), target weed species and biotype and cultural factors (core aerification, for example) that follow application.

All of the products listed in the table above are characterized by long soil persistence, low water solubility and strong adsorption to organic matter. As a result, when they are applied to turfgrasses and activated by water, a very thin herbicide barrier is formed. As the weeds start to germinate, the young seedling comes into contact with the herbicide, absorbs the herbicide and the young seedling dies. It is therefore very important to apply the herbicide and water it in prior to seed germination if maximum results are to be obtained. Activation of preemergence herbicides requires 0.25 to 0.5 inch of rainfall or irrigation. For optimum performance, rainfall or irrigation should occur within 24 hours of application to move the herbicides into the upper layer of the soil. The critical

Major Preemergence Crabgrass and Goosegrass Herbicides

Trade Name(s)	Common Name	Family	Mode of Action
Barricade	Prodiamine	Dinitroaniline	Mitotic inhibitor
Pendulum, Pre-M	Pendimethalin	Dinitroaniline	Mitotic inhibitor
Surflan	Oryzalin	Dinitroaniline	Mitotic inhibitor
Team Pro	Trifluralin + benefin	Dinitroaniline	Mitotic inhibitor
XL	Oryzalin + benefin	Dinitroaniline	Mitotic inhibitor
Dimension	Dithiopyr	Pyridine	Mitotic inhibitor
Ronstar	Oxadiazon	Oxadiazole	Disrupts cell wall synthesis

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

Ideally, preemergence herbicides should be applied just before weed seed germination begins. Applying too early may result in reduced control or no control due to leaching and/or normal herbicide degradation. However, there is a good deal of research that indicates preemergence summer annual grass control applications may be made as early as January. The reason this works is that during cool weather the rate of herbicide degradation is slow and most of the preemergence grass herbicides do not leach readily. Applying early (January-February) is often a must for lawn care companies because a period of several weeks is required to service all of their customers. Preemergence herbicides must be in place and activated before weed seed germination begins.

Crabgrass germinates in the spring (late March-April) when soil temperature at the 4-inch depth reaches 53 to 58ºF. Alternating wet and dry conditions at the soil surface as well as light encourage crabgrass germination. Goosegrass germinates at soil temperatures of 60 to 65ºF. Goosegrass also requires light for germination and is very competitive in compacted, heavy traffic areas with thin turf. Because warmer temperatures are required, goosegrass typically germinates about 2 to 4 weeks later than crabgrass. Thus, when targeting goosegrass only, it is a mistake to apply preemergence herbicides at the crabgrass timing. Apply preemergence herbicides for goosegrass control 2 to 3 weeks later than the crabgrass application date.

Sequential or Repeat Applications

In warm weather, herbicides begin to degrade soon after application, eventually reaching a level at which weed seed germination can occur. Preemergence herbicides will degrade to the point of ineffectiveness from 6 to 16 weeks after application. For this reason, repeat or sequential applications are needed for full-season control.

Core Aerification and Preemergence Herbicides

For years it was assumed that core aerification would disrupt the herbicide barrier in the soil and result in weed seed germination. However, research has shown that core aerification of 'Tifgreen' and common bermudagrass did not stimulate crabgrass germination when done immediately before application and 1, 2, 3 or 4 months after treatment. An exception to this occurred with creeping bentgrass where greater amounts of crabgrass occurred where cores were returned compared to sites not aerified or aerified with the cores removed.

The most common reason for disruptions in the herbicide barrier is due to lack of uniform herbicide application. Poor application of a spray or a granular product can lead to large untreated areas that result in weed outbreaks. Poorly formulated granular products may prevent uniform distribution of the herbicide. The two most common problems with granular herbicides are excessively large particle size or a lack of uniform particle size. Big particles result in fewer particles per square foot and thus less coverage. A mixture of many particle sizes will prevent uniform distribution because heavy particles will behave differently than light particles when they drop on the spreader rotor. The data in the table below illustrates this point. Two experimental formulations of Barricade were compared to the spray formulation. The most concentrated granular product 0.5% granular formulation resulted in fewer particles per square foot compared to the more dilute 0.29% formulation. Note that the 0.29G outperformed the 0.5G. This was due to incomplete coverage by the 0.5G. Remember that most of the preemergence herbicides are largely immobile in the soil.

Preemergence Control of Smooth Crabgrass With Various Barricade Formulations

Barricade Formulation	Rate: lbs ai/ac	% Control
Barricade 65 WDG	0.75	98
Barricade 0.5 G	0.75	81
Barricade 0.29 G	0.75	91
LSD 0.05		9.3

Applied March 4, 1996, rated September 26, 1996.

Other Preemergence Considerations

The majority of preemergence herbicides (dinitroanilines often referred to as DNAs) used in turfgrass weed control are mitotic inhibitors that interfere with cell division. These materials are intended for use on established stands of grass. Plan ahead when using preemergence herbicides, and do not treat areas where new turfgrass is to be established. The same precaution applies to established turf that is to be overseeded. Examples include tall fescue lawns that are to be overseeded in the fall and warm-season grasses that are to be overseeded with a cool-season grass. The waiting period before planting is typically 2 to 4 months. There are exceptions to this rule when the objective is *Poa annua* control in overseeded ryegrass. Planting too soon following a preemergence treatment may result in reduced germination of seeds or root inhibition of sod, sprigs or plugs. Dimension is in a different herbicide family (Pyridines) but has the same root-inhibiting mode of action as the dinitroanilines.

In heavily trafficked areas, bare spots or thin stands, it is often wise to skip applications of preemergence herbicides that are mitotic inhibitors until the grass has recovered. Ronstar (oxadiazon), which is not a mitotic inhibitor, is a good choice for preemergence control of annual grasses on high traffic sites such as par 3 tees. This is why Ronstar is the preemergence herbicide of choice for weed control when sprigging. In tolerant grasses, MSMA is a postemergence alternative for these situations. The disadvantage is temporary turfgrass injury from MSMA.

Preemergence Herbicide Use

Recommended dates of application for control of crabgrass and other summer annual grasses are February 15 - March 5 for southern Arkansas and March 1-20 in northern Arkansas. Goosegrass usually germinates about 2 weeks later than crabgrass. Apply preemergence herbicides for annual bluegrass control on September 1. Herbicides such as atrazine (Aatrex) and simazine (Princep) may be applied in November or December because they will control small annual bluegrass postemergence. A good window to shoot for when using simazine for winter weed control is the period between Thanksgiving and Christmas. Preemergence herbicides should be watered-in immediately after application. Herbicide-only formulations have been the standard for many years, but the practice of impregnating herbicides on dry fertilizer granules is becoming increasingly popular. Common sense suggests that choosing a fertilizer carrier with relatively uniform particle size will improve the uniformity of herbicide distribution. Another factor to consider when using herbicide + fertilizer products for summer annual grass control is that warm-season grasses are dormant at the time of the first application, so much of the fertilizer will be wasted. These products are better used for the second application in May or June when warm-season grasses can use nitrogen fertilizer. When using fertilizer/herbicide combinations, consider whether or not the herbicide/nutrient ratio is right for the turfgrass and the environmental conditions.

Postemergence Herbicides

Postemergence herbicides are intended for use on weeds that have germinated and are visible. They are applied directly to emerged weeds. In contrast to preemergence herbicides, most postemergence herbicides have little or no soil activity. It is possible to conduct a total postemergence weed control program in turfgrass provided multiple applications are used throughout the year. The primary advantage of total postemergence control is that it is possible to wait and see if weeds emerge and thus whether it is necessary to treat. Disadvantages of total postemergence weed control include the need for frequent applications and, in some cases, temporary turfgrass injury. Most turfgrass managers use a combination of preemergence and postemergence herbicides. Preemergence herbicides form the basis of most programs with postemergence herbicides used to control weeds that escape the preemergence treatments. Established perennial weeds, both grasses and broadleaves (dallisgrass, nutsedge, Virginia buttonweed, white clover, plantain) must be controlled with postemergence herbicides. Some postemergence herbicides may be used on newly established grasses.

General guidelines for postemergence applications are small weeds, good soil moisture and air temperatures between 60º and 90ºF. Postemergence herbicides applied at temperatures below 60°F are often effective; however, more time is required for the herbicide to kill the weeds. Annual weeds that are small (two- to four-leaf stage) and actively growing are much easier to control with postemergence herbicides. Control is improved at this stage because young weeds readily absorb and translocate herbicides. Early weed control accompanied by fertilization also provides an opportunity for stoloniferous turfgrasses (bermudagrass, centipedegrass, St. Augustinegrass, zoysiagrass) to fill in the bare areas left by removing the weeds.

Weeds that are stressed due to dry weather, heat or other environmental factors (dust covered leaves) are more difficult to control with postemergence herbicides. Applying herbicides such as MSMA, DSMA, 2,4-D, mecoprop, dichlorprop and dicamba at temperatures above 90ºF increases the risk of turfgrass injury.

The resistance of postemergence herbicides to wash-off by rainfall or irrigation varies among products. Typically, a rain-free period of 6 to 24 hours is sufficient to avoid a reduction in effectiveness. Even if rain falls soon after application, some degree of reduced control will be achieved.

Mowing can affect performance of postemergence herbicides. Avoid mowing 1 to 2 days before application to allow development of greater leaf area to intercept the spray. Delay mowing 1 to 2 days after spraying to provide time for the herbicide to be absorbed and translocated.

Follow the label when using surfactants and crop oil concentrates with postemergence herbicides. Do not add surfactants that are not required because the result may be increased turfgrass injury. In situations where there is good soil moisture, warm temperatures and high humidity, the benefits of surfactants may not be obvious. However, under marginal environmental conditions, failure to use the proper additive may result in reduced weed control.

Rather than a single rate, a range of postemergence herbicide rates for a product usually is given. Repeat applications of a moderate rate are generally more effective than a single application of the higher rate. The follow-up application is timed to be 7 to 14 days after the first or when regrowth appears. For example, for bermudagrass control it is much more effective to apply Roundup three times at 2 quarts per acre (waiting for regrowth between each application) compared to applying one time at 6 quarts per acre.

If possible, avoid using postemergence herbicides during the spring green-up or transition period of warm-season turfgrasses. It is preferable to treat either completely dormant or actively growing grasses. Applying products such as Confront and to a lesser extent Trimec will cause yellowing and stunting of bermudagrass and zoysiagrass that is in transition.

Broadleaf Weed Control

Phenoxy (2,4-D, dichlorprop, MCPA, mecoprop) and benzoic acid (dicamba) herbicides have traditionally been the backbone of broadleaf weed control programs in turfgrass. These are selective, postemergence, foliar-applied herbicides. Rarely applied alone, these materials are typically used in two- and three-way combinations to broaden the spectrum of control. For perennials and tough annuals, repeat applications of these combination products 10 to 14 days apart are often needed for acceptable weed control. Overseeded ryegrass needs to be mowed three to four times before treatment with three-way phenoxy herbicides.

Over the last few years, some alternatives to the phenoxy herbicides for broadleaf weed control have been labeled for use in turfgrass. Triclopyr (Turflon II, Turflon Ester, others) and clopyralid (Lontrel) are now commonly used alone and in combination for postemergence broadleaf weed control. Triclopyr is a good alternative to try when the traditional three-way products (2,4-D + dicamba + MCPP) do not provide control. Triclopyr and clopyralid belong to the carboxylic or picolinic acid family of herbicides and produce symptoms very similar to the phenoxy herbicides. Clopyralid has very good turf safety on cool and warm-season grasses but has a narrow range of control limited to the sunflower (Asteraceae) and legume (Fabaceae) families. Clopyralid is excellent on white clover and other legumes, thistles and other members of the Asteraceae. Confront (triclopyr + clopyralid) has a broader spectrum and is useful on hard to control broadleaves. Care must be taken to avoid overdosing when using triclopyr on warm-season grasses. In fact, Turflon Ester (triclopyr ester) is labeled for suppression of bermudagrass in cool-season turfgrasses.

Metsulfuron (Manor, Blade) is a member of the sulfonylurea family of herbicides. It is an effective product for controlling many species of broadleaf weeds in bermudagrass, zoysiagrass, St. Augustinegrass and centipedegrass. Chlorsulfuron (Corsair) is also member of the sulfonylurea family of herbicides. Corsair controls some broadleaf weeds but does not have the broad control spectrum of metsulfuron.

Grass Control in Bermudagrass and Zoysiagrass

The organic arsenicals (MSMA, DSMA, CMA) have been the standard for postemergence grass weed control in tolerant turfgrass species for many years. Two to four applications spaced 7 to 10 days apart are generally needed for satisfactory control. The rate and number of applications generally increases as weeds mature. Control is also reduced if rainfall or irrigation occurs within 24 hours of treatment.

Alternatives to MSMA have appeared in the marketplace over the past few years. The following section describes postemergence grass herbicides suitable for use on various turfgrass species.

MSMA has been the primary herbicide for postemergence control of crabgrass. Repeat applications with a short time interval between applications are required for control of mature crabgrass. MSMA is not effective for goosegrass or tufted lovegrass control. Dallisgrass control requires five applications of MSMA at weekly intervals. This treatment is limited to use on bermudagrass. Tank mixing low rates of Sencor (metribuzin) with MSMA improves goosegrass control in bermudagrass. Adding metribuzin to MSMA also increases bermudagrass injury, but the bermudagrass will recover quickly under good growing conditions. Do not use Sencor on zoysiagrass. MSMA + metribuzin should be limited to established, actively growing bermudagrass that is being maintained at a mowing height of 0.5 inch or greater.

Drive (quinclorac) is an effective herbicide for control of crabgrass, barnyardgrass and broadleaf signalgrass in bermudagrass and zoysiagrass. Do not use Drive on centipedegrass or St. Augustinegrass. Drive also controls some broadleaf weeds such as white clover and dandelion. It may be tank mixed with MSMA to improve the spectrum of control. Drive will not control goosegrass. Drive is much safer for crabgrass control in cool-season grasses than MSMA.

Diclofop (Illoxan) has shown excellent goosegrass control under the right conditions. Illoxan causes little turfgrass injury, and retreatment is usually not needed. This herbicide is more effective on younger, lower-mowed goosegrass (0.5 inch or less mowing height). It is a slow-acting herbicide usually requiring 2 to 3 weeks for control. Illoxan has little effect on other turfgrass weeds. Treated areas should not be overseeded with ryegrass for 6 weeks following application. Do not tank mix Illoxan with other pesticides.

Fenoxaprop (Acclaim Extra) will control crabgrass in zoysiagrass and tall fescue. The crabgrass should be treated while it is very small (less than four leaf). Acclaim Extra may also be used for bermudagrass suppression in zoysiagrass and tall fescue. Three to four applications of Acclaim Extra per year over a 2-year period are needed to provide significant bermudagrass suppression. Eradicating bermudagrass from zoysiagrass with Acclaim Extra requires a long-term effort.

Sethoxydim (Vantage) is approved for use in centipedegrass. Apply Vantage to centipedegrass to control annual grasses and suppress bermudagrass and bahiagrass. Do not make more than two applications per season. Clethodim (Envoy, Select) is also safe to use on centipedegrass but is not currently labeled in Arkansas.

Fluazifop (Fusilade II) may be used on tall fescue (3 to 6 fluid ounces per acre) and zoysiagrass (3 to 5 fluid ounces per acre) to suppress bermudagrass and control annual grass weeds. Eradicating bermudagrass from zoysiagrass with Fusilade II is a difficult proposition that requires persistence.

Ethofumesate (Prograss) has been approved for bermudagrass suppression in St. Augustinegrass. Research indicates that tank mixing with atrazine and using multiple applications will improve the level of control.

Tranxit (rimsulfuron) may be used on zoysiagrass and bermudagrass for control of cool-season grasses such as annual bluegrass, rough bluegrass, perennial ryegrass and tall fescue. It is not for use on residential lawns. Tranxit may be used on bermudagrass that has begun to green up. Do not apply to slopes that drain onto cool-season grasses such as bentgrass greens or ryegrass overseedings.

Revolver (foramsulfuron) may be used on zoysiagrass and bermudagrass for control of cool-season grasses such as annual bluegrass, rough bluegrass, perennial ryegrass and tall fescue. Use only on sod farms and golf courses. Revolver provides some control of goosegrass and dallisgrass, but the research data is insufficient at this time. Revolver may be used on bermudagrass that has begun to green up. Do not apply to slopes that drain onto cool-season grasses such as bentgrass greens or ryegrass overseedings.

Kerb (pronamide) is used for annual bluegrass control in bermudagrass and for aiding in transition of bermudagrass overseeded with ryegrass. It has both pre and postemergence activity but works very slowly, taking up to 6 weeks for control. Kerb should be watered in after application. Manor (metsulfuron) is also used for ryegrass to bermudagrass transition. Do not apply Kerb or Manor to slopes that drain onto cool-season grasses such as bentgrass greens or ryegrass overseedings.

Roundup Pro (glyphosate) at 1 pint per acre is a cheap and effective way to control annual bluegrass in completely dormant bermudagrass.

Grass Control in Cool-Season Turfgrasses

Postemergence grass control in cool-season grasses with organic arsenicals such as DSMA or MSMA is risky due to the high probability of unacceptable levels of injury. These products can be very damaging to cool-season grasses such as tall fescue, especially during hot weather.

Drive (quinclorac) is an effective herbicide for control of crabgrass, barnyardgrass and broadleaf signalgrass in tall fescue, Kentucky bluegrass, perennial ryegrass and bentgrass fairways. Drive also controls some broadleaf weeds such as white clover and dandelion. Drive has become one of the dominant postemergence grass herbicide in cool-season grasses.

Fluazifop (Fusilade II) may be used on tall fescue to control annual grassy weeds and suppress bermudagrass. Apply when weeds are small and before the onset of hot weather stress.

Sethoxydim (Vantage) at 2.4 pints per acre controls many annual grasses in fine fescue. Spring applications are most effective when weeds are small and the weather is cool.

Corsair (chlorsulfuron) controls tall fescue selectively in Kentucky bluegrass and fine fescues. Low rates (1 to 5 ounces per acre) help to reduce turf injury.

Fenoxaprop (Acclaim Extra) at 13 to 39 fluid ounces per acre may be used on Kentucky bluegrass, fine fescues, tall fescue, annual bluegrass, perennial ryegrass and bentgrass fairways to control most annual grass weeds and to suppress bermudagrass encroachment. Apply in the spring when the turf is not under stress. Acclaim Extra may be tank mixed with Turflon Ester for improved suppression of bermudagrass in tall fescue.

Herbicide Formulations

The two big groups of herbicide formulations are dry and liquid. The amount of active ingredient in a dry formulation is designated as a percent of the weight. Active ingredient in liquid forms is listed in pounds per gallon. Within the dry formulations there are granular or pelletized herbicides that are spread directly on the target in their dry form. These products usually contain a very low percentage of active ingredient (0.1 to 2.0%) and are designated by the abbreviation **G** or **GR** (granule) or **P** (pellet). Other dry formulations are mixed with water and sprayed on the target. These products are designated as **SP** (soluble powder), **W** or **WP** (wettable powder), **WSP** (water soluble packet), **DF** (dry flowable), **SG** (soluble granule) or **WG**, **DG** or **WDG** (water dispersible granule). Liquid formulation designations include, **L** or **F** (liquid suspension), **E** or **EC** (emulsifiable concentrate), **SC** (suspension concentrate), **SL** (soluble liquid), **ME** (microencapsulated) and **CS** (capsule suspension).

Some herbicide formulations may be incompatible. MSMA and 2,4-D amine will sometimes form sludge when mixed. Liquid nitrogen and 2,4-D amine will always form sludge when mixed. One way to avoid a big mess is to combine a small amount of each herbicide in a jar with water, shake and see what happens. In addition to physical incompatibility, two herbicides may mix well but may be chemically incompatible, resulting in a reduction in herbicidal activity. For example, mixing 2,4-D with Fusilade, Vantage or other grass-specific herbicides will result in decreased grass control. This is referred to as antagonism. The label will give instructions on what can and cannot be mixed with that herbicide. When tank mixing different formulations: (1) fill the tank 2/3 full of water, (2) start the agitation and keep it running, and (3) add the respective formulations in this order: wettable powders > dry flowables > liquid suspensions > emulsifiable concentrates > soluble concentrates.

Herbicide Spray Additives and Their Uses

Adjuvant: Any additive used with an herbicide that enhances the performance or handling of the herbicide.

Compatibility agent: A material that allows the mixing or improves the suspension of two or more formulations when applied together as a tank mix. They are used most frequently when a liquid fertilizer is the carrier solution for an herbicide.

Crop oil concentrate: Oil-based material that enhances herbicide penetration through the leaf cuticle.

Defoamer: A material that eliminates or suppresses foam in the spray tank so that pumps and nozzles can operate correctly.

Drift control agent: A material used in liquid spray mixtures to reduce spray drift.

Fertilizer: certain fertilizers added to the spray tank can enhance penetration of the herbicide into the leaf.

Surfactant: A material that improves the emulsifying, dispersing, spreading, wetting or other surface-modifying properties of liquids.

Wetting agent: A material that reduces interfacial tensions between water droplets and the leaf cuticle.

Herbicide Management

Remember that herbicides can injure nontarget or desirable plants. When using any herbicide, manage the application carefully. Take steps to ensure that herbicides are directed to the target. Use them at the proper rate, at the right time and on a site that the label permits. Control each application so there is no off-target movement. Off-target movement may result from drift of actual spray droplets, volatilization and surface runoff water or by tracking with feet or equipment. One way to avoid injury to desirable plants is to apply when the nontarget plants are not present or not actively growing. For example, broadleaf herbicides are usually best applied in late fall to avoid vegetable and ornamentals while controlling perennial broadleaf weeds in turfgrass. In most cases, these products will effectively control perennial weeds in late spring or early summer, too. However, numerous sensitive nontarget plants are also present at those times of year.

Use extreme care when applying nonselective herbicides. Directed sprays are used to prevent contact with leaves, shoots or green stems/bark of desirable plants. Droplets too small to be seen will readily move through the air and damage sensitive plants. Shielded sprays, where a cone surrounds a nozzle, will help prevent the spray from contacting the foliage of a nontarget plant. A wiper (wick) application, where an herbicide solution is wiped on weed foliage only, is another way to use nonselective herbicides safely around desired plants.

Be aware that some herbicides will leach vertically through the soil profile. They may injure or even kill sensitive trees and shrubs if their roots extend under the treated soil. Shallow rooted plant or those with surface roots are especially vulnerable. Rainfall may move these products into the root zone, leading to injury. Atrazine, simazine, metribuzin and dicamba are turfgrass herbicides with potential for vertical and lateral movement. Manor, Tranxit, Revolver, Corsair and Kerb are herbicides that may move with runoff water under certain conditions. It is also possible to cause injury to a bentgrass green if traffic crosses the treated area and moves onto the green before the spray dries. Heavy rainfall shortly after application may cause off-site movement of these products, especially if the soil is already saturated.

When finished applying granular herbicides or fertilizers, sweep or blow them off hard surfaces such as parking lots, driveways, sidewalks and streets to prevent contamination of runoff water. Turf acts as a filter, but the materials left on impervious surfaces go directly into storm sewers or ditches and eventually into the water supply. Monitoring of rivers in the Atlanta area has shown a spike in turf pesticide and fertilizer levels during the busy spring-early summer season.

Herbicide Resistance

A number of weed species that were once susceptible and easily managed by certain herbicides have developed resistance. These weeds are no longer controlled by applications of previously effective herbicides.

Herbicide resistance probably develops through the selection of naturally occurring biotypes of weeds exposed to a family of herbicides over several years. A biotype is a population of plants within the same species that has specific traits in common. Resistant biotypes may have slight biochemical differences from their susceptible counterparts that eliminate sensitivity to certain herbicides. Resistant plants survive, go to seed and create new generations of herbicide-resistant weeds.

While most cases of resistance have appeared in agronomic crops, dinitroaniline-resistant goosegrass has been documented in turfgrass. However, these plants are susceptible to other goosegrass herbicides such as Ronstar, Illoxan and MSMA + metribuzin. Experience has shown that the potential for developing resistance is greatest when an herbicide has a single site of action. Arkansas now has Illoxan- and Oust-resistant ryegrass. Australia has Roundup-resistant ryegrass. Other southern states have documented simazine tolerance in annual bluegrass.

Regardless of the mechanism for resistance, becoming familiar with the herbicide mode of action can help turf managers design programs that prevent the introduction and spread of herbicide-resistant weeds. Management programs for herbicide resistance should emphasize an integrated approach that stresses prevention. Dependence on a single strategy or herbicide family for managing weeds will surely increase the likelihood of additional herbicide resistance problems.

Some strategies for managing resistance include:

1. Rotating herbicides having different modes of action.
2. Using tank mixtures of herbicides having different modes of action.
3. Avoiding sequential application (year after year) of the same herbicides or herbicides having the same mode of action.
4. Controlling weedy escapes in border areas and ditch banks.
5. Practicing good sanitation to prevent the spread of resistant weeds.
6. Integrating cultural, mechanical and chemical weed control methods.

Examples of Turfgrass Herbicides Having the Same Mode of Action

ALS Inhibitors	Lipid Synthesis Inhibitors	Mitotic Inhibitors	Photo-synthetic Inhibitors
Image Manage Manor Corsair Revolver	Illoxan Vantage Acclaim Fusilade	Balan Surflan Barricade Lesco Pre-M Pendulum XL Team Dimension	Princep Aatrex Sencor

Herbicide Use Tips

1. Avoid use of ester formulations of 2,4-D, dichlorprop, triclopyr and other growth regulator herbicides during the hot months. These formulations are more likely to volatilize and damage nontarget plants through vapor drift. To reduce drift, use a nozzle that produces coarse droplets (showerhead, also known as a Chem-Lawn Gun) and avoid spraying when the wind speed is over 5 mph.
2. Avoid applying postemergence herbicides during the spring green-up or fall transition period of warm-season grasses. While 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, the benefits of weed control may outweigh the herbicide injury caused by treating during the transition periods. Compared to the growth regulators, Manor (metsulfuron) is a safer postemergence broadleaf herbicide to use on bermudagrass during the spring transition period.
3. Avoid applying excess amounts of dicamba, atrazine, simazine or metribuzin over the root zone of shallow-rooted trees, shrubs and other ornamentals. They are mobile, soil-active herbicides that, under the right conditions (sandy soil and a heavy rainfall immediately after application), will be taken up by the roots of ornamentals.
4. Do not make a dormant application of Roundup, Reward or Finale to any turfgrass species except bermudagrass. The bermudagrass should be completely dormant. Even if there is only 10 to 20 percent bermudagrass green-up, injury will be severe. Remember that zoysiagrass never goes completely dormant in Arkansas.
5. Be aware that different turfgrass species and varieties differ in their herbicide tolerance. MSMA can be used safely on bermudagrass but will severely injure St. Augustine, centipedegrass and carpetgrass. In general, the *Zoysia japonica* derived zoysiagrasses (Meyer, El Toro, Crowne, Palisades, Empire, etc.) are more herbicide tolerant than the fine textured *Zoysia matrella* derived grasses (Emerald, Cavalier, Zorro, etc.).
6. Grasses growing in shade are more susceptible to herbicide injury. Use reduced herbicide rates or do not treat.
7. Areas on golf courses that drain onto sites (putting greens, tees) where cool-season grasses (rough, bluegrass, ryegrass and bentgrass) are planted should not be treated with Manor, Tranxit, Revolver, Kerb, Sencor, simazine or atrazine for winter weed control. Runoff water containing these herbicide residues may damage cool-season grasses. Heavy rainfall immediately after applying simazine or atrazine to a golf course fairway may result in injury due to accumulation of excess herbicide in low areas due to movement with runoff water.
8. Do your own weed control experiments. Often, control information does not exist for many species that do not occur frequently. Simple control studies may be conducted by treating infested sites with recommended rates of labeled herbicides. It is important to include an untreated area within the experimental site for comparison.

Soil Fumigation

Soil fumigants are volatile liquids or gases that control a wide range of soilborne pests. Soil fumigants are also highly toxic and are expensive. Their use is limited to high-value crops such as fruits, vegetables, tobacco, ornamentals and turfgrass. A cover, usually plastic film, is placed over the treated area to trap the fumigant vapors in the soil. In addition to many weeds, fumigants also control diseases, nematodes and insects. Weed seeds that have hard, water-impermeable seed coats such as sicklepod, white clover, redstem and morningglory are not controlled by fumigants. Factors to consider before choosing a soil fumigant include expense, soil moisture level, soil temperature and time available before planting. There are three compounds available for soil fumigation in turf: (1) methyl bromide, (2) metham or metam-sodium, and (3) dazomet (Basamid).

Methyl bromide is a colorless, nearly odorless liquid or gas. At 38ºF, the liquid turns into a gas and at 68ºF is 3.2 times heavier than air. These properties require that a cover be used or methyl bromide will escape. Methyl bromide is extremely toxic (acute vapor toxicity is 200 ppm) due to inhalation hazard, and it is commonly combined with a warning agent such as chloropicrin (teargas) to warn the user of escaping gas.

Before using methyl bromide, the soil should be in a condition suitable for planting including seedbed preparation by tilling. Control will be only as deep as the soil is adequately tilled. Soil should be moist for adequate soil penetration and dispersion. Saturated soils or extremely dry soil will limit fumigant movement through the soil, thus reducing the level of weed control. Soil temperature at 4 inches should be a minimum of 66ºF. Fumigation will not be effective if soil temperature is below 50ºF. Before or during application, the site should be covered with plastic film with the edges properly sealed to prevent gas leakage. The treated area should be covered for 24 to 48 hours. The cover should then be removed and the soil aerated for 24 to 72 hours before planting.

Metham or metam-sodium. Metham (methyl-dithiocarbamate) is a member of the thiocarbamate herbicide family. Metham is water-soluble and upon contact with the moist soil breaks down to form the highly toxic and volatile chemical methyl isothiocyanate. Metham should be applied to moist soil with a temperature of at least 60ºF. It is most effective when used with a cover, but it may be used with a water and soil-seal method. With the water soil-seal method, the soil is cultivated and kept moist for a week before treatment. The material is applied, roto-tilled and watered in to the desired depth of control (usually 4 to 6 inches). Approximately 7 days after treatment, the area should be cultivated to help release any residual gas. One to 2 weeks later (2 to 3 weeks after initial application), the treated area may be planted. Disadvantages of metham use include the lowered effectiveness when used without a cover and the longer waiting period before planting. The oral LD_{50} of metham is 820 mg/kg while the dermal LD_{50} is 2000 mg/kg.

Dazomet (Basamid) has recently been introduced as a soil fumigant. Dazomet is a granular formulation and is not a restricted use pesticide. Dazomet must be applied accurately and uniformly and then incorporated into the soil. Its use and effectiveness are very similar to metham.

Using Charcoal (Activated Carbon) to Deactivate Herbicides

Plan ahead. Have a supply of activated charcoal on hand. Timing is critical when dealing with herbicide accidents. The rate range for using activated charcoal is 100 to 400 pounds per acre (2.3 to 9.2 pounds per 1,000 square feet). For herbicide spills it is necessary to incorporate the charcoal into the contaminated soil, preferably to a depth of 6 inches. To be effective, charcoal must come in contact with the herbicide. The rule of thumb is to apply 200 pounds per acre (4.6 pounds per 1,000 square feet) charcoal for each pound of herbicide active ingredient per acre. In case of a severe spill, it may be necessary to remove the contaminated soil.

Applying charcoal can be a huge mess. If possible, avoid trying to apply the dry form because it is easily moved by wind. Look for a liquid charcoal product such as **52 Pickup**. Use a sprinkling can for small areas. For larger applications a power sprayer is more convenient. Use tips with a large opening and remove the nozzle screens to avoid clogging. We use Spraying Systems 8008 or 8010 flat fans or a Boom Buster tip. If mixing dry charcoal with water, adding 0.5% nonionic surfactant will help the charcoal go into solution. Fill the tank half full of water and start the agitation. Add the charcoal and the remainder of the water.

The target dilution is 1 to 2 pounds of charcoal per gallon of water. Afterward, clean the sprayer, pump and lines thoroughly because charcoal is very abrasive.

To deactivate an herbicide that is still on the soil surface following an accidental application, apply charcoal slurry at 2 to 4 pounds per 1,000 square feet. Water the slurry into the soil. Use enough water to remove the charcoal from the grass blades. Raking the charcoal into the soil will improve results. The area may be seeded 24 hours after treatment. However, if the herbicide has been moved into the soil by rainfall or irrigation, surface application of charcoal will not be very effective. Charcoal will not leach into the soil.

Turfgrass IPM

Herbicides are not a substitute for a conscientiously applied cultural program. Cultural practices are at least 60 to 70% of turfgrass weed control. The best means of preventing weed encroachment is a dense, vigorously growing turf. By choosing the right grass for the site and following proven fertilization, mowing and irrigation practices, weeds will be less competitive with the turf. Before deciding to use any weed control program, first determine why the turf is thin and weeds are invading. Correct the factors causing unhealthy turf before implementing an herbicide program. Weed prevention is avoiding the introduction of weeds into an uninfested area. One of the keys to making integrated pest management effective in controlling turfgrass weeds is not allowing weeds to become established. Some common sense steps to weed prevention include:

1. Using weed-free mulch and topdressing materials.
2. Using weed-free seed, sprigs, plugs and sod.
3. Keeping border areas such as fence lines, roughs and ditch banks weed-free.
4. Washing or blowing equipment between uses, especially when moving a mower or other piece of equipment from a weedy area to a weed-free area.

Have a Plan

Too often weed control measures are a reaction to crisis rather than part of a well-planned and coordinated effort. Turfgrass professionals should spend at least as much time learning the conditions that lead to weed infestation as they do studying control strategies after weeds have become established.

A big part of having a plan is scouting and mapping the weeds. As you travel the sites that you maintain, collect information that will allow you to be ready with the correct herbicides and plan of attack come treatment time. Late summer or early fall is a good time to make weed surveys. Follow the fall survey with a spring assessment to observe spring germinating weeds. Put your survey data on paper.

Turfgrass Growth Regulators

PGRs are separated into two groups, Type I and Type II, based on how the inhibit growth. Type I inhibitors are primarily absorbed through the foliage and inhibit cell division and differentiation in meristematic regions. They are inhibitors of vegetative growth and interfere with seedhead development. Their growth inhibition is rapid, occurring within 4 to 10 days, and lasts 3 to 4 weeks, depending on application rate. Embark (mefluidide) is an example of a Type I inhibitor that inhibits cell division in growth and development.

Type II inhibitors are generally root-absorbed and suppress growth through interference with gibberellic acid synthesis, a hormone responsible for cell elongation. Type II PGRs are slower to produce growth suppression, but their duration is usually from 4 to 7 weeks, again depending on application rate. Type II PGRs have little effect on seedhead development and result in miniature plants. Trimmit, Scott's TGR (paclobutrazol) and Cutless (flurprimidol) are root-absorbed Type II PGRs. Primo (trinexepac-ethyl) is a foliar-absorbed Type II PGR that is systemically translocated to the site of activity.

Proxy 2L (ethephon) is a PGR with best activity on cool-season grasses. It promotes ethylene production in plants, which is a regulatory hormone that restricts plant growth. Root-absorbed PGRs are activated by irrigation or rainfall after application and are less likely to cause leaf burn due to overlaps in application. Foliar-absorbed materials such as Primo and Embark require uniform and complete coverage for uniform response and must be leaf-absorbed before irrigation or rainfall occurs. Usually low application volumes (0.5 to 1 gallon per 1,000 square feet) are used for foliar-absorbed materials to minimize runoff from the leaf surface, while high volume applications (1 to 5 gallons per 1,000 square feet) are used for root-absorbed materials.

An available plant growth promoter is RyzUp from Abbott Laboratories. RyzUp is gibberellic acid, which encourages cell division and elongation. RyzUp helps initiate or maintain growth and prevent color changes during periods of cold stress and light frosts on bermudagrass such as Tifdwarf and Tifgreen. Bermudagrass greens may experience an early light frost before the overseeding has become established. RyZup helps the turfgrass recover from this discoloration. PGRIV from MicroFlo and Roll Out from Griffin are combinations of gibberellic acid, indolebutyric acid that is foliar-absorbed. Research suggests that his combination promotes root growth and vigor or certain plants growing under stressful conditions.

Trade Name	Common Name	Site of Uptake	Seedhead Suppression	Mode of Action	Comments
Cutless	flurprimidol	roots	incomplete	Inhibits gibberellic acid synthesis.	Occasionally used in a tank mix with Prograss for suppression of bermudagrass encroachment into bentgrass greens. Needs rainfall or irrigation for activation.
Embark	mefluidide	foliage	yes	Cell division inhibitor.	Used for seedhead inhibition in tall fescue and other grasses.
Primo	trinexepac-ethyl	foliage	no	Inhibits gibberellic acid synthesis.	Used on bermudagrass and zoysiagrass fairways to reduce clippings and improve turf density. Also used on bentgrass and bermudagrass putting greens.
Proxy	ethephon	foliage	no	Promotes ethylene production which restricts growth.	Primarily for cool-season grasses. Not much research data available.
Roll Out	cytokinins, gibberellic acid and indolebutyric acid	foliage	no	Encourages cell division and elongation.	Not tested in Arkansas. Label uses include fall color retention for bermudagrass.
Royal Slo-Gro	maleic hydrazide	foliage	yes	Cell division inhibitor.	Occasionally used to inhibit tall fescue seedheads in utility turf.
RyZup	gibberellic acid	foliage	no	Encourages cell division and elongation.	Not tested in Arkansas. Label uses include fall color retention for bermudagrass.
Trimmit, TGR	paclobutrazol	roots	no	Inhibits gibberellic acid synthesis.	Use to suppress Poa annua growth in bentgrass greens. Needs rainfall or irrigation for activation.

Vertebrate Pests (Turf)

Problems with vertebrate pests rarely approach the magnitude of the problems caused by weeds, diseases, weather and insects. Under certain circumstances, however, vertebrate pests problems can be significant and difficult to deal with. Specific questions about laws regulating vertebrate pest control should be directed to the Arkansas Game and Fish Commission, 2 Natural Resources Drive, Little Rock, Arkansas 72205, (800) 364-4263 or (501) 223-6300, www.agfc.com. The following information will offer some basic guidelines for determining if vertebrates are a problem and how to control them if they become a problem.

Factors Affecting Control

Several factors complicate the control of vertebrates, including:

- **Mobility.** Certain mammals and birds may come from long distances to damage crops. Thus, they may spend most of their time where they are not a problem.
- **Unpredictability.** Many factors, such as population density, weather and availability of natural food, influence the transition of a normally harmless vertebrate population into the role of a pest problem.
- **Public perception.** The public holds most vertebrates, especially larger ones such as geese or deer, in high esteem. Efforts to control them can then become a complex social problem as well.
- **Legal status.** Most mammals and birds are provided some protection under state and/or federal law as game animals, migratory birds or endangered species. Thus, you need to be aware of the species involved in damage and the legal restrictions relative to controlling it.
- **Control techniques.** Often because of environmental complications or the legal status previously mentioned, control techniques are limited for vertebrate problems. Control may incorporate cultural practices or physical barriers, which admittedly break down under some conditions.

In a turfgrass environment in Arkansas, some vertebrate pests that may occur include moles, skunks, armadillos and geese. All except moles and armadillos are protected under Arkansas and/or federal wildlife laws. The Arkansas Game and Fish Commission should be consulted for appropriate legal aspects concerning relief from nuisance animals.

Moles

The eastern American mole is the only mole of concern in Arkansas. Moles are not rodents and live underground, preferring moist soil. Moles are 4 to 9 inches long and have a rather short tail. Though rarely seen above ground, the eastern mole can be distinguished from other small mammals by its soft, velvety fur and huge, flattened front feet that are equipped with large, broad claws for digging. Eyes are tiny, like a pinhead, and the tail and feet are usually pink. Moles have no visible ears. Earthworms and insect larvae/grubs are their main food source.

Moles owe their status as pests to the feeding tunnels they construct as they burrow in the surface of lawns and golf courses. Moles dig two kinds of tunnels. The feeding tunnel is made only an inch or two below the surface of the ground by the mole "swimming" through the loose topsoil. This kind of runway leaves a ridge of earth on the surface of the ground. The tunnels interfere with mowing and expose roots to air, sometimes killing grass or other plants. More permanent tunnels are made 6 to 10 inches below the surface, and mounds of earth are thrown up at intervals. From the main tunnel of the mole run, a short shaft extends straight up to the surface. The soil that is expelled from this vertical shaft wells up like water, and successive loads form a nearly circular mound of which there may be "ripple marks" in the form of complete circles.

Toxic baits and fumigants are available for controlling moles; however, these control measures often are not very effective. Toxic baits are often based on peanuts, grain or other food items that are not the mole's preferred food, and thus moles seldom take poisonous baits. Fumigants may be inserted in surface feeding tunnels and may kill moles if they happen to be in the tunnels at the time of the treatment. When the use of poisons seems to be effective, the user has probably either frightened the mole out of his present runway by the scent or has killed the food upon which the mole feeds. If moles are deprived of their food supply, they will be forced to seek another area. Several insecticides are capable of reducing populations of earthworms and soil insects to a point where the soil no longer provides sufficient food to fulfill the mole's daily requirements. The effect on the moles cannot be expected for several weeks, and moles can cause increasing damage as they search in a decreasing food supply.

Mole Control Techniques

The most effective method for controlling moles is the use of lethal traps, though this method is also time-consuming. Traps must be carefully placed so as not to arouse the suspicions of moles, which are very sensitive to unnatural changes in their environment.

To establish which tunnels are active, step down on tunnels in several places in the yard. Mark the tamped area with a peg or wire flag. If the tunnel has been pushed back up in a day or so, set the trap in that section of the tunnel. Seek a long, straight runway for setting the trap.

Three trap types are the harpoon, scissor-jawed and choker loop. The scissor-jawed and choker traps require digging and exposing the tunnel. The jaws or loops are set to encircle the tunnel and are triggered when the mole moves through the trap. The harpoon trap is set directly over the runway so that the supporting stakes straddle the runway and its spikes go into the runway. The trap is triggered when the mole's tunneling activity causes the soil to strike the pan and trigger the spikes. Set the trigger pan where it just touches the earth where the soil is packed down. Setting the trigger too high or too low will result in misfires. If any of these traps fail to catch a mole after 2 or 3 days, move the trap to a new location.

When using traps:

- Place a plastic pail with a warning sign over each trap.
- An average set will require three to five traps per acre.
- Check the trap every day.

Skunks

The striped skunk is the species most commonly encountered in Arkansas. They are black in color with distinctive white stripes that extend laterally over the back. The adults normally weight about 6 to 8 pounds and are 24 to 30 inches long. Skunks have short, stocky legs and disproportionately large feet equipped with will-developed claws for digging. Skunks are usually active from early evening through most of the night. During the day they usually sleep in dens under logs, woodpiles or buildings.

The high nuisance value attributed to skunks is caused by their habit of burrowing in flowerbeds, lawns and golf courses in search of food. Skunks are carnivores and eat insects such as grasshoppers, beetles and crickets, as well as mice, moles, young rabbits, grubs, bees, wasps and their hives. Skunks also eat fruits, some grasses, leaves, buds, roots, nuts and grains. Insects, however, are a preferred food, and skunks often tear up and destroy turf during their search for white grubs and other insect larvae. Digging normally appears as 3- to 4-inch cone-shaped holes or patches of overturned sod. This grubbing activity is most common in the spring and fall when larvae are found near the soil surface.

Skunks are classified as furbearers and as such, are protected in Arkansas by state regulations. A hunting license is required from the Arkansas Game and Fish Commission for either live trapping or administering lethal methods of control. With a hunting license, skunks may be live-trapped or killed during furbearing season. If skunk problems need to be handled outside furbearing season, a depredation permit is required. Contact the Arkansas Game and Fish Commission for information on obtaining this permit. Note that a depredation permit does not include permission to shoot skunks when local law prohibits discharge of firearms.

Skunks can carry rabies, and thus skunks that are overly aggressive or show abnormal behavior should be treated cautiously. The Arkansas Department of Health suggests that any skunk that is observed during daylight is acting abnormally and should be destroyed to prevent the spread or rabies. Contact the local animal control or sheriff's office for assistance with disposing of a rabid skunk. Avoid shooting or striking the head to protect against damaging the brain for testing for rabies, and keep in mind that most skunks will release their scent when shot, so try to avoid shooting them near buildings. If removing a potentially rabid skunk, gloves and/or shovels should be used. Place the skunk in a sealed plastic bag and bury the carcass where pets will not dig it up.

Skunk Control Techniques

Removal and relocation in combination with exclusion methods oftentimes is the best option for addressing skunk problems. Shooting is also an option, where legal and with proper hunting license or depredation permit. There are no toxicants or repellents registered for skunks.

Typically, skunk problems involve removing and excluding skunks from a den site. Avoid skunk removal from May through early August when den-bound, immobile young may be present. A combination of live trapping, relocation and exclusion are recommended as follows.

- **Live trapping.** Bait live traps with a few tablespoons of pet food having a fish base. When using a wire cage trap, place a tarp or plywood shell around the cage. Check the trap, frequently particularly in the summer, as skunks could die from excessive heat, leading to accusations of inhumane treatment. After a skunk is trapped, cover the opening so the skunk cannot see. With a minimum of jarring or shaking, the trapped skunk can be transported and released with little concern for a musk discharge. Leg-hold traps can be used to catch skunks, but because of odor problems, this method should not be used near housing.
- **Relocation.** When relocating skunks, transport them at least 10 miles and release in habitat far from human dwellings.
- **Exclusion.** Typically, more than one skunk occupies a denning site. Seal off all foundation openings except one. Cover openings with wire mesh, sheet metal or concrete. Skunks may dig to gain entry, so obstructions such as fencing should be buried 1 1/2 to 2 feet. In front of the remaining opening, spread a layer of flour on the ground. Typically, skunks are active at night. Check at night for tracks indicating the skunks have left the den and then seal the opening. To ensure no skunks are sealed inside, use one or both of the following approaches.
  - For several successive nights, unseal one opening at dark and place flour on the ground. After a couple hours, check for tracks exiting the den and reseal the opening. If no tracks are detected after several nights, seal the opening permanently.
  - Place a trap inside the sealed up area. Bait with pet food and water. Remove and translocate any trapped skunks. Repeat until no skunks are trapped on successive days.

Odor Abatement

When a skunk raises its tail, it is a warning. When a skunk's hind legs begin hopping, leave the vicinity as quickly as possible. Ordinarily, there is no discharge. But, if a skunk believes it is in danger, one discharge will not empty the reservoir. Many people find the odor repugnant or even nauseating. Because of its persistence, the scent is difficult to remove. Diluted solutions of vinegar or tomato juice can have limited effectiveness when applied to pets, people or clothing. Clothing can be soaked in weak solutions of household chlorine bleach or ammonia, but oftentimes the clothing is also ruined using this treatment. For spraying under foundations or structures, a number of skunk deodorizers are on the market. These offer some relief by masking, rather than removing, the odor.

Armadillos

The armadillo is mainly nocturnal during the summer and may be diurnal during the winter. It digs burrows that are usually 7 inches to 8 inches in diameter and as much as 15 feet in length. The burrows are located in rock piles and around stumps, brush piles and dense woodlands. More than 90 percent of the armadillo's diet consists of insects, but the animals also feed on lizards, frogs, snakes, bird eggs, berries, fruits and roots. An armadillo pursuing insects in the ornamental landscape or in turf will tear and uproot an area similar to skunks but at somewhat deeper depths.

The young are born in a nest within the burrow. The female produces only one litter each year in March or April. The litter always has quadruplets of the same sex and each appears identical since they are derived from a single egg. The armadillo has poor eyesight but a rather keen sense of smell. In spite of its cumbersome appearance, the agile armadillo can run well when in danger.

Armadillo Control Techniques

Since most of the damage caused by armadillos is a result of their rooting for insects and other invertebrates in the soil, an insecticide may be used to remove the food sources and make areas less attractive to armadillos. Also, trapping armadillos has proven to be a fairly successful elimination method. Armadillos can be captured in live or box traps such as the Havahart or Tomahawk. If bait is desired, use overripe or spoiled fruit. Other suggested baits are fetid meats or mealworms.

Geese

Wild geese are a federally protected migratory species. Domestic geese, such as white geese and graylags, are not under the jurisdiction of the Arkansas Game and Fish Commission or the federal government. Because wild geese are federally protected, USDA Wildlife Services (501-362-5382, 870-673-1121) can provide the best information concerning alternatives for controlling geese problems. Resident Canada geese should be referred to the Arkansas Game and Fish Commission (800-364-4263).

Canada geese need a permanent body of water on which to land, escape, rest and roost. They also a need suitable open feeding area that provides a place to land, has good visibility of the surrounding territory and has abundant tender young grass and other vegetation for feeding. Canada geese in Arkansas consist of both migratory and nonmigratory populations. Migratory birds nest in Canada and migrate south for the winter.

Most complaints about damage come from areas where birds congregate in public or private ponds and feed in mowed areas in parks, near beaches and on golf courses and lawns. Fecal droppings damage lawns and golf greens and can limit recreational use of the area. Fecal contamination of water may pose a local pollution problem, although typically it is not a threat to human health. Geese defending their territory can injure people who come too close.

Goose Control Techniques

Hunting

Geese may be taken during declared open hunting seasons. Hunting, where safe and legal, is the preferred method of reducing nonmigratory waterfowl, and over time, may serve to decrease damage. Hunting also makes frightening techniques more effective. In some cases, local ordinances would need to be changed to permit hunting in nontraditional areas such as parks and golf courses. Special restrictions on hours and dates open to hunting can be implemented. Contact the Arkansas Game and Fish Commission for current information on waterfowl hunting regulations and seasons.

Discontinue Feeding

Well-fed domestic “park ducks” and geese serve as decoys, encouraging wild birds to congregate in unnaturally high concentrations. Therefore, discontinued feeding should be the first control measure.

Frightening

Geese can be repelled by almost any large foreign object or mechanical noise-making device. Frightening devices should be in place before the start of the damage season to prevent geese from establishing a use pattern. To prevent birds from becoming accustomed to the frightening device, it should be moved every 2 or 3 days and used in varying combinations.

Visual repellents such as flags, balloons and scarecrows can be used at a density of one per 3 to 5 acres before waterfowl settle into the area. If birds are already present, an additional one or more visual repellents per acre may be necessary. Because geese can quickly acclimate to stationary visual repellents, reinforcement with audio repellents may be necessary. A unique “nonstationary” visual repellent on the market is a simulated floating alligator head for small ponds. However, the effectiveness of this product has not been studied.

Pyrotechnics, shell crackers or other noise-making devises can be effective if used before birds become established. A disadvantage is that neighbors may not appreciate the loud noises that are produced. A less-invasive product on the market is a programmable electronic devise that plays recorded goose alarm calls in random combinations. The recordings can be set to play at dawn and dusk using multiple speakers to create natural sound patterns of disturbed geese.

Dogs trained to chase waterfowl have been used to protect golf courses and orchards. In certain situations, they can be very effective, such as when geese become adapted to pyrotechnics and other forms of hazing. Dogs can be free running, on slip-wires, tethered, contained by an underground “invisible fence” or controlled by a handler. On one golf course in Oregon, a professional dog trainer used four border collies to frighten geese three to five times per day for the first several days. The geese soon left, and hazing diminished over time. The golf course purchased one dog to continue the program.

All applicable laws must be observed when using these devices, particularly those governing loud noises, discharging of firearms, use of pyrotechnics and use of free-ranging dogs. Note that nesting waterfowl cannot be harassed without a federal permit. In addition, flightless geese should not be harassed.

Habitat Modification

There are several ways to make a pond and its surroundings unattractive to waterfowl. However, these practices may also degrade habitat quality for other wildlife and fish species, so use with caution. Constructing an abrupt 18- to 24-inch vertical bank at the water's edge will deter geese. On levees or banks, use large boulder riprap, which geese cannot easily climb over. Eliminate emergent aquatic vegetation with herbicides or an aquatic weed harvester or by temporarily draining the pond. If possible, allow woody brush to grow around shorelines.

On lawns or areas surrounding ponds, reduce or eliminate fertilizer applications so that grass is less nutritious for grazing waterfowl. If possible, increase grass height to 10 to 14 inches, especially along shorelines. Consider replacing large lawn areas with clumps of shrubs or trees, ground covers such as myrtle or less palatable grass species such as fescue. Planting trees will interfere with the bird's flight paths and shrubs reduce the birds' ability to see from the ground. Landscaping techniques that reduce the birds' view to less than 25 to 30 feet discourages grazing, especially if harassment programs are also used.

Exclusion

Canada geese may be discouraged from using ponds by installing a 30- to 36-inch high poultry wire fence at the water's edge. (This technique, however, is not effective for ducks.) Geese are reluctant to pass under a wire fence, so installing a single-strand fence or one made of Mylar flashing tape at a height of about 15 inches may discourage geese from entering an area. Good results have been reported using 20-pound test, or heavier, monofilament line to make a two- to three-strand fence in situations where aesthetics preclude the use of wire fencing. String the first line 6 inches off the ground, with each additional line spaced 6 inches above the preceding line. Suspend thin trips of aluminum foil at 3- to 6-foot intervals along lines to increase visibility of the barrier for wildlife and people.

To stop waterfowl from using lakes, ponds or reservoirs, construct overhead grids of thin cable visible to both humans and waterfowl. White or brightly colored cables may improve visibility. Because these materials are extremely light, several hundred feet can be supported between two standard 5-foot steel fence posts. Grids on 20-foot centers will stop geese, and grids on 10-foot centers will stop most ducks. When necessary, grid lines should be installed high enough to allow people and equipment to move beneath them. Excessive rubbing will result in line breakage, so grid wires should be tied together wherever lines cross. Attach lines independently to each post and not in a constant run, to prevent having to rebuild the entire grid if a line breaks. Polypropylene UV-protected netting can be used to provide total exclusion from a lake or pond. Support the netting with 0.19 inch 7 x 19 strand galvanized coated cable on 20-foot centers.

Repellents

Repellents can be effective for short-term control. Methyl anthranilate is a chemical that has taste and olfactory repellent properties that can be sprayed on turf. Other chemicals may be on the market as well. Once the repellent dries, it does not wash off the grass, even in heavy rain. However, mowing treated grass will expose untreated grass to geese and reduce the repellent's effectiveness. One study of a product with methyl anthranilate indicated that treating the first 100 feet of turf from the water's edge reduced bird activity over the remainder of the area; therefore, treating the entire area was unnecessary. Additionally, methyl anthranilate was mixed and applied with the herbicide 2,4-D, which did not change its effectiveness in repelling geese. Repellents, when used in combination with other techniques, may help reduce goose damage to lawns, golf courses and other turf areas.

Summary

The key to controlling nuisance flocks of geese is promptness and persistence. Methods of controlling damage will work only as well as their implementation. Once nuisance waterfowl are gone from an area, the area must be made unattractive to waterfowl so they will not return. As soon as one goose or duck lands, it should be frightened until it leaves. Otherwise, the bird will act as a decoy and attract others.

Pesticide Application

Pesticide Safety

Pesticide safety begins with the selection of the pesticide to be purchased. Various considerations, including who is going to be exposed during and after application, ease of application, potential harm to the environment, toxicity of the pesticide, the pest to be controlled and the cost of the material, must be considered.

Storage and Inventory

The first safety step is proper storage. Without proper storage, pesticides can be damaged due to weather or mechanical situations. Correct storage also decreases the chance of contamination between two different types of pesticides and decreases the chance of the wrong pesticide being used.

A good storage building should be constructed of nonflammable material. It should have a floor that will prohibit liquids and dry pesticides from penetrating and leaking through and yet provide for easy cleanup. The building should be well ventilated and lighted with temperature control to prevent freezing and excessive heat. All storage buildings should be well marked and locked. If possible, the building should be fenced to further keep unauthorized people away. The storage area should be supplied with detergent, hand cleaner and water; absorbent materials, such as absorbent clay, sawdust and paper to soak up spills; a shovel, broom and dustpan; and a fire extinguisher rated for ABC fires.

Inventory control includes obtaining a Material Safety Data Sheet (MSDS) for each pesticide stored and used. It is also good management to have a current label for each pesticide stored and used on the facility. Both the MSDS's and labels should be stored in location(s) that permit the workers and staff to easily obtain them at any hour. This usually means having duplicates of each MSDS and label and having two separate filing places. It is usually best to designate one or two persons to be responsible for inventory control.

Applicator Safety

There are four areas of pesticide application that expose the pesticide user. The first is mixing/loading. Mixer/loaders must be aware that this is usually the most likely area for personal contamination to occur. Simple steps can greatly reduce exposure during the operation. Proper equipment must be available for accurate mixing/loading operations. This includes, but is not limited to, proper measuring devices (containers/scales), hoses and cutoff valves, backflow valves and personal protective equipment (PPE).

The PPE can include a plastic apron, rubber or plastic gloves, rubber or plastic boots, arm protection (either with long-sleeve shirts or disposable sleeves), leg protection, face shield, hat, respirator and disposable coveralls. Not all the above PPE is needed for all pesticides, and some can be used in place of others. Disposable coveralls can replace the leg and arm protection and the need for an apron. Regular tightly woven coveralls can replace disposable ones for certain pesticides if they are washed after each day's use. PPE can be determined from the label and MSDS for each pesticide used. When using pesticide mixtures, select the PPE for the most hazardous pesticide. The mixers/loaders should be very aware of the fact that they **should not use leather or canvas gloves or boots**. These types of gloves and boots retain pesticide residues and cannot be cleaned.

The next area for safety is the application. Generally, the applicator should use the same PPE as the mixer/loader. Although most applications are made at times of low wind speeds and with booms that are not far from the ground, there is still a good potential for the applicator to be exposed to pesticide drift or vapors. Plus, the applicator will have available the necessary PPE in case the sprayer malfunctions.

Sprayer cleanup is the third area of safety concern. Persons cleaning the spray equipment should use the same PPE as the mixer/loader. The cleanup people should be extra aware of the initial rinse/wash water containing pesticides. This is more from the chronic toxicity standpoint than from the acute. They should be especially wary about walking around in water without proper foot protection.

The last segment of applicator safety is personal cleanup. Each person should always clean up before eating, smoking or using the bathroom. They should also shower after working with pesticides, preferably right after the job is completed or at the end of the day. Their clothes are to be laundered separately from the family clothes.

Before laundering, it is helpful to rinse the clothes by hanging them on a line and hosing them down with water. This gets a fair amount of pesticide out of the clothes before washing. Then one should use hot (140ºF) water and a strong detergent with a 12-minute wash cycle. After the wash is finished, remove the clothes and run another wash cycle to "rinse" the washer. All clothes used for pesticide applications should be air-dried. Do not dry the clothes in a dryer because there is a chance of some pesticide residue being left on the dryer drum.

Turfgrass User Safety

Whenever possible, pesticide applications to turfgrass areas should be applied to provide the maximum amount of time from application to use of the turf. This translates into not allowing access to treated areas until the sprays have dried or for 24 hours. Never spray a turf area and then permit people or pets to have immediate access.

One must realize that users of turfgrass areas will be doing things (picnicking, walking, sunbathing) that increase their exposure. The clothing worn by turfgrass users is not conducive to reducing chronic exposure. Their leather or canvas shoes can retain pesticide residues if they walk in areas that have been recently treated with pesticides. The residues are not easily removed; therefore, the users can get a small dose every time the shoes are worn. Likewise, persons going barefoot or sunbathing can come into direct contact with spray residues. Children often have direct contact with the grass. Therefore, do not permit access to areas that have been treated with pesticides until the sprays have dried or 24 hours has elapsed, whichever is specified on the pesticide label.

Wildlife Safety

The use of pesticides on turfgrass must also take into consideration possible impact on wildlife. Many pesticides are toxic to fish and/or wildlife. Therefore, do not spray pesticides in or on water or under situations that can lead to fish and/or wildlife kills. Also, be careful that pesticides are not applied just before a thunderstorm or irrigation schedule. You do not want to wash the pesticide into the water system.

Many parks and golf courses have creeks and waterways. One must be careful in the selection and use of pesticides in these aquatic areas. The applicator must also be careful not to permit sprays to drift or be carried into water that may be near the turf area.

Summary

Both the turfgrass manager and the user of the turfgrass should be aware of the benefits and risks involved with pesticides. The immediate risks are from acute toxicity. If the mixer/loader, applicator and cleanup person use proper PPE and techniques, their risks are greatly reduced. The user of the turf area is at the "mercy" of the turfgrass manager. Once again, if the turfgrass manager has taken the proper steps, the risk to the turfgrass user is also greatly reduced. The chronic risk for each party is more difficult to determine. By using proper application techniques and PPE, the turfgrass manager will reduce the chronic toxicity problems to the workers. Likewise, if the turfgrass manager has taken proper steps during and after application of pesticides, then the chronic risks to the turfgrass users should be reduced.

These are just a few items for turf managers to be aware of when using pesticides. Responsibility does not stop with the production of turf – it goes to the persons using that turf.

Pesticide Laws and Regulations

There are many federal and state laws that regulate the use of pesticides. These laws must be followed to the best of your ability to insure the proper results and protect people and the environment from unnecessary dangers and contamination. The best way to meet most of these regulations is to follow the directions on the pesticide label. The label in itself is a "law," and all directions on the label are to be followed. To do differently is to be in violation of the label and the law.

The state of Arkansas requires all persons purchasing and/or applying a restricted-use pesticide to be certified applicators. For turfgrass managers, they would be certified in the Ornamental and Turf category. Study material may be obtained from your local Cooperative Extension Service office, and testing is conducted by the Arkansas State Plant Board. Persons certified as commercial or noncommercial applicators are required to keep records of all pesticide applications. These records are to be kept at the office of the business for a minimum of 2 years. The records should contain the following: time and place of each application, name of applicators, legal land description, date used, tank mix, dilution rate (rate of carrier), quantity used, complete trade name and registration number of product used, target pest and use site.

There are several other laws and regulations that may affect a turfgrass manager. One should check with the Arkansas State Plant Board, Arkansas Department of Labor, Arkansas Department of Health and local authorities to determine other regulations that may affect your business.

SARA, Title III, or Community Right-to-Know

SARA stipulates that anyone who has specific hazardous materials above a certain quantity on their facility must report the storage of those materials to the State Emergency Response Committee (SERC) and to the Local Emergency Planning Committee (LEPC). A list of the chemicals that must be reported can be obtained from your local Cooperative Extension Service office. One should check with their LEPC on the various requirements of the Act for the business. This Act requires those who fall under it to develop an emergency response plan for accidents. This plan can be developed in conjunction with your LEPC. This is an area where a good storage inventory program will greatly assist the turfgrass manager.

Disposal

This is the most unclear aspect of pesticide application. Disposal of metal, glass and plastic containers can best be handled by triple rinsing and pouring the rinsate into the spray tank. These containers can then be disposed of in a permitted landfill. For paper bags, empty their contents into the spray tank, and then cut the sack so that the remaining material can be "shaken" into the tank. These bags can then be disposed of in the trash or taken to a permitted landfill. Some landfills have local ordinances against disposing pesticide containers even if they are properly rinsed or cleaned, so check your local situation.

Disposal of excess pesticide tank mix material and water used for cleaning spray equipment is a very difficult problem. Presently, the only thing anyone will agree on is to apply excess tank mix and/or water used for cleaning spray equipment to sites that are listed on the pesticide label. This would include the sites just sprayed or similar areas.

Environmental Factors Affecting Pesticide Effectiveness

Many factors determine the effectiveness of a pesticide program. Using the right pesticide and applying it correctly are the most important factors that determine the final outcome. However, there are some environmental factors that can have a negative or positive effect on pesticides. Environmental factors that affect pesticides can be divided into three (3) groups: climatic, plant and soil factors.

Climatic Factors

Temperature affects the amount of time required for a pesticide to do its job. For example, when air temperatures are between 65°F to 85°F, a plant is rapidly growing and herbicides will be more effective. Long periods of cold or hot temperatures will slow down herbicide activity.

High humidity allows foliar-applied pesticides to enter a plant quicker than at low humidity. During a period of high humidity and moderate temperature is the optimum time to spray a pesticide that must be taken up by plant foliage.

Precipitation soon after a pesticide application may help or hurt the final results. A moderate (1 inch or less) rain just after a soil-applied preemergence herbicide or soil insecticide will move the product down into the soil where it is needed. A rain shortly after an application of a foliar-applied herbicide or systemic fungicide will drastically reduce the level of control. Any pesticide that needs to be taken up through the turf foliage should not be applied if there is a good chance of rain within a few hours. The decision not to spray because of the possibility of rain must be made by the applicator.

Wind is definitely the most important climatic factor. Excessive wind does not have a direct effect on pesticide effectiveness; however, indirectly it is a major problem. Excessive wind (greater than 10 mph) distorts spray patterns and hinders the application of the pesticide. Using a drift control additive will help, but knowing when not to spray because of excessive winds is more important. Applying pesticides in the early morning or late evening hours may help avoid the more windy parts of the day.

Plant Factors

For several pesticides, it may be necessary for them to enter the plant through the leaf surface (foliar-applied). The cuticle and wax on the surface of a leaf is a barrier the pesticide must cross before it can enter the leaf. Older plants or plants under stress will tend to have thickened, waxy layers making the leaves harder to penetrate. It may be necessary to use a crop oil if you are making late season applications. Also, on the leaf surface of certain plants there may be an abundance of leaf hairs. Spray droplets tend to stand up on the hairs and do not contact the leaf surface. The addition of a surfactant to the spray mix would help the spray droplet penetrate the hairs and allow the pesticide to come in contact with the leaf surface.

An important plant factor that influences herbicides is the growth pattern and growth stage of the plant. Each year weeds complete four stages of growth: (1) seedling, (2) vegetative, (3) seed production, and (4) maturity. Annual and biennial plants are easiest to control at the seedling stage, but perennial plants can be more effectively controlled during their vegetative stage. Treating perennial plants at this stage allows for better control of the underground parts of the plant.

Location of growing points on a plant can affect their level of control. Applying an herbicide directly to the growing point will generally increase the effectiveness of the herbicide. A grassy weed has its growing point(s) below the soil surface that makes it difficult to apply an herbicide directly to the growing point. A broadleaf weed has an exposed growing point at the top of the plant and along leaf axils. Herbicides can be applied directly to growing points on broadleaf plants.

Soil Factors

The texture and organic matter content of a soil has a definite effect on soil-applied pesticides. Soil texture depends on the percent of sand, silt and clay. Soils high in clay content will tie up or adsorb soil pesticide particles, making them unavailable for effective pest control. Higher pesticide rates may be recommended on fine-textured clay soils. Sandy or silty soils do not adsorb very much of the pesticides, making them more available for pest control. Lower rates of soil-applied pesticide can be used on coarse-textured sandy soils without sacrificing pest control (check the label for range of rates). Arkansas has a wide variety of soil textures which range from very fine-textured clay soils to very coarse textured sandy soils. Erratic pest control from a successful application of a soil-applied pesticide could very likely be attributed to the texture of the soil.

Soil organic matter content also has a dramatic effect on soil-applied pesticides, especially on organic products. Soils with 2 percent organic matter content or greater will require higher pesticide rates for successful pest control (check label for range of rates). High organic matter soils have a greater potential to tie up pesticides than any other soil factor. Most Arkansas soils have less than 3 percent organic matter.

Another factor that can affect a soil-applied pesticide is the pH of the soil. Some pesticides will be less effective in soils with a low pH (less than 6.0), while others are relatively unaffected by soil pH.

Pesticides can also be affected by the pH of the water that is used for mixing. Few Arkansas water sources contain what is termed "hard water." Hard water has an overabundance of calcium, magnesium and many other elements which increase the pH of the water. Mixing certain pesticides with water that has a high pH (8.0 or higher) can reduce their effectiveness. If applications of a pesticide have been producing erratic results in the past, it would be worth the time to check the pH of the water source. Since pH levels of any given water source fluctuate during the year, a pH reading should be taken as near to application time (month of application) as possible. If the water source has a pH level of 8.0 or higher, then a buffer should be added to each tank of water to lower the pH.

Application Equipment

Liquid Application

Most common pesticides are applied in a liquid form. They may be distributed as a liquid or powder, but are mixed with water, oil or some other liquid carrier for application. Some fertilizers also are applied as liquids, so liquid application equipment has long been the standard for pesticide and fertilizer application. This equipment generally consists of several different types of boom and boomless (or broadcast) sprayers, which have unique characteristics.

Boom Sprayers

Boom sprayers are sprayers which have nozzles arranged along a boom for uniform distribution of material. They vary in size, depending on the type of use. Some agricultural sprayers may have boom widths of 60 feet to 80 feet, while hand-held or push type booms may be only 1 foot to 4 feet wide. When properly adjusted and calibrated, each type of sprayer can provide uniform coverage.

Turfgrass managers typically use boom sprayers on flat surfaces, such as fairways and greens. Large open areas, such as practice areas or wide fairways, can be sprayed with wide booms with little problem, but wide booms are difficult to maneuver in tight areas. If terrain is uneven, a shorter boom width is recommended for the best distribution.

Boomless Sprayers

Boomless or broadcast sprayers are essentially the same as boom sprayers, except a single jet or multiple jet cluster nozzle replaces the boom. Boomless nozzles can be used to spray widths up to 40 feet. However, spraying wide swaths from a single nozzle makes uniform coverage difficult to obtain. Boomless sprayers are also extremely susceptible to drift, especially when operating at pressures over 40 psi. Boomless sprayers are not recommended for use on fairways and other areas where uniform coverage is needed. They are best suited for areas where boom sprayers are difficult to use, such as rough terrain, areas with many trees, fencerows and roadsides.

Spray guns, whether operated from manual (backpack) or powered sprayers, are another type of boomless sprayer. They are primarily used for ornamental plants and are not recommended for use on turf grass except for spraying areas less than 10 or 20 square feet. Operators should use boom sprayers with conventional nozzles whenever possible. Spray guns should only be used around shrubs, trees and areas where it is not feasible to use hand-held or push type booms. Spray gun operators should strive for uniform coverage.

Nozzle Types

Nozzle selection is one of the most important decisions relating to pesticide application. Nozzle type determines not only the amount of spray applied to a particular area but also the uniformity of the applied spray, the coverage obtained on the sprayed surfaces and the amount of drift that can occur. Each nozzle type has specific characteristics and capabilities and is designed for use under certain application conditions. Regular flat-fan, flooding flat-fan and boomless nozzle types are commonly used for ground application of turf chemicals.

Regular flat-fan nozzles are used for most broadcast spraying of herbicides and for certain insecticides when foliar penetration and coverage are not required. These nozzles produce a flat oval spray pattern with tapered edges. They are available in various standard spray fan angles and are usually spaced 20 inches apart on the boom at a height range of 10 to 23 inches.

Recommended boom heights for standard spray angles are:

Spray Angle (degrees)	Boom Height for 20 Inch Spacing (inches)
65	21-23
73	20-22
80	17-19
110	10-12

The normal recommended operating pressure range for regular flat-fan nozzles is 15 psi to 30 psi. In this range, this nozzle type will produce medium to course drops that are less susceptible to drift than finer drops produced at pressures of 40 psi or greater. Regular flat-fan nozzles **(Figure 2.7.1)** are also recommended for some foliar-applied herbicides and fungicides at pressures of 40 psi to 60 psi. These high pressures will generate finer drops for maximum coverage on the plant surface, but the possibility of drift increases significantly, so appropriate precautions must be taken to minimize its effects.

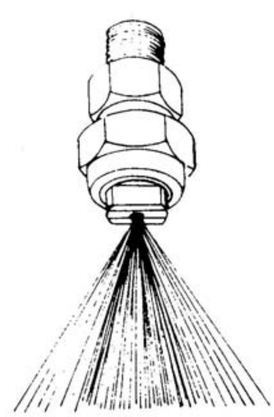


Figure 2.7.1. Regular flat fan.

Because the outer edges of the spray patterns of these nozzles have tapered or reduced volumes, nozzles must be carefully aligned and at the proper height so adjacent patterns along the boom will overlap to obtain uniform coverage **(Figure 2.7.2)**. The most effective pattern is achieved when this overlap is 30 percent to 50 percent of the nozzle spacing. Because of their ability to produce a very uniform pattern when correctly overlapped, the regular flat-fan nozzle is generally the best choice for the broadcast application of herbicides.

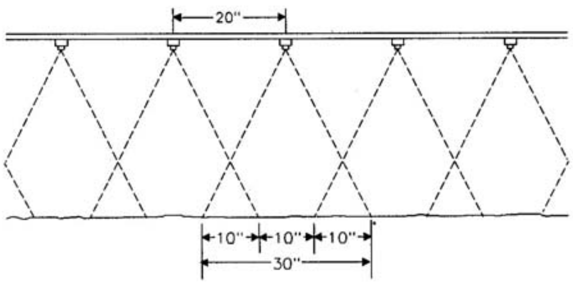


Figure 2.7.2. Fifty percent overlap.

LP or "low-pressure" flat-fan nozzles are available from the Spraying Systems Company. This nozzle develops a normal fan angle and distribution pattern at spray pressures from 10 psi to 25 psi. Operating at a lower pressure results in larger drops and less drift than the regular flat-fan nozzle designed to operate at pressures of 15 psi to 30 psi.

Flooding flat-fan nozzles produce a wide-angle, flat-fan pattern and are commonly used for applying herbicides and mixtures of herbicides and liquid fertilizers **(Figure 2.7.3)**. The nozzle spacing on the boom for applying herbicides and fertilizers is generally 40 inches. These nozzles should be operated within a pressure range of 8 psi to 25 psi for maximum effectiveness and drift control. Changes in pressure will affect the width of the spray pattern more with this type of nozzle than with regular flat-fan nozzles. Also, the distribution pattern is usually not as uniform as that of a regular flat-fan tip. The most effective pattern is achieved when the nozzle is mounted at a height and angle to obtain at least double coverage or 100 percent overlap **(Figure 2.7.4)**.

Flooding nozzles can be mounted so that they spray straight down, straight back or at any angle in between. However, the most uniform coverage is obtained when the nozzle is oriented to spray at about 45 percent above the horizontal.

The flooding flat-fan nozzle is the best choice for applying a liquid fertilizer or a liquid fertilizer-herbicide mixture. Due to large droplet size, they are effective when applying straight herbicides in situations where drift is a problem. However, they do not produce as uniform a pattern as regular flat-fan nozzles. Regular flat-fan nozzles operated at low pressures (10 to 15 psi) should be used when drift is a problem and precise uniform coverage is required.

Nozzle Material

Nozzle tips are available in a wide variety of materials, including ceramic, hardened stainless steel, stainless steel, nylon and brass, Ceramic and hardened stainless steel are the most wear-resistant materials, but are also the most expensive. Both stainless steel and ceramic tips have excellent wear resistance with either corrosive or abrasive materials. Ceramic tips are more susceptible to breakage and are used less than stainless steel tips. Ceramic and stainless steel tips wear uniformly so gradual pressure reduction during calibration will allow extended nozzle life.

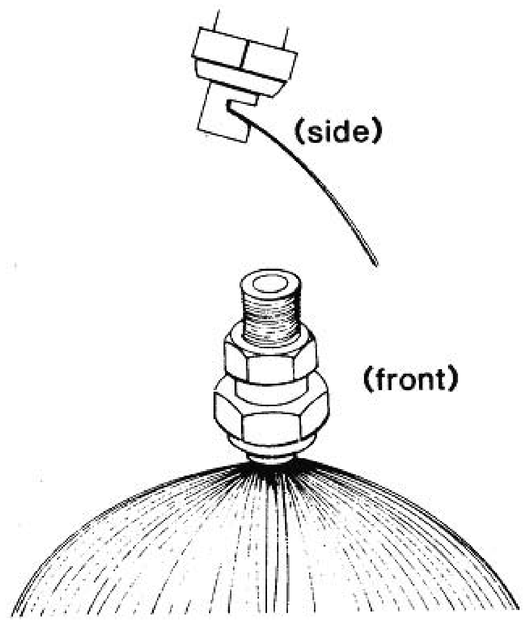


Figure 2.7.3. Flooding flat fan.

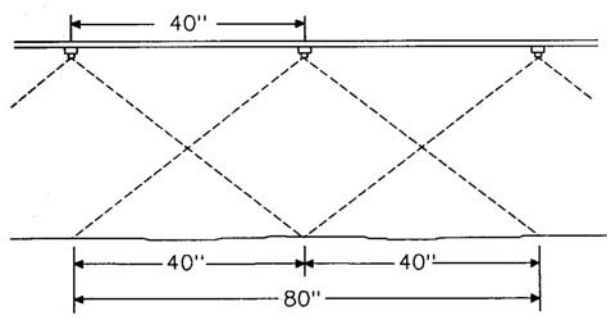


Figure 2.7.4. 100 percent overlap.

Nylon tips are also very resistance to corrosion and abrasion. They are, however, subject to swelling when exposed to some solvents. Brass tips are the most common but wear rapidly and less uniformly due to variations in material hardness when used with abrasive materials such as wettable powders; they also corrode easily with some liquid fertilizers. As brass nozzles wear or corrode, the orifice size changes, making calibration tables for these nozzles inaccurate. Each nozzle will wear or corrode at different rates, making it difficult to maintain boom spray uniformity or calibration. Wear and corrosion may also alter the spray pattern of nozzles. Brass tips are only economic when used on sprayers with very low annual use. For sprayers that have more extensive use, stainless steel or nylon tips are a better choice because of their longer wear life and uniformity of wear.

Calibration

Calibration is the process of adjusting spray equipment to uniformly apply the desired rate of chemical. The performance of any chemical depends upon the proper application of the correct amount on a given area. Most chemical performance complaints can usually be traced to errors in mixing or applying the chemical. The purpose of calibration is to ensure that the sprayer is applying the chemical uniformly and at the correct rate.

Variables Affecting Application Rate – Three variables affect the amount of chemical mixture applied per acre:

1. The nozzle flow rate
2. The ground speed of the sprayer
3. The effective sprayed width per nozzle

To calibrate a sprayer accurately, the effect of each of these variables on sprayer output must be understood and controlled.

Nozzle Flow Rate – The flow rate through the nozzle varies with orifice tip size and nozzle pressure. Installing nozzles with a larger or smaller orifice size is the most effective way to change the sprayer's output if major volume changes are required.

Changes in nozzle pressure should be used for minor increases or decreases of sprayer output, since pressure changes have significantly less effect than nozzle changes. It takes a fourfold increase in pressure to double nozzle flow rate. For example, to increase nozzle flow rate from 25 GPM at 20 psi to 0.50 GPM, pressure would have to be increased to 80 psi (4 x 20). Decreasing nozzle pressure can be used effectively to maintain an application rate due to nozzle wear. It should never be used to make major changes. Most nozzles work best at pressures between 20 psi to 40 psi. Lower pressures may distort the spray pattern, while higher pressures increase spray drift.

Ground Speed – The spray application rate varies inversely with the ground speed. Doubling the ground speed of a sprayer reduces the gallons of spray applied per acre (GPA) by one-half. For example, a sprayer applying 20 GPA at 3 mph would apply only 10 GPA at a speed of 6 mph if all other factors remained the same. A sprayer calibrated at 4 mph, but actually operated at 3 mph, will overspray by 33 percent and significantly increase chemical costs and the potential for turf damage.

Sprayed Width Per Nozzle – The effective width sprayed per nozzle also affects the spray application rate. Doubling the effective sprayed width per nozzle will decrease the gallons per acre (GPA) applied by one-half. For example, if the nozzle is applying 40 GPA on a 20-inch spacing, a change to a 40-inch spacing will decrease the application rate to 20 GPA.

Precalibration Checks

Before calibrating a sprayer, service the entire unit, check for uniform nozzle output and pattern, and determine exactly how much liquid your sprayer tank holds.

Servicing – Clean all lines and strainers, making sure the strainers are in good condition and are the correct size for the type of chemical formulation that is to be applied. Inspect all hoses for signs of aging, damage or leaks and hose clamps for corrosion and adjustment. Check the pressure gauge to determine if it is working properly (is the pressure holding constant and does it read zero when the pump is shut off?). The actual accuracy of the gauge is not as important as its ability to give the same pressure reading each time it is produced, At least once a year, preferably at the beginning of the spraying season, check the gauge against another gauge that is known to be accurate. Also, boom pressure will be lower than remote-mounted gauge pressure. To determine pressure loss, operate the sprayer at a known pressure, then install a gauge on one of the nozzle outlets on the boom and record the lower pressure. Check nozzle pressure at several operating pressures to develop a nozzle pressure table.

Nozzle Output and Pattern – Check for uniformity of nozzle output and for consistency of spray angles, spacing and height. To check for uniform nozzle output, install the selected nozzle tips, partially fill the spray tank with clean water and operate the sprayer at a pressure within the recommended range. Place a container (for example, a quart jar) under each nozzle and check to see whether all the jars fill in about the same time. Inexpensive calibration flow meters are available for direct readings of individual nozzle flow rates as a method to quickly check nozzle calibration. Replace any nozzle tips that have an output that varies more than 5 percent from the output of the rest of the tips or has an obviously different fan angle or distorted spray pattern. An effective way to determine whether a uniform pattern is being produced and whether the boom is at the proper height is to spray some water on a warm, dry surface, like a paved road or gravel drive, and observe the drying pattern. If the pattern is not uniform, some strips or areas will dry slower than others.

Tank Capacity – Knowing the exact capacity of your sprayer's tank is necessary for accurate mixing of chemicals in the tank. The use of an inaccurate tank capacity when determining application rates is a common cause of under and over application. A tank thought to hold 200 gallons but which actually holds 250 gallons results in a built-in calibration error of 25 percent.

The best and easiest way to accurately determine tank capacity is to fill the tank using any convenient container for which an exact capacity is known. If container capacity is unknown, it can be determined by filling the container with water and then checking its weight (water weighs 8.33 pounds per gallon). Another effective way of measuring tank capacity is with an accurate flow meter. Flow meters should be checked for accuracy by weighing sample volumes taken over a given amount of time.

Measuring Ground Speed

To apply chemicals accurately, ground speed must be constant. Field conditions such as surface roughness, softness and slopes will all affect ground speed and significantly change application rates. Speedometers and tachometers are generally not a good means of determining ground speed as wheel slippage can result in speedometer reading errors of 25 percent or more. Changes in tire size can also affect speedometer readings. The most accurate way to maintain a constant ground speed is with a special sprayer speedometer that is run off a nondriven ground wheel. These speedometers are available from a number of spray equipment manufacturers and are a good investment if a considerable amount of spraying is done. Some sprayer monitors have the ability to accurately measure ground speed.

If an accurate speedometer is not available, the next best method to establish a calibrated ground speed is to measure the speed of the sprayer at a variety of throttle and gear settings in an area that has surface conditions like those of the turf to be sprayed. To measure ground speed, stake out a known distance in the turf. Suggested distances are 100 feet for speeds up to 5 mph, 200 feet for speeds from 5 mph to 10 mph and at least 300 feet for speeds above 10 mph. At the throttle setting and gear to be used during spraying, determine the travel time between the measured stakes in each direction. To ensure the greatest accuracy, the sprayer should be at least half full of liquid. Average the two speeds and use the following equation to determine the ground speed.

$$\text{Speed (mph)} = d/t \times 0.682$$

"d" is the distance between the two stakes, in feet.
"t" is average time it took to drive between the stakes, in seconds.
The number, 0.682, converts feet per second into mph.

Determining Sprayer Output

There are a number of ways to determine sprayer output. One of the easiest and most effective methods is the nozzle output method. The advantage of this method is that it is done with the sprayer stationary. In order to use this method, three pieces of information must be known:

Operating Pressure – This will generally be in the 20 psi to 40 psi range depending on the type of nozzle used.

Ground Speed – This speed will normally be in the 3 mph to 8 mph range depending upon conditions of the area to be sprayed.

Sprayed Width Per Nozzle – Varies with the type of nozzle arrangement used but effectively is the spacing between nozzles on the boom.

To calibrate a sprayer using this method, follow these steps.

Step 1. Fill the sprayer partially with water and operate it at the correct pressure. Use a container marked in ounces to collect the output of a nozzle for 1 minute or some convenient fraction of a minute. Check all nozzles to determine the average number of ounces per minute (OPM) of output for each nozzle and for wear uniformity comparisons (very important for brass nozzles spraying wettable powders).

Step 2. Convert the OPM determined in step 1 to gallons per minute (GPM) by dividing the OPM by 128 (the number of ounces in 1 gallon).

Step 3. Select the ground speed (mph) at which the sprayer will operate, normally 3 mph to 8 mph.

Step 4. Determine the sprayed width per nozzle (W), in inches. For broadcast spraying, "W" will equal the distance between nozzles.

Step 5. Once these values are known, the sprayer's output in gallons per acre (GPA) can be calculated using the following equation:

$$GPA = \frac{GPM \times 5{,}940}{MPH \times W}$$

"GPA" is the sprayer's output in gallons per acre.
"GPM" is the nozzle output determined in Step 2.
"5,940" is a constant used to convert inches, gallons per minute and miles per hour to gallons per acre.
"MPH" is the ground speed selected in Step 3.
"W" is the sprayed width in inches per nozzle that was determined in Step 4.

Example: A sprayer is set up to broadcast spray an herbicide with regular flat fan nozzles spaced 20 inches on center. A ground speed of 5 mph has been selected. The average collected nozzle output is 54 OPM.

What is the application rate in gallons per acre?

$$GPM = \frac{54}{128} = 0.42 \qquad \text{(Step 2)}$$

$$GPA = \frac{0.42 \times 5{,}940}{5 \times 20} = 24.94 \qquad \text{(Step 5)}$$

Under this set of conditions, the sprayer will apply approximately 25 gallons per acre. If this is not the application rate desired, then one or more conditions will need to be changed. If only a small change is needed, this can generally be accomplished by either raising or lowering the pressure. Remember to stay within the pressure limitations of the nozzle being used. If a larger change is required, change ground speed or switch to larger or smaller nozzle tips.

Calibration Jars

Calibration jars are available which further simplify the calibration process. These jars require that the following basic information be known or measured: pressure, ground speed, nozzle output and effective spray width per nozzle. They do, however, eliminate calculations involved by use of graduated charts on the calibration jars. Calibration jars are available from a number of sources and are effective when used according to the instructions that accompany them.

Determining How Much Chemical To Put In Tank

To determine the amount of pesticide to add to the spray tank, the following must be known:

1. Recommended application rate of pesticide, from product label
2. Sprayer tank capacity
3. Calibrated sprayer output

A key concern here is to know the exact tank capacity. The recommended application rate of the pesticide is given on the label. The rate is usually indicated as pounds of total product per acre for wettable powders, and pints, quarts or gallons per acre for liquids. Sometimes the recommendation is given as pounds of active ingredient (lbs. a.i.) per acre rather than the amount of total product per acre. The active ingredient must be converted to actual product.

Dry Formulation

Example: A pesticide recommendation calls for 2 pounds of active ingredient (a.i.) per acre. An 80 percent wettable powder has been purchased. The sprayer has a 200-gallon tank and is calibrated to apply 40 gallons per acre. How much pesticide should be added to the spray tank?

Step 1. Determine the number of acres that can be sprayed with each tank full. The sprayer has a 200-gallon tank and is calibrated to apply 40 gallons per acre (200/40 = 5 acres per tank).

Step 2. Determine the pounds of pesticide product needed per acre. Because not all of the product in the bag is an active ingredient, more than 2 pounds of the total product must be added for each "acre's worth" of water in the tank. To determine how much more, divide the amount of active ingredient needed per acre (2 pounds) by the percent of active ingredients in the product (80%, which equals 0.80).

Two and one-half (2.5) pounds of product (2 pounds a.i./0.80 = 2.5 pounds) will be needed for each "acre's worth" of water in the tank to apply 2 pounds of active ingredient per acre.

Step 3. Determine the amount of pesticide to add to each tank full. With each tank full, 5 acres will be sprayed (Step 1), and 2.5 pounds of product per acre are required (Step 2); therefore, 12.5 pounds (5 acres x 2.5 pounds/acre = 12.5 pounds) of product will need to be added to each tank full to obtain the desired application rate.

Liquid Formulation

Example: A pesticide recommendation calls for 1 pound of active ingredient (a.i.) per acre. A pesticide that has 4 pounds of active ingredient per gallon has been purchased. The sprayer has a 150-gallon tank and is calibrated at 30 gallons per acre. How much pesticide should be added to the spray tank?

Step 1. Determine the number of acres that can be sprayed with each tank full. The sprayer has a 150-gallon tank and is calibrated for 30 gallons per acre (150/30 = 5 acres per tank).

Step 2. Determine the amount of product needed per acre by dividing the recommended a.i. per acre by the concentration of the formulation. To apply 1 pound of active ingredient (a.i.) per acre, one-fourth gallon or 1 quart of product is needed for each "acre's worth" of water in the tank (1 lb./acre x 4 lbs./gallon = 0.25 gallons/acre).

Step 3. Determine the amount of pesticide to add to each tank full. With each tank full, 5 acres will be sprayed (Step 1), and 0.25 gallon (1 quart) of product per acre is required (Step 2). Add 5 quarts (5 acres x 1 quart per acre = 5 quarts) of pesticide to each tank full.

Granular Application

Granular application equipment is traditionally used to apply fertilizers, but many pesticides are now available in granular form. Application equipment for granular pesticides is somewhat different than that for fertilizers because the volume of material applied is usually considerably less and uniform distribution is very important.

Equipment

Granular application equipment consists of drop, rotary and air spreaders. All of these consist of a hopper and some type of metering device. Granules are metered through orifices in the bottom of drop spreaders and fall directly to the ground. Since granules drop straight down, there is little chance for drift, and distribution is more uniform. Drop spreaders usually have narrow widths and are not recommended for large areas. Also, since particles fall straight down, the edge of the pattern is well defined, and small steering errors will cause areas to be missed or doubled.

Rotary or centrifugal spreaders are the most common granular applicators. They are available in hand-powered or tractor-powered models. With this type of spreader, granules are metered through an orifice onto a rotating disk. Granules are deflected off of the disk into an approximate half circle pattern. Because granules are thrown away from the spreader, wider swaths can be attained and large areas can be covered quickly. The pattern is feathered on the edges, so steering errors are less critical.

Air spreaders are popular in the agricultural market but are just now beginning to receive attention from turfgrass managers **(Figure 2.7.5)**. Air spreaders meter granules through an orifice, or with a fluted roller, into a venturi cup where they are suspended in an airstream and travel through hoses to deflectors mounted on a boom. At the deflectors, the granules are distributed in a pattern similar to that of a flat fan nozzle. When properly calibrated, air spreaders can uniformly distribute materials over a wide range of application rates.

Figure 2.7.5. Example of air spreader.

Calibration

Chemical producers may provide information for settings on granular applicators, but these should be used only as a starting point. Manufacturers are as precise as possible with calibration guidelines, but there are several variables that must be measured for accurate calibration. Variables affecting granular application rates are ground speed, swath width and orifice size. Ground speed will vary on hand pushed spreaders based on operator walking differences, so operators should calibrate spreaders. Swath width depends on the type of spreader, and uniform application of the pesticide is dependent on the operator's ability to maintain constant spacing between swaths. Orifice size is adjusted to distribute a certain amount of pesticide for a given speed and swath width. It cannot be accurately set if the operator does not maintain a nearly constant ground speed and swath width. Since different granules have different flow characteristics, granular applicators must be calibrated for each particular material.

One method for spreader calibration is to apply a known weight of material on a measured area (1,000 square feet for drop or 5,000 square feet for rotary) that is away from fairways or greens, then weigh the remaining material to determine exactly how much was applied. For safety reasons, this method is not recommended, because pesticide may be over applied to an area, causing contamination. A better calibration method is to lift the drive wheel of the spreader and spin it at the proper ground speed (approximately 3 mph) while letting the granules fall on the floor or into a catch pan. This method works well for drop spreaders. The best method is to hang a catch pan under the spreader, push it a known distance, and then weigh the material.

Rotary spreaders may be calibrated by lining up a row of shallow boxes or pans perpendicular to the line of motion **(Figure 2.7.6)**. The row should cover 1.5 to 2 times the expected swath width. Put material to be spread in the hopper and make three passes over the boxes operating in the same direction on every pass. The material in each box can be weighed to plot the pattern of the spreader. The effective swath width is determined by the following steps:

Step 1. Average three to five center boxes.

Step 2. Find the point on each side away from the center where the quantity in a box is half of the average found in step 1.

Step 3. Measure the distance from the center of these two boxes for the effective swath width.

If the two boxes used to determine effective swath width do not contain approximately the same amount of material, the pattern is not symmetric and the spreader is performing unsatisfactorily.

Operation

Where possible, flags can be used to mark the effective swath width to help the operator achieve uniform coverage. If markers cannot be used, operators should focus on an object past the point where they will stop spreading to help make a straight pass.

When operating a spreader with an unacceptable pattern, the operator should reduce the application rate by half and go over the area twice. For best coverage the second passes should be perpendicular from the first passes. Small spreaders were designed to be pushed; unacceptable patterns occur when they are pulled. If conditions exist where the spreader is easier to pull than push, the spreader must be calibrated moving backwards.

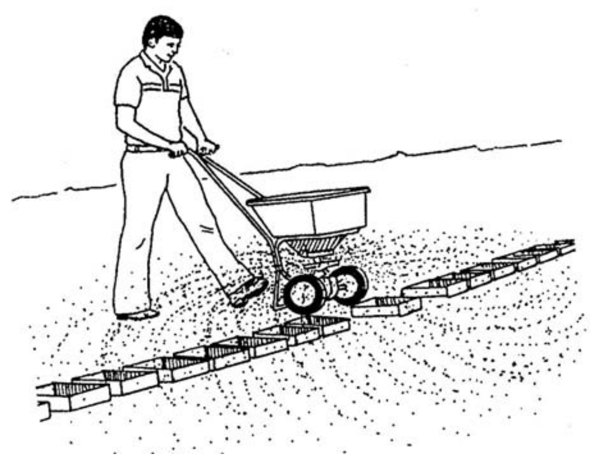


Figure 2.7.6. To make a quick pattern check, lay out a row of shallow cardboard boxes in a line perpendicular to the direction of travel.

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Turfgrass Glossary

Abdomen: The third or most posterior of the three major body divisions of an insect.

Absorption: The process by which an herbicide passes from one system into another, e.g., from the soil solution into a plant root cell or from the leaf surface into the leaf cells.

Acid equivalent (ae): The theoretical yield of parent acid from a pesticide active ingredient, which has been formulated as a derivative. For example, Roundup Pro contains 4 pounds per gallon of the isopropylamine salt form of glyphosate but 3 pounds per gallon of the parent acid.

Acid soil: Soil with a pH value less than 7.0.

Activation: The process by which a surface applied herbicide is moved into the soil where it can be absorbed by emerging seedlings. This is normally accomplished by rainfall, irrigation, or tillage. Activation does not imply any chemical change in the active ingredient.

Active ingredient (ai): The chemical in an herbicide formulation primarily responsible for its phytotoxicity and which is identified as the active ingredient on the product label.

Adjuvant: Any substance in an herbicide formulation or added to the spray tank to modify herbicidal activity or application characteristics.

Adsorption: The process by which an herbicide associates with a surface, e.g., a soil colloidal surface.

Aestivate: To spend the summer in a dormant condition; opposed to hibernate.

Alate: Winged.

Alkaline soil: Soil with a pH greater than 7.0.

Allelopathy: The adverse effect on the growth of plants or microorganisms caused by the action of chemicals produced by other living or decaying plants.

Antagonism: An interaction of two or more chemicals such that the effect when combined is less than the predicted effect based on the activity of each chemical applied separately.

Antennae: In larval and adult stages of an insect, paired segmented appendages, on each side of the head, functioning as sense organs.

Anterior: Toward the front (head), as opposed to posterior.

Antibiosis: Plant characteristics that affect insects in a negative manner (such as increased mortality or reduced fecundity); a type of plant resistance to insects.

Apical: At, near, or pertaining to the tip or apex.

Apices: At or near the apex or “top” of a structure.

Arthropods: Invertebrate animals with jointed appendages; members of the phylum Arthropoda.

Band treatment: Applied to a linear restricted strip on or along crop rows rather than continuous over the field area.

Beneficial: A useful insect, often one that is a predator or parasitoid of a harmful insect.

Bioassay: Quantitative or qualitative determination of herbicide by use of sensitive indicator plants or other biological organisms.

Biological control of weeds: Control or suppression of weeds by the action of one or more organisms, through natural means, or by manipulation of the weed, organism, or environment.

Biological control: Using any biological agent (often an insect) to control a pest.

Biotype: A population within a species that has a distinct genetic variation.

Bivoltine: Two generations per year.

Boot or Booting: A growth stage of grasses (including cereal crops) when the upper leaf sheath swells due to the growth of the developing spike or panicle.

Brachypterous: Having short wings not covering the abdomen.

Broadcast treatment: Applied as a continuous sheet over the entire field.

Broods: A group or cohort of offspring produced by a parent or parent population at different times or in different places.

Callow adult: A recently molted, soft-bodied, pale adult.

Carrier: A gas, liquid, or solid substance used to dilute or suspend an herbicide during its application.

Caterpillar: The larva of a moth, butterfly, skipper, or sawfly.

Cephalothorax: The combined head and thorax of spiders and other arachnids.

Cerci: A pair of appendages at the tip of the abdomen.

Chemical name: The systematic name of a chemical compound according to the rules of nomenclature of the International Union of Pure and Applied Chemistry (IUPAC), Chemical Abstracts Service, or other organization.

Chitin: A colorless, nitrogenous polysaccharide secreted by the epidermis and applied to the hardened parts of an insect body.

Chlorophyll: The green, light-sensitive pigment of plants that in sunlight is capable of combining carbon dioxide and water to make carbohydrates.

Chlorosis: Yellowing of normally green tissue due to chlorophyll destruction or failure of chlorophyll formation.

Chlorotic: Having a fading of green color in plant leaves to light green or yellow.

Chorion: The outer covering of an insect egg.

Cocoon: The silken or fibrous case spun by a larva for protection during its pupal period.

Common name: A generic name for a chemical compound. Glyphosate is the common name for Roundup.

Compatibility: The characteristic of a substance, especially a pesticide, of being mixable in a formulation or in the spray tank for application in the same carrier without undesirably altering the characteristics or effects of the individual components.

Competition: The active acquisition of limited resources by an organism, which results in a reduced supply and consequently reduced growth of other organisms in a common environment.

Concentration: For herbicides, the quantity of active ingredient or parent compound equivalent expressed as weight per unit volume (such as pounds per gallon for liquids). Dry herbicide concentrations are expressed as percent by weight.

Contact herbicide: An herbicide that causes injury to only the plant tissue to which it is applied, or an herbicide that is not appreciably translocated within plants.

Cool-season grass: A cold-tolerant grass with an optimum temperature range of 60-75ºF. (15.5-to 24ºC).

Costal margin: The front edge of a wing.

Crochets: Hooked spines on the underside of prolegs of caterpillars.

Culm: The stem of a grass plant.

Cultivar: Cultivated variety.

Cultural control: Manipulation of a crop environment to reduce pest increase and damage.

Cuticle: The outer covering of an insect formed by a layer of chitin.

Cyst: A sac or vesicle.

Degree-day: An accumulation of degrees above some threshold temperature for a 24-hour measure of physiological time for cold-blooded organisms, like insects. Degree-days can be expressed in Fahrenheit (FDD) or Celsius (CDD).

Developmental threshold: The minimum temperature required for development.

Diapause: Physiological state of arrested metabolism, growth, and development that may occur at any stage in the life cycle.

Dicot: Abbreviated term for dicotyledon; preferred in scientific literature over broadleaf to describe plants.

Dicotyledon (dicot): A member of the Dicotyledoneae; one of two classes of angiosperms usually characterized by the having two seed leaves (cotyledons), leaves with net venation and root systems with tap roots.

Diluent: Any gas, liquid, or solid material used to reduce the concentration of an active ingredient in a formulation.

Directed application: Precise application to a specific area or plant organ such as to a row or bed or to the leaves or stems of plants.

Dispersible granule: A dry granular formulation that will separate or disperse to form a suspension when added to water.

Dormancy: The state of inhibited seed germination or growth of a plant organ when in an environment normally conducive to growth.

Dormant: A state of reduced physiological activity.

Dorsum: The upper surface, or back.

Eclosion: Emergence of the adult insect from the pupa; act of hatching from the egg.

Economic injury level (EIL): The number of insects (amount of injury) that will cause losses equal to insect management cost.

Economic threshold (ET): The pest density at which management action should be taken to prevent an increasing pest population from reaching the economic injury level.

Ecosystem: A living community and its nonliving environment.

Ecotype: A population within a species that has developed a distinct morphological or physiological characteristic (e.g., herbicide resistance) in response to a specific environment and that persists when individuals are moved to a different environment.

Elytra (sing., elytron): The two thickened, hardened forewings of beetles.

Emergence: The event in seedling establishment when a shoot becomes visible by pushing through the soil surface.

Emulsifiable concentrate (EC): A single-phase liquid formulation that forms an emulsion when added to water.

Encapsulated formulation: Herbicide enclosed in capsule or beads of material to control the rate of release of active ingredient and thereby extend the period of activity.

Endoparasite: Parasitic organism living inside its host.

Entomophagous: Insect-eating.

Epinasty: That state in which more rapid growth on the upper part of a plant organ or part (especially leaf) causes it to bend downward.

Exoskeleton: The outside skeleton of insects.

Femur (pl., femora): The thigh; in insects, usually the largest segment of the leg articulated at the proximal end nearest the body to the trochanter and distally to the tibia.

Flowable: A two-phase formulation containing solid herbicide suspended in liquid and that forms a suspension when added to water.

Formulation: (1) A pesticide preparation supplied by a manufacturer for practical use. (2) The process, carried out by manufacturers, of preparing pesticides for practical use.

Frass: Solid larval excrement.

Generation: A group of offspring of the same species that develop in approximately the same time frame.

Granular: A dry formulation consisting of discrete particles generally $<10\ mm^3$ and designed to be applied without a liquid carrier.

Gregarious: Occurring in aggregations.

Grub: An insect larva; a term usually with specific reference to larvae of Coleoptera and Hymenoptera.

Head capsule: The combined sclerites of the head, forming a hard, compact case.

Head or heading: A growth stage of grasses (including cereal crops) when the spike or panicle is emerging or has emerged from the sheath.

Hemimetabolous: Simple, incomplete metamorphosis where larval stages (nymphs) are often similar to adults in appearance and feeding behavior.

Herbaceous plant: A vascular plant that does not develop persistent woody tissue above ground.

Herbicide resistance: The trait or quality of a population of plants within a species or plant cells in tissue culture of having a tolerance for a particular herbicide that is substantially greater than the average for the species and that has developed because of selection for naturally occurring tolerance by exposure to the herbicide through several reproductive cycles.

Herbicide: A chemical substance or cultured biological organism used to kill or suppress the growth of plants.

Hibernate: To pass the winter in a dormant state.

Hindgut: The posterior region of the digestive tract, between the midgut and anus.

Holometabolous: Having a complete transformation, with egg, larval, pupal, and adult stages distinctly separated.

Incorporate: To mix or blend an herbicide into the soil.

Indigenous: Native to an area.

Insectivorous: Feeding on insects.

Instar: The stage between molts or shedding of the exoskeleton.

Integrated pest management (IPM): A system of economically and environmentally sound practices to reduce the deleterious impact of pest activities; frequently, associated with the use of multiple management tactics (e.g., pesticides, cultural control, host plant resistance, and biological control).

Interference: For plants, the total adverse effect that plants exert on each other when growing in a common ecosystem. The term includes competition, allelopathy, biotic interference, and other detrimental modifications in the community or environment.

Label: The directions for using a pesticide approved as a result of the registration process.

Larva: A young insect; an immature form called a caterpillar, slug, maggot, or grub, depending on the kind of insect.

Lateral movement: Movement of an herbicide through soil, generally in a horizontal plane, from the original site of application.

Leaching: (1) The removal of materials in solution from the soil. (2) The downward movement of material(s) into a soil profile with soil water (material may or may not be in true solution and may or may not move from soil).

Life cycle: The period between egg deposition and attainment of sexual maturity as shown by egg laying.

Macropterous: Long- or large-winged.

Maggot: The larval stage of a true fly (Diptera).

Mandibles: An insect's jaws.

Maxilla: The hind or second set of jaws behind the mandibles.

Metamorphosis: The process of changes through which an insect passes during its growth from egg to adult.

Microsporidium: Any of a group of protozoans some of which are pathogens to insects and other animals.

Migrant: An insect that migrates. Commonly, migrations are usually one way (usually northward) and are dependent on wind currents and weather patterns.

Molt: To cast off or shed the outer skin and so forth at certain intervals before replacement of the cast-off parts by new growth.

Monocot: Abbreviated term for monocotyledon; preferred in scientific literature over grass to describe plants.

Monocotyledon (monocot): A member of Monocotyledoneae; one of two classes of angiosperms, usually characterized by the following: one seed leaf (cotyledon), leaves with parallel venation, root systems arising adventitiously and usually diffuse (fibrous).

Moth: An adult insect (Lepidoptera) with two pairs of scale-covered wings and variously shaped (but never clubbed) antennae.

Multivoltine: Having more than one generation in a year or season.

Nematode: Any of a class of phylum of elongated cylindrical worms that are parasitic in animals or plants or are free-living in soil or water.

Nocturnal: Active at night.

Nonselective herbicide: An herbicide that is generally toxic to all plants treated. Some selective herbicides may become nonselective if used at very high rates.

Nontarget species: A species not intentionally affected by a pesticide.

Nymph: An immature stage in insects with incomplete metamorphosis.

Overtop application: A broadcast or banded application applied over the canopy of crops such as by airplane or a raised spray boom of ground equipment.

Overwinter: To survive the winter.

Oviposition: Egglaying.

Palidia: A group of spines, usually in a line, found near the anus of scarab grubs.

Palp: A segmented process on an arthropod's mouthpart.

Parasite: Any animal that lives in, on, or at the expense of another.

Parasitoid: An arthropod that parasitizes and kills an arthropod host; parasitic in the immature stages but free-living as an adult.

Pathogen: A disease-causing organism.

Pelleted formulation: A dry formulation consisting of discrete particles usually larger than 10 cubic millimeters and designed to be applied without a liquid carrier.

Peripheral: Relating to the outer margin.

Persistent herbicide: A herbicide that, when applied at the recommended rate, will harm susceptible crops planted in normal rotation after harvesting the treated crop, or that interferes with regrowth of native vegetation in non-crop sites for an extended period of time. See residual herbicides.

Pesticide interaction: The action or influence of one pesticide upon another and the combined effect of the pesticide(s) on the pest(s) or crop system.

Phenology, phenological: Temporal and seasonal pattern of life history events in plants and animals.

Pheromone: A substance secreted by an animal that influences the behavior of other individuals of the same species.

Phloem: The living tissue in plants that functions primarily to transport metabolic compounds from the site of synthesis or storage to the site of use.

Phytophagous: Feeding upon plants.

Phytotoxic: Injurious or lethal to plants.

Plant growth regulator: A substance used for controlling or modifying plant growth processes without severe phytotoxicity.

Polyphagous: Eating many kinds of foods.

Postemergence (POST): (1) Applied after emergence of the specified weed or crop. (2) Ability to control established weeds.

Posterior: Toward the rear, as opposed to anterior.

Predator: An animal that preys on another.

Preemergence (PRE): (l) Applied to the soil before emergence of the specified weed or crop. (2) Ability to control weeds before or soon after they emerge.

Preplant application: Applied before planting or transplanting a crop, either as a foliar application to control existing vegetation or as a soil application.

Preplant incorporated (PPI): Applied and blended into the soil before seeding or transplanting, usually by tillage.

Prepupa: A transitional stage between the end of the larval period and the pupal period.

Profile: An outline as seen from a side view.

Prolegs: Fleshy, unsegmented abdominal walking appendages of some insect larvae.

Pronotum: The upper or dorsal surface of the prothorax.

Prothorax: The first, or anterior, of the three segments of the thorax.

Pubescence: Fine hair or setae.

Pupa: The resting, inactive stage between the larva and the adult in all insects that undergo complete metamorphosis.

Raster: A complex of specifically arranged bare places, hairs, and spines on the ventral surface of the last abdominal segment, in front of the anus; found on scarabaeid larvae.

Rate: For herbicides, the quantity of active ingredient expressed as weight per unit area of treated surface or per unit volume of the treated environment for aquatic applications.

Registration: The process designated by the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) and carried out by the Environmental Protection Agency (EPA) by which a pesticide is legally approved for use in the U.S.

Residual herbicide: An herbicide that persists in the soil and injures or kills germinating weed seedlings for a relatively short period of time after application. See persistent herbicide.

Residue: That quantity of an herbicide or metabolite remaining in or on the soil, plant parts, animal tissues, whole organisms and surfaces.

Resistance: Ability to withstand exposure to a potentially harmful agent without being injured (There is no general agreement as to the distinction between herbicide tolerance and herbicide resistance in plants.)

Rhizome: A jointed underground stem that can produce roots and shoots at each node.

Rostrum: A snoutlike projection on an insect's head.

Safener: A substance that reduces toxicity of herbicides to crop plants by a physiological mechanism.

Sclerotized: Of an insect, hardened in definite areas by formation of substances other than chitin.

Selective herbicide: A chemical that is more toxic to some plant species than to others.

Snout: The prolongation of the head of weevils at the end of which the mouthparts are located.

Sod: Plugs, blocks, squares, or strips of turfgrass plus soil that are used for planting.

Soluble concentrate (SC): A liquid formulation that forms a solution when added to water.

Soluble granule (SG): A dry granular formulation that forms a solution when added to water.

Soluble powder: A dry formulation that forms a solution when added to water.

Solution: A homogeneous or single-phase mixture of two or more substances.

Species: The smallest taxonomic group; a population that has a defined range and can exchange genes.

Spiracle: A breathing pore through which air enters the trachea; in insects, located laterally on body segments.

Spittle: A frothy fluid secreted by insects; saliva.

Spot treatment: An herbicide applied to restricted area(s) of a whole unit; i.e., treatment of spots or patches of weeds within a larger field.

Spray drift: Movement of airborne spray from the intended area of application.

Stage: An insect's developmental status (e.g., the egg stage).

Stipe: A small stalklike structure associated with the maxilla.

Stolon: A jointed, aboveground, creeping stem that can produce roots and shoots at each node and may originate extravagantly from the main stem.

Stylet: One of the piercing structures in piercing-sucking mouthparts.

Subterranean: Existing under the surface of the earth.

Surfactant: A material that improves the emulsifying, dispersing, spreading, wetting or other properties of a liquid by modifying its surface characteristics.

Susceptibility: The sensitivity to or degree to which a plant is injured by an herbicide treatment.

Suspension: A mixture containing finely divided particles dispersed in a solid, liquid, or gas.

Systemic: Synonymous with translocated herbicide, but more correctly used to describe the property of insecticides or fungicides that penetrate and disperse throughout a plant.

Tank-mix combination: Mixing of two or more pesticides or agricultural chemicals in the spray tank at the time of application.

Tarsal claw: The claw, usually paired, found on the end of the last tarsal segment.

Tarsus (pl., tarsi): The foot; the distal part of the insect's leg that consists of one to five segments.

Teneral (callow) period: The time immediately after adult emergence; the adult is soft-bodied and pale.

Thatch: The layer of plant litter from long-term accumulation of dead plant roots, crowns, rhizomes, and stolons between the zone of green vegetation and the soil surface.

Thorax: The second or intermediate region of the in- sect's body, bearing two legs and wings and composed of three rings, the pro-, meso-, and metathorax:.

Threshold: A beginning point in physiology; the point at which a stimulus is just strong enough to produce a response.

Tibia: In insects, the fourth division of the leg articulated at the proximal end nearest the body to the femur and at the distal end to the tarsus.

Tiller or Tillering: A growth stage of grasses when additional shoots are developing from the crown.

Tolerance: (1) Ability to continue normal growth or function when exposed to a potentially harmful agent (there is no general agreement as to the distinction between herbicide tolerance and herbicide resistance in plants). (2) The concentration of a pesticide residue that is allowed in or on raw agricultural commodities as established by the Environmental Protection Agency.

Topdressing: A light covering of soil spread over an established turf grass.

Toxicity: The quality or potential of a substance to cause injury, illness, or other undesirable effects.

Toxicology: The study of the principles or mechanisms of toxicity.

Toxin: A poisonous substance.

Trade name: A trademark or other designation by which a commercial product is identified.

Translocated herbicide: An herbicide that is moved within the plant. Translocated herbicides may be either phloem mobile or xylem mobile. However, the term frequently is used in a more restrictive sense to refer to herbicides that are applied to the foliage and move downward through the phloem to underground parts.

Turgidity: The extent of being distended, swollen or bloated.

Univoltine: Having one generation in a year or season.

Vapor drift: The movement of pesticides as vapor from the area of application after the spray droplets have landed on the target.

Vector: An organism that is the carrier of a disease-producing organism.

Ventral: The underside.

Warm-season grass: A cold-intolerant grass with an optimum temperature range of 80-95°F (27-35°C).

Weed control: The process of reducing weed growth and/or infestation to an acceptable level.

Weed eradication: The elimination of all vegetative plant parts and viable seeds of a weed from a site.

Weed: Any plant that is objectionable or interferes with the activities or welfare of man.

Wettable powder (WP): A finely divided dry formulation that can be readily suspended in water.

Wetting agent: (1) a substance that serves to reduce the interfacial tensions and causes spray solutions or suspensions to make better contact with treated surfaces (see surfactant). (2) A substance in a wettable powder formulation that causes it to wet readily when added to water.

White grub: Whitish, C-shaped larva of insects belonging to the family Scarabaeidae.

Wing pads: The undeveloped wings of nymphs of hemimetabolous insects (e.g., Hemiptera), which show behind the thorax as two lateral, flat structures.

Witches'-broom: An abnormal brushlike growth of weak, tightly clustered plant shoots.

Worker: Among social bees, ants, and wasps, a female either incapable of reproduction or capable of laying only unfertilized eggs from which males emerge.

Xeric: Adapted to an extremely dry habitat.

Xylem: The nonliving tissue in plants that functions primarily to conduct water and mineral nutrients from roots to the shoot.

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