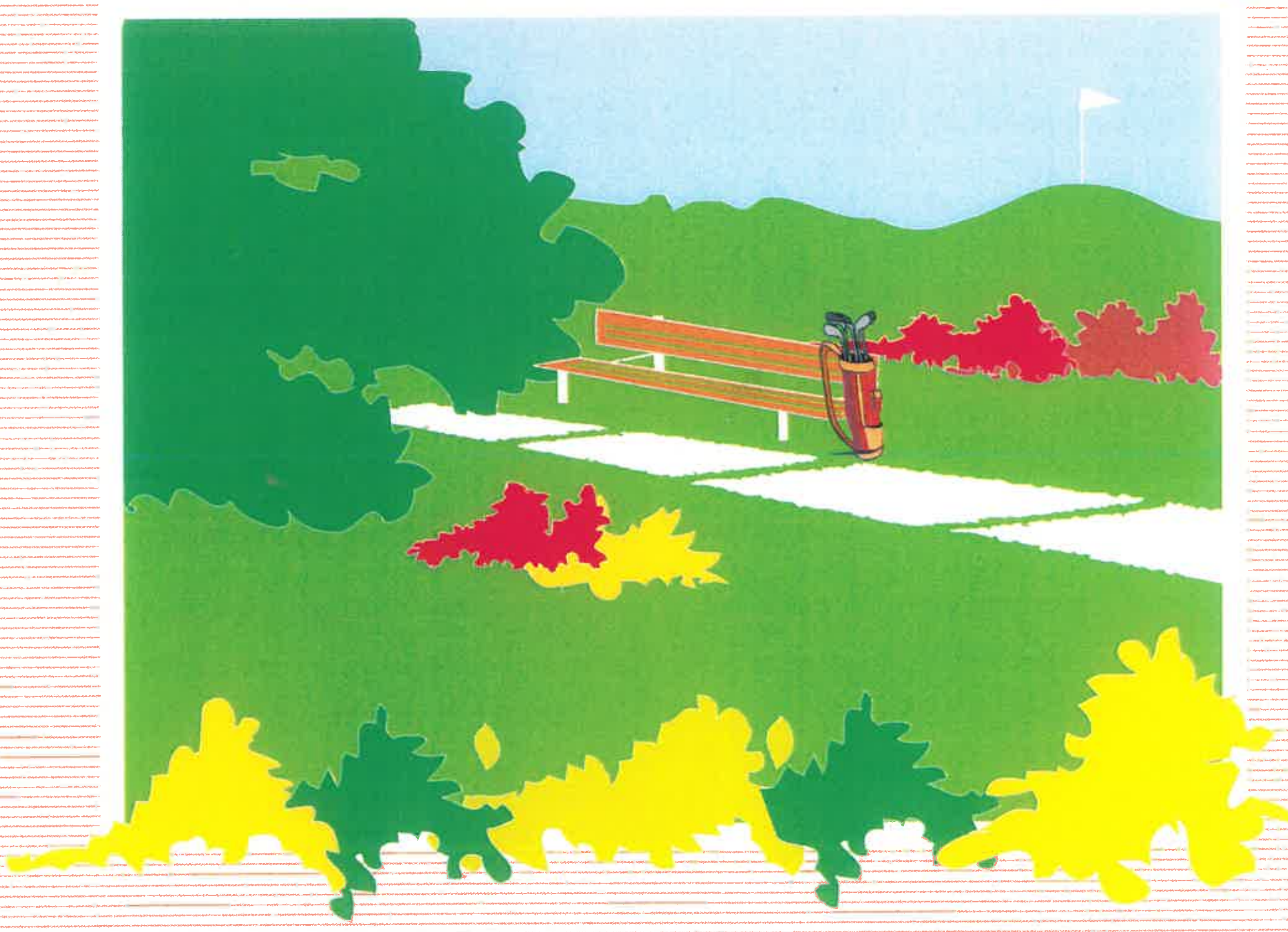
ARIZONA PESTICIDE APPLICATOR
TURF AND ORNAMENTALS



TRAINING MANUAL
CATEGORY 3

The University of
Arizona®
College of Agriculture
and Life Sciences

ARIZONA

PESTICIDE APPLICATOR TRAINING MANUAL

CATEGORY 3

TURF AND ORNAMENTALS

The University of Arizona, Cooperative Extension,
Pesticide Coordinator's Office

Sheila D. Merrigan, M.S.
Research Specialist

Paul B. Baker, Ph.D.
Associate Specialist, Entomology
and
Pesticide Coordinator

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INTRODUCTION

This manual is intended to be used statewide. While every effort has been made to make this manual specific to turf and ornamental applicators, there are many pesticide applicator practices that should be understood regardless of which category of applicator you are. Therefore, there may be some overlap of information from the core manual or other category manuals. Appendix A provides basic core information which every applicator should be familiar with prior to studying this category manual.

Chapter 4, "Beneficial Organisms and Major Pests in Arizona", provides information on beneficial organisms and major pests (insects and related pests, weeds, and pathogens) within the state. We have tried to focus on the pests that are a problem throughout the state. Unfortunately, we have had to omit some pests which may have a severe impact in one part of the state, but are nonexistent in another part.

This manual has been purposely prepared for ease in updating or modifying. It is the hope of the authors that funding will be available for periodic updating.

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CHAPTER 1 SAFETY

INTRODUCTION

Safety, not only of the applicator, but also of fellow workers, the public, and the environment, is extremely important when working with pesticides. This section on safety and the safety section in the core manual are the most essential parts of your training because the whole purpose of certification is to improve your ability to protect yourself, other people, and the environment. Since much of the turf and ornamental applicator's work is performed in an urban setting, the potential of adversely affecting the public is usually higher than for agricultural applicators. As a certified applicator, once you have shown your competence and awareness of the risks involved, you will be able to buy and use restricted-use pesticides. Always keep in mind that pesticides can be dangerous if improperly used, stored, or discarded.

PERSONAL SAFETY

When you consider how hazardous a pesticide may be, you need to consider not only toxicity, but also the risk of exposure. For example, a highly toxic compound that is carefully packaged and used in a closed mixing system offers little hazard to the user, while a mildly toxic substance in an open package may be very hazardous to everyone nearby. The following formula illustrates how to determine risk:

RISK = TOXICITY x EXPOSURE

The basic principle in avoiding pesticide poisoning is to exercise caution and simple common sense. Familiarize yourself with the section on safety in the core manual: in a pesticide emergency, you CANNOT count on having the time to consult a book for information.

SAFE PRACTICES

Safe practices associated with pesticides are covered in detail in the core manual. All safety practices are important and all applicators should follow these practices. Because turf and ornamental pesticide applicators often work near the public, there are three practices which should be followed to help ensure the safety of nontarget organisms in these situations:

1. Do not allow children, unauthorized people, or animals near where pesticides are being mixed, loaded, or applied.

2. Remove lawn furniture, toys, bird baths, and pet dishes before application.

3. Never leave pesticides unattended in a vehicle or at the application site. There is a much higher risk of children or other unauthorized persons seeing and touching unattended pesticides in an urban setting than in an agricultural field.

OBSERVE REENTRY TIMES

No one should enter a treated site without the proper protective clothing (as outlined on the pesticide label) until after the amount of time specified on the pesticide label has elapsed. If no reentry time is specified, follow the general standards established by the EPA: no one should enter a treated area without the proper protective clothing, as specified on the label, until after the pesticides that were applied have completely dried or settled. Recently, however, EPA has indicated that these general standards may be modified so that the reentry time will be 48 hours for some category I (signal word **danger**) pesticides and 24 hours for some category II (signal word **warning**) pesticides.

PERSONAL PROTECTIVE EQUIPMENT (PPE)

For personal safety, always check the label to see what type of protection you will need to protect your eyes and to guard against skin contact and inhalation. Wearing protective clothing and equipment may be uncomfortable in Arizona's hot climate; however, it may save your life, and at the very least it will reduce your chances of exposure. To reduce the discomfort of protective clothing, anticipate the environmental condition you will be working in. If the temperature is very high, try to schedule application for early mornings. Wear undergarments made of breathable fabric such as cotton. When the temperature is low, wear warm clothes under the protective equipment. Schedule short application times, if possible. Schedule breaks long enough to get out of the protective equipment if the application job is lengthy, or trade off jobs with a co-worker. Personal protective equipment is covered in detail in the core manual, and a quick review is provided in Table 1. There are, however, a

Table I **PERSONAL PROTECTIVE EQUIPMENT**

Coveralls can be reusable or disposable, and should be worn over a long-sleeved shirt and long pants. Cotton fabric is popular because it is comfortable, ut it and other tightly woven fabrics act as a wick and carry liquids (including pesticides) to the inside of the garment, thereby increasing the potential for contamination. Reusable protective clothing is usually made of woven or nonwoven fabrics coated with, or laminated to, a waterproof material. Do not use protective clothing that is lined with a woven fabric.

Aprons offer additional protection when pouring or handling concentrated materials. They should be made of rubber or synthetic, liquid-proof material, and should cover the front of your body from chest to boots.

Spray suits are often recommended for working with highly toxic compounds. These waterproof, chemical-resistant, tear-resistant, plastic suits come in either one or two pieces with an attached hood.

Gloves should be made of flexible, impervious plastic or rubber, and must be unlined. Never use leather gloves or gloves with a cloth lining or wristband, which can absorb pesticides and may increase exposure to pesticides. Gloves made of natural rubber, latex, butyl, or neoprene provide good protection. Select the material that will provide adequate protection from the types of pesticide used and the amount of exposure expected. Wear sleeves outside the gloves to prevent spills and splashes from running into the gloves and onto your hands. If you are spraying overhead (e.g., shade trees), gloves should be worn on the <u>outside</u> of sleeves.

Hats should be made of liquid-proof plastic, with plastic or disposable sweatbands. Avoid felt, cloth, or straw hats with leather headbands, which can absorb chemicals and become a source of chronic pesticide exposure. Choose the widest brim hat that meets the above criteria. For highly toxic chemicals, it is advisable to wear a spray suit with attached hood so that as much of the head is covered as possible.

Boots should be impervious to pesticide materials, unlined, and nearly knee-high. Select the boot material (e.g., PVC, nitrile, neoprene, butyl) that provides the greatest protection against the pesticide type you are using. Most pesticides contain hydrocarbon materials, oils, and solvents. PVC, neoprene, butyl, and especially nitrile provide protection against these types of pesticides. Wear pant legs outside boots to prevent spills and splashed from running into the boot.

Goggles fit over eyeglasses and should not fog. The headband should be made of nonabsorbent material.

Surgical masks may be worn when handling dusts to prevent inhaling the dust. Surgical masks do not provide respiratory protection as adequately as other respiratory equipment, but may be used for protection against nontoxic nuisance dust.

Shields provide full face protection from splashes, but do not protect against airborne dust, spray droplets, or vapors.

Respiratory equipment usually consists of chemical-cartridge respirators, canister gas masks, or air-supported respirators. Masks must fit tightly. Long sideburns and beards prevent a good seal from forming between the face and respirator. It is illegal for applicators with long sideburns or beards to use cartridge respirators or apply pesticides that require them.

few points especially relevant to applicators dealing primarily with ornamental pests of trees or other overhead vegetation:

1. If you need to raise your arms when spraying, be sure to wear gloves <u>outside</u> the sleeves. Tape gloves to sleeves to be certain no pesticide runs down the inside of the gloves when arms are lowered.

2. Wear appropriate face protection so that pesticide applied at face level or higher does not contact the face if it drifts back toward you.

3. Wear head and neck protection when applying pesticides overhead so that any drops will not come in contact the skin.

PUBLIC AND ENVIRONMENTAL SAFETY

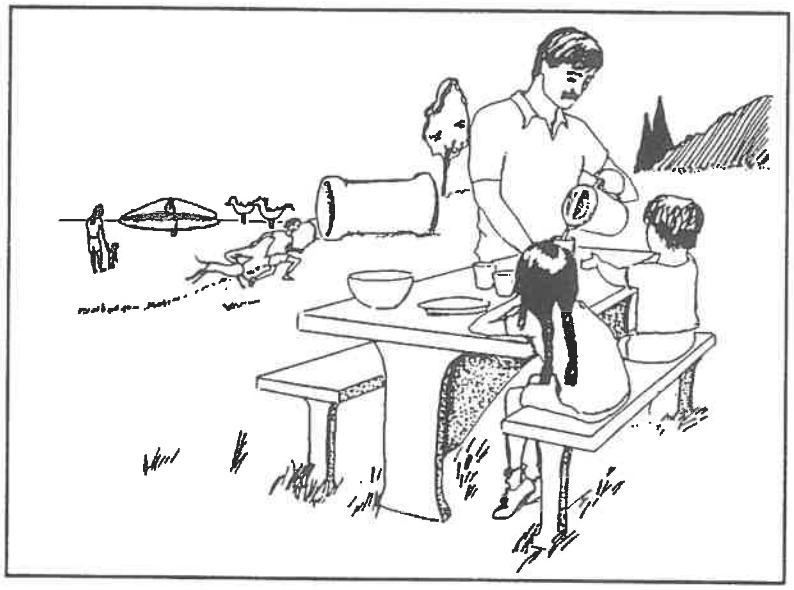
There is increasing public and governmental concern about the effects of extensive pesticide use on the environment. These concerns are being voiced across the nation and have resulted in a demand for more ecologically oriented approaches to pest management. The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), as amended, governs the regulation of pesticides in the United States. Under FIFRA, a pesticide product may be sold or distributed in the United States only if it is registered with EPA. Before a product can be registered, it must be shown that the pesticide can be used without "unreasonable adverse effect on the environment," that is, without causing "any unreasonable risk to man or the environment, taking into account the economic, social, and environmental costs and benefits of the use of the pesticide," when used in accordance with label directions.

Integrated pest management (IPM) involves selective use of pesticides, careful timing of application, augmentation of chemical control with natural enemies, and cultural practices. IPM programs are designed to pose minimal hazard to people and the environment because they usually require fewer pesticides, and the pesticides used are generally less toxic than chemicals used in the past. IPM programs, however, are often not well received by pesticide users if the programs are more difficult to implement, more time-consuming, more expensive than conventional pest management programs, or if they result in unacceptable plant damage.

The next two sections will review information regarding safety and hazards to humans (other than the applicator) and the environment (i.e., groundwater, endangered species, wildlife, and bees).

THE PUBLIC

According to researchers, public acceptance of pesticide use is at an all-time low. Growing concern by the public is being voiced, and this concern will probably continue to generate more stringent pesticide-use regulations in the future. Nonagricultural applicators of pesticide, using pesticides in urban settings (lawns, trees) or for vegetation management (utility corridors, rights-of-way), will likely face even stiffer rules and regulations.



The public's "right to know" has recently become an important issue. In Arizona, community right-to-know laws refer only to storage or accidental release of hazardous substances. There are no requirements for notification as to when pesticides are used. If pesticide from an application is drifting out of the target area, the person(s) affected by the drift can report the incident to the Structural Pest Control Commission which, in turn, will send an inspector to the site to investigate.

The public's major concerns deal with insecticide residues in food and contamination of drinking water. However, dislodgeable residue resulting in potential human exposure after pesticide application is also becoming a controversial issue. Current regulations adequately protect the applicator; however, these regulations may not protect residents of the treated site. There is potential for exposure to residents reentering the treated area. These residents include children and pets playing in the areas where pesticides have been applied. Pesticide application may also trigger allergic reactions or other health problems in some individuals. Therefore, as the certified applicator, you should be aware of your customers' concerns regarding pesticides and provide them, when possible, with the necessary information about the pesticides you are using. For example, you should inform customers whenever a specific pesticide has caused allergic reactions in previous customers. Be certain that your customers understand that no one (including children and pets) should enter a treated area until it is safe to do so, and provide them with a time frame.

ENVIRONMENT

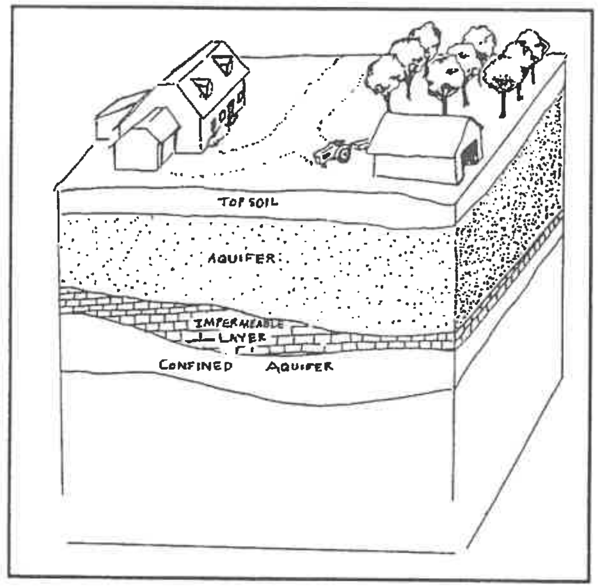
It is important for an applicator to have a good understanding of pesticides and the potential impact of those pesticides on the environment. Pesticides have had a negative impact on many segments of the environment. Four segments of the environment covered in this section of the chapter are water quality, endangered species, wildlife, and bees (since there are some special considerations for bees, they are discussed separately from wildlife). Pesticide applicators have the ability to reduce the negative impact of pesticides on the these environmental segments.

WATER QUALITY[1]

Our nation's water quality has been contaminated by the intrusion (into groundwater) of chemicals applied to soil, crops, and other vegetation. The extent of the contamination has yet to be determined. In its natural state, groundwater is usually of excellent quality and can be used with no costly treatment or purification. It can be tapped at the point of use, thereby eliminating transport or storage costs. Most of the rural population in the U.S. currently relies on groundwater for drinking water, and the demand for this water is increasing. In Arizona, approximately 71% of the state's population relies on groundwater (nearly 100% of the rural population does so). Therefore, protection of existing and potential groundwater sites is essential. Unfortunately, many rural groundwater areas are very vulnerable to various types of contamination. A pesticide applicator has the responsibility to minimize pesticide contamination of groundwater by using all pesticides according to label instructions and by being aware of the factors that make groundwater vulnerable to contamination.

Groundwater is defined as the source of water for wells and springs which fills spaces between particles of soil, or cracks in bedrock. Geologic formations containing groundwater are called aquifers. Groundwater is heavily used for both irrigation and drinking water. Groundwater moves slowly through irregular spaces within rock fractures or between soil particles. It may move only a few feet per month, or even per year; therefore, it may take years for contaminated water to flow past affected wells. Pesticides degrade very slowly in

[1]Much of the information presented in this section has been taken from *Protecting Groundwater: A Guide for the Pesticide User* by K.S. Porter and M.W. Stimmann. This publication consists of a slide-set storyboard and a manual for instructors. Published by NYS Water Resources Institute, Center for Environmental Research, Cornell University, May 1988.



groundwater due to cold temperatures and low microbial activity. Once contaminated, groundwater is extremely difficult (often impossible) and expensive to clean. Attempts to clean a contaminated aquifer are rarely successful, but may be accomplished by (1) using biological or chemical agents to detoxify contaminants in the ground, or (2) pumping groundwater to the surface for treatment, and then using it or returning it to the aquifer. One consequence of contamination, regardless of how the contamination occurred, may be restricted use or elimination of some pesticides.

There are many federal, state, and local laws and regulations intended to provide protection of groundwater. Two federal acts, the Clean Water Act and the Safe Drinking Water Act, deal with water issues only. The Resource Conservation and Recovery Act (RCRA), the Toxic Substances Control Act (TSCA), the Comprehensive Environmental, Response, Compensation, and Liability Act (CERCLA), the Federal Food, Drug, and Cosmetic Act (FFDCA), and the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) all either directly or indirectly protect groundwater.

The Arizona Department of Environmental Quality (DEQ) was established in 1986 to deal with many aspects of environmental concerns. The primary function of DEQ is to protect public health and to preserve, protect and enhance the environment of Arizona. One division within the Department of Environmental Quality which has pesticide-related responsibilities is the Pesticide Contamination Prevention Program. This program is responsible for reviewing environmental fate data on pesticides registered in Arizona. These data, submitted by manufacturers, are used to determine if a chemical should be listed on the Groundwater Protection List. DEQ has the further responsibility of monitoring the soil and water for contamination by pesticides on the Groundwater Protection List. Finally, DEQ has enforcement authority over pesticides on the ground water protection list that are found in concentrations that harm human health. DEQ has the authority to force label changes or cancellation of pesticide registrations.

While much of the concern over groundwater contamination focuses on pesticides applied to agricultural crops, pesticides applied to turf and ornamentals can also cause problems. Some researchers believe water pollution from runoff of paved areas may be the largest urban source of groundwater contamination, since any chemical sprayed near, or spilled on, paving materials has great potential to be carried to the aquifer. Other sources of contamination of urban groundwater come from extensive chemical use on roadsides and industrial sites. As an applicator, you should be aware of the following major factors which determine whether a pesticide is likely to reach groundwater when applied in a turf and ornamental setting: (1) pesticide properties, (2) soil properties, (3) site conditions, and (4) management practices. A discussion of these four factors follows.

(1) Pesticide Properties

Solubility

The higher the solubility, or tendency of the pesticide to dissolve in water, the greater the chances that a pesticide will be washed (or leached) downward through the soil, possibly into the groundwater.

Volatilization

A pesticide with a high volatilization rate, or tendency to become a gas and vaporize into the atmosphere, is less likely to contaminate groundwater than is a pesticide with a low volatilization rate. This is true, however, only if these volatile pesticides are applied to the soil surface. Pesticides that are injected into the soil or are highly soluble have limited contact with the atmosphere and may not volatilize. These pesticides, therefore, have the potential to reach groundwater.

Adsorption

Adsorption, or the attraction between a chemical and soil particles, also affects pesticide leaching. Pesticides that are adsorbed to the soil are less likely to leach, regardless of their solubility. Whether or not a pesticide will be adsorbed to the soil depends upon the chemical properties of the pesticide, the soil type, and the amount of organic matter present in the soil. With most chemicals, the greater the organic matter or clay content in soil, the greater the attraction of that chemical to the soil particles. The coefficient used to estimate adsorption of a chemical to soil organic carbon is called the "organic carbon partition coefficient" (symbolized by K_{oc}). In general, the larger the value of K_{oc}, the slower a pesticide will move through the soil. However, for some chemicals that have more affinity for soil minerals than for organic matter, this will not hold true.

Degradation

The longer a pesticide remains in the soil before it is degraded, or broken down, the longer it is subject to the forces of leaching. How a pesticide reacts with water, sunlight, air, and microorganisms determines how fast it breaks down. The longer the half-life, or length of time which half the original amount of the pesticide takes to degrade, the greater the chances that the pesticide will reach groundwater. Half-life estimates are difficult to determine because they depend greatly on soil conditions such as soil type, soil temperature, and soil moisture content. Half-life of a pesticide may also be affected by concentration of the chemical, method of application, chemical structure, amount of sunlight, and microbial populations.

(2) Soil Properties

Soil characteristics such as soil texture, soil permeability, soil organic matter content, and soil structure affect the leaching ability of a pesticide. Soil texture is determined by the amount of sand, silt, and clay present. Soil permeability is a measure of how fast water can move downward through the soil. Highly permeable sandy soils will allow water and chemicals to leach through more rapidly, while clay soils, which hold water and chemicals longer, have a lower leaching potential. Since clay soils have lower permeability, however, there may be a problem with runoff, particularly if the chemical has a long half-life. Organic matter tends to increase retention of water, and therefore increase retention of pesticides in the root zone, where they will be available to plants and subject to breakdown by microbial agents present in that zone. The soil structure, or the way soil particles are combined, may also affect movement of water, and therefore pesticides, through the soil. If the soil is structured so as to allow for large openings or channels (from such things as roots or animal diggings), there will be greater and faster movement of pesticide through the soil, whereas smaller openings will slow the movement of pesticide through the soil.

(3) Site Conditions

Site conditions may also influence pesticide leaching. Depth of groundwater is the most important condition. The shallower the depth of groundwater, the less soil there will be to act as a filter, and the fewer the chances of breakdown or adsorption of pesticides. Within Arizona, some regions may have groundwater only a few feet below surface level. In areas with high rainfall and permeable soils, leaching of pesticides may be very rapid. The potential for groundwater contamination from pesticide leaching may be reduced where the aquifer is hundreds of feet below ground level. Groundwater in areas with shallow aquifers, high rainfall, or permeable soils is most likely to be contaminated.

Depth of groundwater fluctuates throughout the year. In Arizona, precipitation is generally greatest in summer and winter. Aquifer recharge depends greatly on topography, precipitation amounts, and soil types. Therefore, pesticide contamination may or may not occur during the wet season; it may be several months after precipitation falls before the aquifer recharges and potential contamination occurs.

(4) Management Practices

Management practices provide applicators with several possible ways to prevent groundwater contamination. Always read the pesticide label; many labels contain information on preventing groundwater contamination. To reduce the amount of pesticides used, evaluate the need for a pesticide. Apply only if needed, and at the minimum rate necessary. Avoid using pesticides that are likely to leach. Application techniques such as injection or incorporation into the soil make the pesticide most readily available for leaching. As mentioned earlier, timing of pesticide application is important; applying more soluble chemicals during the rainy seasons may increase chances of contamination. An example where this is not the case here in Arizona is that preemergence herbicides (which do not leach and bind to the soil) are often applied just before rains to help incorporate the chemical.

Avoid handling, loading, mixing, or applying pesticides near surface water, shallow aquifers, or wells. Knowing the life stage at which a pest is most susceptible to pesticides, and applying pesticides at that time, may reduce the number of applications required to control the pest. Fewer applications means fewer chances of contaminating the groundwater. When applying a pesticide near open water, use the pesticide formulation least likely to drift to avoid contaminating the open water. After applying a pesticide, delay irrigating plants for one or more days to allow more time in which the plants and soil can take up the pesticide. This reduces the amount of pesticide available for movement through the soil with irrigation. Be aware that applying pesticides on clay soils is particularly hazardous, since clay soils are especially susceptible to runoff.

Since turf and ornamental pesticide applicators generally do not apply large quantities of pesticides (compared to agriculture), they may be most likely to contaminate groundwater when cleaning equipment and disposing of leftover pesticides. Keep in mind that it is illegal to simply pour leftover pesticide on the ground. Any leftover pesticide, and/or rinsate, must be applied to a labeled application site.

Alternatives to pesticide use should always be considered. For example, instead of using herbicides to control weeds, consider using ground covers, paving materials, mulches, or crushed rock to help control weeds. Also consider such things as using beneficial insects, instead of insecticides, to help control insect and mite pests.

ENDANGERED SPECIES[2]

An endangered species is one in danger of extinction throughout all or a portion of its range. A threatened species is one that is likely to become endangered within the foreseeable future. It is important to protect endangered species. Although there are an estimated 80,000 species of edible plants in the world, 90% of the world's food comes from fewer than 20 plant species. In addition to a multitude of other reasons, maintaining this wild plant gene pool is essential to discovering new food sources, and enhancing disease-resistant, climate tolerant, or perennial strains of plants. A 1988 review of a sample of the nation's endangered and threatened species indicated that about 20% were listed, in part, because of pesticide use. Within Arizona, 116 species (or subspecies) are on the Threatened Native Wildlife in Arizona list. Many of these species are also federally listed as threatened or endangered.

Before pesticides reach the market, they must be registered for specific uses under the federal pesticide and food and drug laws. Congress passed the Endangered Species Act (ESA) of 1973 to provide protection for animal and plant species that are threatened or in danger of becoming extinct, and to conserve the ecosystems upon which they depend. The ESA allows the EPA to register only those pesticides which do not harm listed endangered species. Under the provisions of the ESA, the U.S. Fish and Wildlife Service helps implement pesticide programs by conducting biological analyses of the effects of pesticides on threatened or endangered species. It is through contacts such as these with federal and state agencies that EPA determines whether a

[2]The U.S. Department of the Interior and U.S. Fish and Wildlife Service brochure *Pesticide Use and Endangered Species* provided much of the information presented in this section.

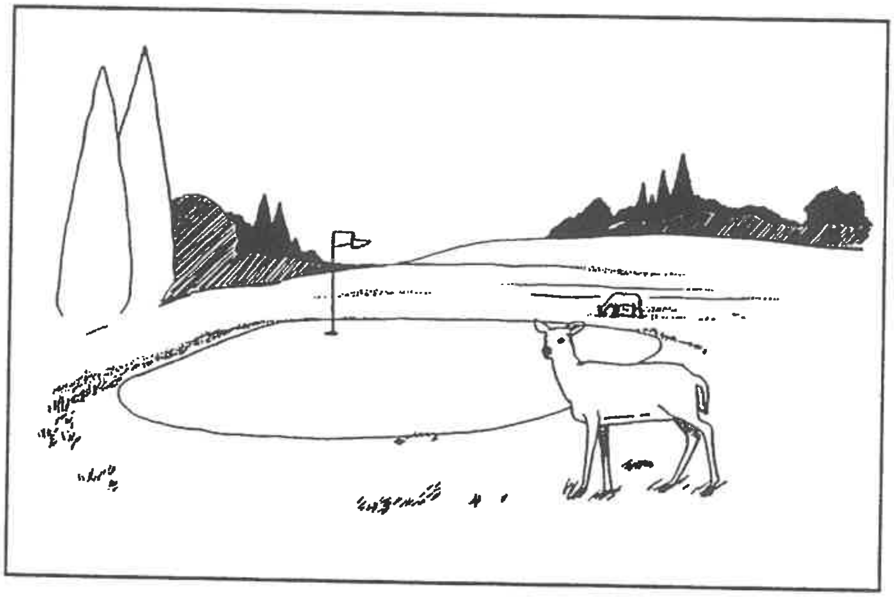
pesticide may affect an endangered species. If any adverse impact is demonstrated, then a restriction is imposed. For example, if the Fish and Wildlife Service determines that pesticide application may harm a threatened or endangered species, they may request an applicator to use ground, rather than aerial, application and/or a different formulation or a suitable substitute pesticide.

Very seldom will an endangered species, or its habitat, be directly encountered by turf and ornamental pesticide applicators; however, the possibility does exist. Applicators who apply pesticides to areas such as highway rights-of-ways or utility corridors may encounter an endangered species or its habitat. An endangered species or its habitat may also be encountered in public natural areas, such as city parks which have been left in a natural state. Be certain when disposing of pesticide containers that (1) the area is not located near endangered species or their habitat and (2) you read and follow label guidelines and restrictions regarding cleaning of equipment and disposal of pesticides and pesticide containers.

Beginning 1992, the Environmental Protection Agency (EPA) initiated the Endangered Species Protection Program. The program is expected to be in place across the nation by 1994 and is designed to protect federally listed endangered and threatened species from exposure to pesticides. The new program is intended to provide information concerning, and regulation for, the use of pesticide that may adversely affect the survival, reporduction, and/or food supply of listed species. EPA and the U.S. Fish and Wildlife Service (FWS) will identify currently occupied endangered species habitats on a county by county basis. USDA will provide land use information for those designated areas. It will then be determined what (if any) pesticide uses may occur in the vicinity of an endangered species. County bulletins containing a detailed map on which protected habitats and corresponding pesticide use limitations are indicated will be distributed at various locations. In Arizona, bulletins are available for 10 counties (Cochise, Coconino, Gila, Graham, Maricopa, Mohave, Navajo, Pima, Pinal, and Yavapai). These interim bulletins are provided for use in voluntarily protecting endangered and threatened species from harm due to pesticide use—their limitations on pesticide use are not law at this time.

WILDLIFE

Wildlife should be a consideration for turf and ornamental pesticide applicators, since wildlife is found throughout the urban setting. An abundance of birds, small mammals, and reptiles is found in city parks, cemeteries, and other public places. There may also be fish ponds in these settings. Applicators who work on golf courses or highway rights-of-way may even come into contact with large mammals such as deer, coyotes, and bobcats. When a pesticide is potentially hazardous to birds, fish, wildlife, or pollinating insects, caution statements are required on the label, stating the nature of the hazard and the necessary precautions to avoid accident, injury, or damage to nontarget species. The applicator must understand that merely following the instructions on the product label will not ensure that wildlife will not be killed when pesticides are applied. Prior to application of a pesticide, environmental circumstances should be carefully evaluated and the benefits of pesticide use should be weighed against potential adverse effects. The season, with respect to migratory, breeding, and nesting species, should be considered, as well as the specific habitats to be treated. This is a particularly important consideration for migratory bird flyways. For example, hawks and cranes migrate through Arizona. Thus, if at all possible, the time for spraying should be selected to avoid those periods when birds are present.



Weather conditions influence aerial drift and subsequent pesticide runoff into ponds and wetlands inhabited by fish and wildlife. Recommended application rates should not be exceeded, and application should be conducted carefully to avoid overspray. Pesticides can be applied while leaving buffer zones around areas where wildlife tend to feed and nest. Additionally, the use of pesticides less hazardous to nontarget species, but still effective against target species, will help minimize wildlife mortality. There may be some trade-offs associated with less hazardous pesticides. A safer pesticide may not be as effective as a more toxic one, but perhaps it can still be a suitable substitute if wildlife injury can be prevented.

BEES

Bees are a special consideration because they are very susceptible to pesticide poisoning, and they may be located very near where turf and ornamental applicators apply pesticides. Honey bees not only produce honey and beeswax, but they also pollinate many types of plants. Most bee poisoning occurs when pesticides are applied to blooming plants on which the bees are feeding. Dusts or encapsulated pesticides may become attached to the bees in the same way pollen becomes attached. At the hive, the bee removes the pesticide along with pollen. Toxic sprays or dusts that drift from nonblooming plants to blooming plants or the bee hive may also be hazardous to the bees.

Applicators should cooperate with beekeepers to reduce the hazard of pesticide poisoning to bees. Consider the following factors when applying pesticides near bee foraging areas or hives:

- Use biological or other nonchemical controls if possible.
- Choose a pesticide that is nonhazardous or least toxic to bees, and apply the minimum amount of pesticide needed to accomplish pest control goals.
- Choose the least hazardous pesticide formulations. Dusts are more hazardous than liquids of the same pesticide. Emulsifiable (liquid) formulations usually have a shorter residual toxicity to bees than do wettable powders. Granules are usually the safest and least likely to harm bees, since the particle size is too large for bees to carry back to the hive.

- Notify the beekeeper in advance, so that the bees may be moved or confined if hazardous pesticides are to be applied.

- Do not apply pesticides that are toxic to bees on plants or nearby crops in bloom, or allow pesticides to drift onto plants or nearby crops in bloom.

- In areas where there is bee activity, make as few treatments as possible, because repeated applications greatly increase the damage to colonies.

- Apply chemicals with a lengthy (5 to 16 hours) residual toxic effect only in late evening or at night. Chemicals with a residual toxic effect of only 2 or 3 hours can be applied either in the early morning, evening, or at night while bees are not actively foraging (generally between 8:30 p.m. and 4 a.m. in Arizona). Evening applications are generally less hazardous to bees than early morning applications. When high temperatures cause bees to start foraging earlier or continue later than usual, shift application time accordingly.

- Do not apply pesticides when temperature is expected to be unusually low following treatment. Residues can remain toxic to bees for up to 20 times as long under cooler conditions as during warm weather. Bee activity may decline during cooler weather if the plants they are foraging on stop producing nectar and/or pollen. If, however, the plants continue to produce nectar and/or pollen, then the bees will continue to forage, and the extended toxicity of pesticide residues could be very damaging.

- Always read the pesticide label for instructions specific to bees.

- Ground application is generally less hazardous than aerial application because there is less drift of the pesticide, and smaller areas are treated at one time.

REFERENCES AND ADDITIONAL INFORMATION

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SAMPLE TEST

QUESTIONS

1. Risk = ______________ x ______________

2. If you need to raise your arms up when spraying, be sure gloves are worn inside/outside the sleeves.

3. IPM programs are designed to pose minimal hazards to people and the environment because they generally require more chemicals. True or False?

4. Pesticides degrade very slowly in groundwater due to hot/cold temperatures and high/low microbial activity.

5. Surface water pollution from ______________ of paved areas may be the largest urban source of groundwater contamination.

6. The four major factors which determine whether a pesticide is likely to reach groundwater when applied in a turf and ornamental setting are ______________________________, ______________________________, ______________________________, and ______________________________.

7. What percentage of the nation's endangered and threatened species are listed on the endangered and threatened species list, in part, because of pesticide use?
   a. 50%
   b. 20%
   c. 5%
   d. 35%

8. Wildlife is not found in the urban setting and is therefore of no concern to turf and ornamental pesticide applicators. True or False.

9. Most bee poisonings occur when pesticides are applied to ______________________ on which the bees are feeding.

10. Residues can remain toxic to bees for up to 10/15/20/25 times as long under cooler conditions as during warm weather.

ANSWERS

1. toxicity, exposure 2. outside 3. false 4. cold, low 5. runoff 6. pesticide properties, soil properties, site conditions, management practices 7. 20% (b) 8. false 9. blooming plants 10. 20

Chapter 2 TURFGRASS MANAGEMENT AND PEST CONTROL STRATEGIES[1]

INTRODUCTION

Turfgrass in Arizona is comprised of home lawns, golf courses, institutional and commercial grounds, sod farms, athletic fields, recreational turf, parks, right-of-way greenbelts, roadsides, airports, and cemeteries. Homeowner lawns and golf courses are the major areas of turf within the state.

Maintaining high quality turfgrass requires proper care and management, including timely pest control practices. Turfgrass management includes selecting the right species and variety of grass, mowing height, watering regimes, fertilization levels, and thatch control. All of these factors play a role in integrated pest management (IPM). IPM is the use of various pest control tactics to form a strategy to reduce pests populations (or their damage) to an acceptable level. Pesticides should be used as an aid in turfgrass management, not as a substitute for good cultural practices. Relying solely on pesticides for pest control can result in many problems such as pesticide resistance and harm to nontarget organisms. Pesticides do have a place in an IPM plan, however, they can not offset the effects of improper mowing height, watering, and fertilizing practices, or thatch accumulation, poor design, and poor drainage. A successful turf management program containing IPM practices includes the careful selection and establishment of turf, and the use of cultural practices that favor a healthy environment for growth.

TURF MANAGEMENT

In planning a turf management program, consider the following: (1) selection of a turfgrass species and cultivar that fits most of your needs; (2) sound site preparation; (3) mowing, core aerification, and thatch removal procedures; (4) watering and fertilization regimes; and (5) local environmental factors (rainfall, humidity, etc.).

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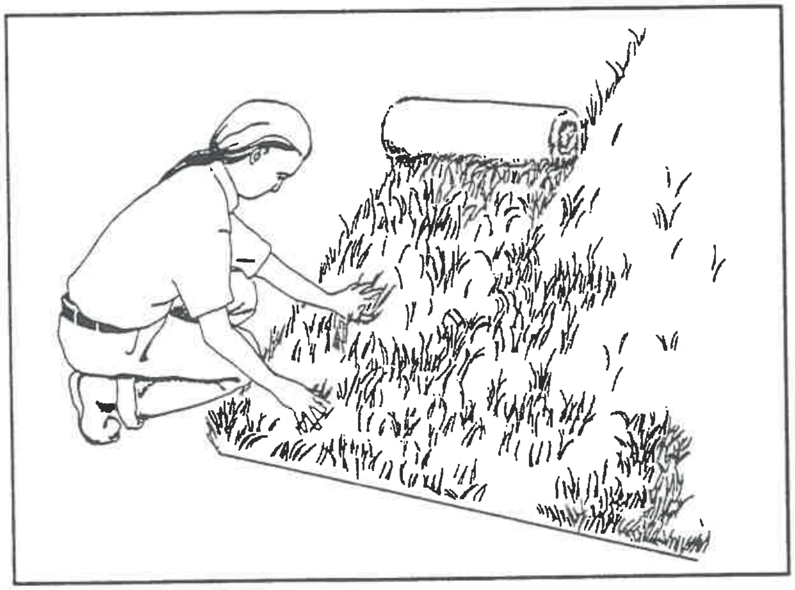
[1]Much of the information for this section has been taken from *Pesticide Applicator Training Manual; Category 3, Ornamental and Turf Pest Control* written by Cynthia L. Brown and published by the University of Delaware, College of Agricultural Sciences, Communications Office, 1990.

(1) TURFGRASS SELECTION

When selecting a turfgrass variety consider the intended use of the turf. Will it be used in a homeowner's lawn, or an athletic field? Different species of grass are better suited for different uses. The wrong grass for the wrong situation may result in continual problems that are almost impossible to correct, even with good management and the aid of pesticide applications.



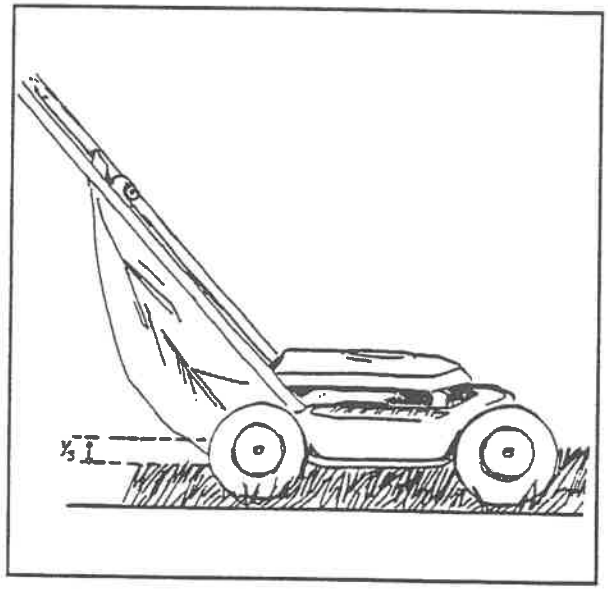
Selecting turfgrasses that are certified weed-free is one of the best means of preventing pest activity. There are cultivars that have improved resistance to certain diseases such as leaf spot, rust, dollar spot, and patch diseases. Mixtures of different species (called blends) of various varieties are used to ensure turf quality over a wide range of environmental conditions.

(2) SITE PREPARATION

Proper site preparation that includes the removal of existing vegetation can help prevent the development of future problems. Good soil and surface drainage can reduce disease and weed problems. Compost should be incorporated into the soil prior to sodding or seeding to increase the amount of organic material in the soil.

For establishing new turfgrass stands, good seed-soil contact is critical, along with adequate moisture to develop the root systems. If overseeding is needed, tillage, light verticutting, or raking should occur prior to seed application. By establishing a good stand, weed invasion is minimized.

(3) MOWING AND THATCH REMOVAL



A key aspect of maintaining vigorous turf is mowing at the correct height at regular intervals. The correct mowing height is determined by the species of grass and use of the turf. For example, an athletic field may need to be cut short (less than 1½"), while a recreational park and most home lawns may require a higher mowing height. A good rule of thumb for mowing heights is never to remove more than 1/3 of the grass blade. Cutting too low results in a weakened stand, which is more vulnerable to weed competition and may require extra irrigation and fertilization. Keep your mower blades sharp. Dull mower blades shred grass blades, which not only makes the turf unsightly, but also increases the surface area for possibility of fungal infection.

Thatch is the layer of living and dead plant tissue, composed of stems, leaves and roots, that develops between the soil surface and green vegetation. Thatch layer buildup can create a tightly woven mat that reduces light, air, and water penetration. Thatch may provide favorable environments for disease and insect pests, and reduce the effectiveness of pesticides. Factors that contribute to thatch buildup include heavy fertilization, vigorously growing cultivars, poor soil aeration and drainage, and extremes in pH. In addition, repeat applications of pesticides inhibit development of earthworms and microorganisms that naturally break down dead plant materials. Reduce fertilization and increase soil drainage and aeration to reduce the thatch layer.

(4) IRRIGATION AND FERTILIZATION

Irrigation is required for both the establishment of turfgrass (seed, sod, or sprigs) and for maintenance. If turf does not receive adequate watering during dry periods, it will become dormant and turn brown. Once temperatures favorable for growth are reached and moisture is provided, most dormant turfs will break dormancy and green up. To prevent dormancy, the turf should be irrigated at the first visible symptoms of wilt: a blue-gray appearance and footprinting. Footprinting occurs because the wilted grass is slow to return to an upright position when stepped or driven on.

Scheduled irrigations should apply enough water to wet the soil to a depth of several inches. Light, frequent waterings should be avoided on established turf, because they promote shallow root systems, which can lead to an increased incidence of weeds and diseases. The timing of irrigations can influence pest development. For example, late afternoon or evening waterings can leave standing water on the leaves, which promotes the development of certain fungal diseases.

A fertilization management plan is vital to maintaining a healthy, good stand of turf that can compete against invading weeds, and recover quickly from disease and insect injury. Turfgrass is responsive to nitrogen, and routine soil and leaf analysis is advisable to be certain the correct nitrogen levels are being maintained. Turf that has either too low or too high a nitrogen level is susceptible to pests. Low levels can leave a turf thin and bare, and susceptible to weed invasion, while high levels of nitrogen can lead to lush, succulent plants that are susceptible to diseases such as leaf spot and brown patch. Therefore, turfgrass should be fertilized based on the analyzed needs of the stand and of each individual species or cultivar.

(5) ENVIRONMENTAL FACTORS

Environmental factors that may affect turfgrass health include humidity, sun/shade, air movement, temperatures, and soil compaction. Turf grown in shady areas usually is less vigorous, spotty, and more prone to invading weed competition. If repeated planting or selective pruning does not eliminate the problem, you may consider replacing the grass with wood chips, or decorative stones. Good air movement over the surface of the turf can have a drying effect, which will help deter the development of diseases. Increased air movement can sometimes be accomplished by pruning trees and shrubs. Temperatures impact grass growth, particularly on southern-exposed, sunny locations and on steep slopes or banks. Elevated temperatures may require additional water and fertilizer to maintain the quality of turf. Soil compaction may lead to increased pest problems, since turf is difficult to maintain in a healthy state when soil is compacted. Compacted soils allow little water or air penetration. Water and air penetration can be increased with core aeration.

INSECT CONTROL

Many insects and other arthropods commonly inhabit turf, but only a few cause serious injury. However, the few that do cause injury must be managed before they become a problem. Healthy turf has a greater capacity than does weak turf for producing new roots and leaves, as older ones are destroyed by insects. To manage insect pests effectively, applicators must have a working knowledge of the various pest's life cycles and habits in their areas. It is impossible to eliminate all turf insects. However, pest numbers may be reduced to a manageable level by good management practices, which include pesticide application.

INSECT DETECTION

Managing pests successfully requires recognizing problems, responding appropriately, and making a follow-up assessment. Accurate diagnosis of insect problems requires periodic visual observation of the landscape. This includes getting down on your hands and knees, and inspecting the problem. With experience, you will learn what to look for when you suspect an infestation. For example, the potential for turf-damaging populations of grubs can be estimated by the number of adults either feeding on host plants or physically trapped. Turf that has been ripped up by skunks or raccoons is a good indicator of grubs. The presence of beak holes in the sod from foraging birds is another indication of the presence of grubs. If, while walking over the turf at dusk, you see moths fly up erratically in front of you and then land suddenly, it is a good indication of sod webworms.

Pests are never found evenly distributed throughout the turf, but occur in isolated spots or pockets. Usually certain areas, such as a windbreak area, a low spot that collects extra moisture, or a slope that dries out faster, are more susceptible to infestation than others. Thus, when examining these areas, look for thinning stands, dead or dying patches, chewed or frayed grass blades, or possible webbing and frass (fecal pellets). The best indication of an insect pest problem is the physical presence of the insect. With other indicators, you can only assume that the damage is being caused by a certain pest.

SAMPLING TECHNIQUES

Flotation is a sampling technique that uses water to sample arthropods associated with the thatch area. Take a 6"-diameter (or larger) can and remove both ends. Force one end of the can onto an area suspected of being infested. Fill the can with water and stir. Continue to fill the can with water for

5 to 10 minutes, and observe the arthropods as they come to the surface. This method is used particularly for chinch bugs.

Another sampling technique involves the use of irritants. Irritants are sold commercially and are applied to turf in order to bring insects hiding in the thatch area to the surface. They are used primarily for caterpillar-type larvae, but are not effective in sampling for root feeding pests.

Soil sampling is the most destructive type of sampling but is necessary for determining the presence of soil-inhabiting insects such as white grubs. Cut three sides of a square-foot area of sod from 1/4 to 1/2 inch below the root zone and peel back. Inspect the sod roots and soil beneath for the presence of grubs. To inspect a large area, use a sod cutter to reduce the destructive nature of the sample. A standardized golf-cup cutter can also be used as a sampling tool, but several cuts are required. Upon completion of the sampling, place the sod back, tamp, and water.

Applications of insecticides are warranted only if a certain number of grubs are present. The number of grubs that indicates a problem can vary with the time of year. Make sure that adequate samples are taken before applying an insecticide.

METHODS OF INSECT CONTROL

Turfgrass insect control methods include cultural controls, biological controls, resistant cultivars, and chemical controls.

Cultural Controls

Cultural controls such as proper mowing height, fertilization, soil aeration, and watering are important components of insect control. Well-managed, healthy turf can withstand higher pest populations without serious harm than can turf in poor condition. A turfgrass manager, who provides adequate water with nutrients, good drainage, and sharp mower blades allows the turf to grow to its fullest potential.

Biological Controls

Biological control organisms, or natural enemies, such as pathogens and predators, occur naturally in turf. In most cases natural enemies do not completely control the insect problem, and you may need to apply insecticides. Do so only when necessary, to minimize adverse effects of the insecticide on the natural enemies.

Resistant Varieties

Insect-resistant varieties of turfgrass are rarely available. When possible, select a variety or species that is best adapted to your area. Recently, some cultivars that have been infected with endophytes have shown resistance to insects. Endophytes are fungi that live in the turfgrass tissue and make plant tissues toxic to plant-feeding insects. Endophytes are primarily found in ryegrass and fescue cultivars.

Chemical Controls

Chemical controls, if used correctly, can be a reliable means of controlling insects. The keys to a successful application are knowing your target pest, selecting the appropriate insecticide, timing the application to coincide with the period of peak susceptibility, and correctly placing the insecticide. The objective is to eliminate the need for repeat applications.

Make sure you have identified your target pest. Misidentification can lead to repeat applications and extra costs. When selecting the pesticide, make sure you follow the label instructions regarding rates and site selection. Research in some regions has shown that turf insects have developed tolerance or resistance to certain insecticides. You may want to consult with local experts regarding selection.

Timing of the insecticide application is one of the most critical aspects of pest control. An insect is most vulnerable to chemicals at specific times in its life. Usually, the resting stages of the egg and pupa are unaffected by chemical controls. The active stages of the insect life cycle (larva, nymph, and adult) are usually susceptible to pesticides. The goal is to make an application at the time of peak susceptibility of the target pest.

Placement of the insecticide is important. Most insecticides kill only when the insect comes into direct contact with the insecticide. You may need to manipulate the environmental conditions such as irrigating before a chemical application to get the insects to move toward the surface or watering the chemical in to get it to move through the thatch area.

Many factors influence the effectiveness of chemical controls. Even when you do all the right things regarding a pesticide application, there are factors that can reduce the effectiveness of that application. These factors include thatch, pH of the tank mix, water, and soil, insect resistance, and microbial degradation. A thick thatch layer contains high levels of organic matter, which can bind with the pesticide and limit the penetration of the insecticide, and thus the ability of the insecticide, to reach the target pest. In addition, thick thatch layers may contain microbial organisms that aid in the breakdown of the pesticide. Ideally, you want the insecticide to break down after it controls the pest. Unfortunately, some microbial organisms have the capacity to consume the pesticide at a rapid rate, even before it can control the target pest.

Many of the insecticides available today are affected by extremes in pH. Some organophosphates, for example, are broken down into ineffective by-products when in high-pH (alkaline) conditions. Thus, it is important to read the label and determine the pH of the water used in the mix. If necessary, use a buffer or other additives to adjust the pH.

The best way to avoid insect resistance is to (1) use insecticides only when necessary, (2) spot-treat areas if possible, (3) alternate the chemical classes, and (4) use the minimum dose needed to adequately control the pest.

DEVELOPING AN INSECT CONTROL PROGRAM

In developing an insect control program, consideration should be given not only to current needs, but also to long-term management factors affecting the turf. Factors that influence specific insect problems include insect identification, method of sampling, thatch conditions, safety concerns, and seriousness of the pest problem. When developing an insect control program, consider the following:

- Accurately identify each insect pest; learn about its life cycle.
- Determine which turfgrass species or cultivar is damaged.
- Take enough samples to get an accurate idea of pest population density and distribution.
- Vary level of control with time of year and turf conditions.

- Allow for effects of excessive thatch when applying insecticide.
- Time application of insecticide to most vulnerable stage of pest's life cycle.
- Rotate chemical classes to reduce potential resistance.
- If damage is beyond repair, replace turf with resistant or tolerant cultivars, where available.
- Keep accurate records of infested areas for consideration at later dates.
- Monitor the effectiveness of the program. If an application failed to control the target insect, try to determine why the failure occurred (e.g., timing, too much thatch).

WEED CONTROL

Controlling weeds is the primary objective of many turfgrass pest management programs. The reasons for controlling weeds are that they

- compete with desirable plants for light, moisture, and nutrients
- crowd out desirable plants
- destroy the uniformity and detract from the aesthetic appearance of lawn, park, athletic, and recreational turfs
- are capable of producing large quantities of seeds
- reduce footing and resiliency, and increase the risk of bodily injury on athletic and recreational turfs
- may produce pollen that can cause allergic reactions
- can become a fire hazard along roads and near buildings when the top growth dries
- can harbor undesirable insects and rodents, and provide a favorable environment for the development of disease-causing organisms
- may be poisonous to people, pets, and livestock

The first step in implementing a control program is to identify the weeds.

WEED TYPES

There are two basic kinds of weeds: monocotyledons and dicotyledons. Grasses are monocotyledons, whereas broadleaves and sedges are dicotyledons. Grasses have jointed, hollow stems, leaf blades that are several times longer than they are wide, and parallel leaf veins. All grasses have leaves which attach to the stem in a straight line. Annual bluegrass, crabgrass, and bermudagrass are typical grasses. Broadleaf weeds often have conspicuous flowers. Their leaves have a network of small veins which originate from the major vein that divides the leaf in half. Dandelion, knotweed, and plantain are typical broadleaf weeds. Sedges are grass-like plants with three-cornered stems, and leaves extending in three directions. Yellow nutsedge is an example of a sedge that invades turfgrass.

Weeds can be further classified by their life cycle—annual, biennial, or perennial. Knowing the life cycle of a plant is important in selecting a control strategy. An annual plant begins growth from a seed, produces flowers, and dies in less than a year. Crabgrass and purslane are examples of annuals. Summer annuals germinate in the spring and complete their life cycle during the summer. Winter annuals germinate in the fall and flower the following spring.

A biennial requires two years to complete its life cycle. The plant forms a rosette (dense compact growth) and develops a large root system in the first year, then produces flowers and dies in the second year. Wild carrot and bull thistle are examples of biennials. Biennial weeds are usually easier to kill in their first year, but in their rosette forms are easily overlooked.

Perennial weeds live for more than two years. They are very persistent and can spread rapidly. Most perennials die back to the ground during the winter, then resume growth from buds on the rootstock the following spring. Simple perennials, such as dandelion and plantain, reproduce only from seed. Creeping perennials such as ground ivy and Johnsongrass can reproduce from seed and vegetative structures such as stolons or rhizomes.

Some common annual grasses are large crabgrass, goosegrass, and annual bluegrass. Some examples of perennial grasses are Johnsongrass, orchard-grass, bermudagrass, and nimbleweed. Dandelion, ground ivy, plantain, and black medic are perennial broadleaves commonly found in lawns. Annual broadleaves include common chickweed, henbit, purslane, and spurge.

When first learning to identify turfgrass weeds, particularly grasses, pictures, keys, and other aids are often needed. Some useful publications are listed in the References and Additional Information section.

THE DEVELOPMENT OF WEED PROBLEMS

Most turfgrass weeds develop from seeds that were present, but inactive, in the soil. Some weeds develop from seeds introduced in contaminated topsoil, manure, compost, mulch, turfgrass seed, or sod. Still others develop from seeds carried into an area by wind, equipment, or animals. Regardless of their origin, thousands of seeds are always present in the soil.

Weed Establishment and Competition

In a healthy, dense stand of turf little light reaches the soil surface. Any weed seedlings that do emerge through the soil surface are short-lived because their leaves do not receive enough light for photosynthesis. If, however, favorable light, moisture, and temperature conditions exist, seeds germinate and weeds become established. Once established, weeds compete with surrounding plants for the available light, water, and nutrients. The most aggressive plant ultimately dominates. Broadleaf weeds such as common mallow, field bindweed, and red sorrel have foliage that can shade the lower, narrowleaf grass plants. Without light, turfgrass plants cannot survive.

A given area of soil can provide nutrients for only a limited amount of vegetation. Weeds that have extensive root systems may be more efficient at obtaining nutrients from the soil than turfgrass plants. Plants with broad, flat leaves may also receive more fertilizer from liquid spray applications than narrow, vertically oriented grass blades. By understanding how weeds become a problem, a turf manager is better able to implement successful controls.

METHODS OF WEED CONTROL

Depending on herbicides as the only method of weed control often leads to disappointing results. Controlling weeds is best done with a season-long, integrated approach. Three general methods of weed control include cultural practices, mechanical procedures, and chemical control.

Cultural Practices

Many turf areas contain weeds because they were present in the seed or sod. High-quality, weed-free seed or sod should always be used, particularly to prevent the introduction of difficult-to-control perennial grasses such as quack grass. Study the grass seed label before purchase; it will tell you what percentage of the seed is actually weed seed. Regardless of how a new turf is being established, close attention must be given to ensure adequate water, fertilization, mowing, and control of insects and diseases. Lack of water is a common cause for weak and dead turf, resulting in weed infestation during establishment.

Mowing should be done at the recommended height for the turfgrass. For example, cutting Kentucky bluegrass at the recommended height keeps the turf dense and relatively tall. Shading from the turfgrass stems and leaves protects the roots of the turfgrass plants from summer heat, and deprives weed seedlings of the sunlight they need for growth. If cut too short, however, the turf becomes weak and less competitive, and weeds can become established. Fertilization that provides turfgrasses with the nutrients needed throughout the growing season discourages weeds by keeping plants vigorous and dense.

Damaging infestations of insects or diseases should be controlled. Turf that is injured by chinch bugs or severe leaf spot, for instance, will become thin and susceptible to weed invasion.

Mechanical Procedures

In certain situations, a mechanical procedure may be a practical weed control method. Tillage, which disrupts root systems and buries weeds, can temporarily eliminate germinated annual weeds and seriously inhibit many perennial weeds. Tillage is particularly useful when preparing a seedbed. In some situations, mechanical procedures such as spring and summer aeration or dethatching should be avoided, to prevent the movement of weed seed to the soil surface. This is especially true for cool season turfgrasses, like Kentucky bluegrass, ryegrass, and fescue grasses. Core aeration is best practiced in the fall. To prevent rapid regrowth from the rootstock of perennial weeds such as dandelion and quackgrass, remove as much of the root as possible. Remaining pieces of rhizomes or roots will develop into new plants. Areas left bare from weed removal should be seeded or sodded to prevent reinvasion. Regular mowing can remove the seedheads of some weeds, and reduce the amount and spread of seed in an area.

Chemical Controls

Herbicide use can be a very effective and economical method of controlling weeds. Herbicides can control a broad spectrum of weeds, and are especially useful during turf establishment and renovation. The large number of herbicides available today makes it necessary for turf managers to do some evaluating before determining which product is most appropriate. Most herbicides control more than one weed species, yet some are very specific in the weeds they control. Some may control many broadleaf and grass weeds, while others are effective against annual grasses or broadleaf weeds only.

The performance of any herbicide is dependent upon the environmental conditions before, during, and after the application. Successful weed control with herbicides also requires accurate weed identification, careful herbicide selection, and proper application of the herbicide according to the directions on the label. Improper use of a herbicide can result in poor weed control, damage to turf and other plants, groundwater and surface water contamination, and other problems.

HERBICIDE USE

Once a weed has been identified and it has been determined that herbicides must be part of the weed control program, the next step is to select the appropriate herbicide.

Herbicide Selection

Frequently, two or more herbicides are available that can control the same problem weed. Some factors to consider when comparing herbicides include the type of turfgrass, the risk of injury to the turf or nearby ornamentals and trees, the type of application equipment needed, and the cost of treatment. A turf composed primarily of cool-season turfgrasses such as Kentucky bluegrass and red fescue will require a different weed control program than a turf composed of Bermuda grass or zoysiagrass. Turfgrass species vary in their sensitivities to herbicides. Check the label carefully for restrictions concerning the use of a herbicide on specific turfgrasses.

Another important consideration is the timing of a herbicide application in relation to the stage of growth of the weed and the turf. A preemergence herbicide kills emerging weed seedlings, and is applied to an existing turfgrass area before weed seeds germinate. A postemergence herbicide is applied to growing weeds after they have emerged from the soil. A preplant application is made to eliminate certain problem weeds before the turfgrass is planted. The control strategy using herbicides depends on the particular weed problem. Control strategies are usually separated as follows: controlling annual grasses, controlling broadleaf weeds, and controlling perennial grasses.

Controlling Annual Grasses

Because of their similarity to desirable turfgrass species, control of annual grasses such as crabgrass, annual bluegrass, and goosegrass in established turf is difficult, once the weeds become established. Preemergence herbicides are commonly used to control annual grasses. These herbicides, effective only against plants that are just beginning growth from seeds, must be applied early in the spring or fall before the seeds begin to germinate. They are applied and incorporated into the soil one or two weeks before seed germination is expected, and remain in the soil for several months. Crabgrass seed germination normally begins when the soil temperature near the surface reaches 60° F. Applying most preemergence herbicides after weed emergence will have little or no effect on the seedlings.

Preemergence herbicides must reach the soil in order to be effective. They must be applied without skips or streaks in order to establish a uniform chemical barrier in the soil. Plant debris or compost that has been spread on the soil surface can intercept spray applications, or adversely affect the distribution of granules. To ensure the herbicide reaches the soil, surface debris can be removed, or the herbicide can be incorporated into the soil during or after application.

Preemergence and other soil-applied herbicides are degraded by sunlight and microorganisms during the summer months. The rate of breakdown and the length of time a given herbicide will prevent annual grass establishment cannot be predicted with absolute certainty because it is dependent, in part, upon weather conditions. In general, warm, moist conditions favor the breakdown of organic pesticides. If weather conditions favor a faster than normal breakdown of a preemergence herbicide, a turf area could be infested with late-germinating annual grasses such as crabgrass that may have a long season for germination in certain areas.

Labels provide specific restrictions and recommendations for using preemergence herbicides. Some general guidelines include the following:

- Wait two to four months after a preemergence herbicide has been applied before seeding; read the label for the time that must elapse before it is safe to seed.
- Do not use a preemergence herbicide at the time of turfgrass seeding, unless that is a labeled procedure.
- Wait until new turfgrass seedlings have been mowed three times before applying a preemergence herbicide.

- Do not apply a preemergence herbicide to the soil prior to laying sod.
- Do not dethatch or severely cultivate the soil surface after applying a preemergence herbicide. Som › research has shown that leaving the cores from core aeration on the turfgrass surface can reduce annual weed control.

Postemergence herbicides for controlling crabgrass and other annual grasses are also available. In the past, postemergence herbicides have not been as effective as preemergence herbicides and have caused discoloration and thinning of desirable grasses. New materials are available which are more effective and less harmful to desirable plants.

Controlling Broadleaf Weeds

A large number of herbicides are available to control annual and perennial broadleaf weeds in turf. Although some preemergence herbicides will control certain summer annual broadleaf weeds, postemergence herbicides are most commonly used to control broadleaf weeds.

Most of the herbicides used for postemergent control of broadleaf weeds are systemic and foliar. They must remain on the weed foliage long enough to allow an adequate amount of chemical to penetrate the leaves (several hours to a full day). If it rains before enough time has elapsed, weeds may not be affected by the application. Postemergence herbicides are most effective when weeds are young and actively growing and will readily translocate the chemical within the plant. Adequate soil moisture, high humidity, bright sunshine, and air temperatures between 65° F and 85° F favor weed control. Control of biennial and perennial weeds is generally most effective if herbicides are applied in the spring to early summer or in the fall.

Summer annual weeds (e.g., prostrate spurge, pigweed, lambsquarter) can be very difficult to control because they have multiple germination periods, and can geminate over a period of several weeks to several months. In addition, the thick, waxy leaf tissue that summer weeds develop in order to slow water loss makes it difficult to get a broadleaf herbicide inside the weed as it matures. Nonpesticide approaches such as mowing high, watering deeply, providing adequate fertilization, and reestablishing thin portions of a turf should be considered.

Read labels carefully for instructions when using postemergence herbicides. Additional guidelines include the following:

- Avoid applications when rain is expected; if rainfall occurs soon after application, another application may be necessary.
- Delay mowing a treated area for at least three days after application.
- Delay applications to newly seeded areas until the grass has been mowed at least three times.
- Delay seeding bare spots left by weeds until three weeks have passed and the area has received rain or irrigation to favor any herbicide remaining in the soil.
- Delay applying a herbicide to a newly sodded area for four to six weeks.
- Carefully operate application equipment and monitor weather conditions to prevent spray drift and herbicide volatilization during application.

Controlling Perennial Grasses

Undesirable perennial grasses are usually the hardest weeds to control. If only small, scattered areas of the weeds are present, manual removal may be possible. Because perennial grass weeds are so similar to turfgrasses, herbicides that kill the grass weed will also kill the turf. However, there are selective postemergence grass herbicides scheduled to be marketed soon. The most effective method of controlling a large infestation of a perennial grass is to spot-test the infested area with a selective or nonselective herbicide. Complete turf renovation may be the best choice, if a large area is infested. Before reseeding or resodding a treated area, it may be necessary to wait several weeks to allow the herbicide to break down. The residual activity of different nonselective herbicides varies.

Factors Influencing the Effectiveness of Herbicides

Herbicide failures do occur, usually as a result of weather conditions or improper use. Some of the most common reasons for weed control failure are described below.

1. If a herbicide is applied at a rate lower or higher than the recommended rate, it may not kill the targeted weeds. When the application rate is too low, weeds may be injured but continue to grow. When the rate is too high, particularly with systemic foliar herbicides, the chemical will burn weed leaves, but little will be translocated through the plant. Applying a herbicide at a higher-than-recommended rate also increases the chances that the

herbicide will leach into the soil to nontarget plants and to groundwater. It is also illegal to apply herbicides at a higher rate.

2. If it rains within four to eight hours after application of a systemic foliar herbicide (for some chemicals, within 24 hours), the chemical may be washed off the plants before enough can be absorbed by the plant.

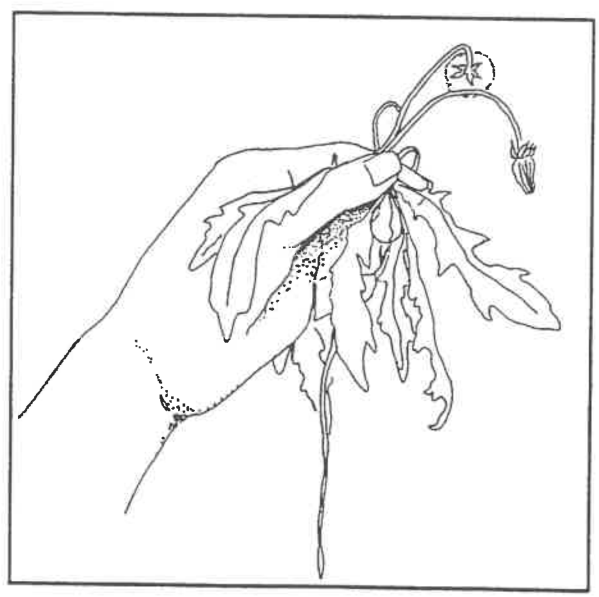
3. If weeds are not actively growing, or are dormant because of weather extremes (too dry, too hot, too cold), they will not absorb herbicide through their foliage or roots, and will not translocate it throughout the plant.

4. If herbicides leach or are incorporated too deeply into the soil, they may go beyond the reach of weeds, but remain within the reach of desirable plants.

Herbicide Tolerance

Selected weeds have become tolerant to herbicides that have been repeatedly used for their control. Frequent applications of the same herbicide result in the selection of individual plants that are tolerant. When these plants produce seeds, the new generation of weed species also shows tolerance.

As turfgrass manager, you can slow the tolerance process down by (1) reducing the number of herbicide applications, (2) alternating applications with different classes of herbicides, (3) minimizing the reproductive stage of the weed by using mechanical control methods, and (4) using an integrated approach to weed control, including mechanical control, physical barriers, and cultural controls.



DEVELOPING A WEED MANAGEMENT PROGRAM

Factors that will influence specific weed control decisions include time, labor, expense, safety concerns, prevailing social attitudes, weather, soil characteristics, and the seriousness of the weed problem. Steps for developing a weed management program are outlined below.

- Determine what types of turfgrass are present.
- Identify the problem weeds and note what time of year they occur. Past records of weed problems and weedy areas will help you to stay one step ahead of problem weeds.
- Determine what level of control is appropriate, both economically and aesthetically.

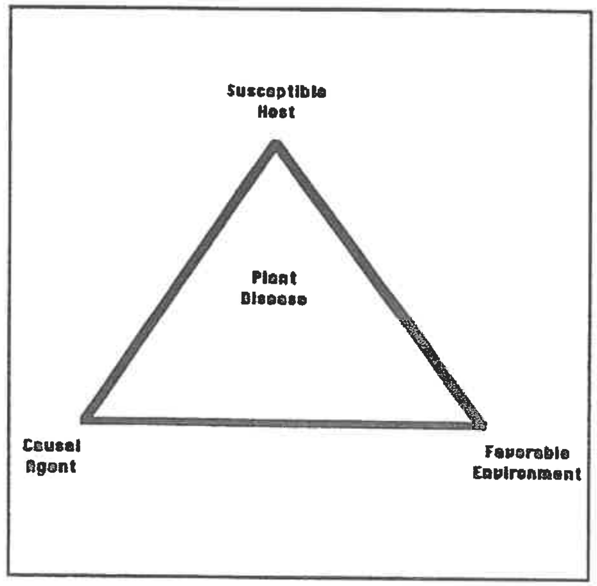
For many areas, such as campgrounds, roadsides, low-use park areas, and many commercial and home lawns, complete weed control is unnecessary and impractical. Once the goal has been determined, appropriate control measure can be selected.

- In most cases, weeds are the result of a poor turf, and not the cause. Determine why the weeds invaded the turf, and correct the conditions or cultural practices that caused the problem. Some weeds are very specific in their site requirements, and can provide clues about a particular site. For example, ground ivy, violets, oxalis, chickweeds, and moss are very shade-tolerant; knotweed grows in compacted soils; prostrate spurge grows in hot locations with high soil temperatures (e.g., along sidewalks and driveways).
- Follow a good turf management program. The most effective, long-term solution to minimizing weed problems is proper turf maintenance. If herbicides are not accompanied by basic improvements in the turf management program, weeds will probably reinfest the area, or be replaced by other weeds that are more difficult to control. A healthy, dense turf will naturally suppress weeds.
- If a herbicide is needed, select a chemical that is effective for the weeds and safe for the turfgrass, follow all label directions, and apply the herbicide at the correct time and rate. Survey the site for sensitive areas, and consider the factors discussed in other chapters regarding drift and off-site movement of pesticides.
- Include an adjuvant in the spray mix if it will enhance the effectiveness (spreader-sticker) or reduce the potential hazard (drift control agent) of the application. Use equipment that is in good working order and calibrated properly.
- Monitor the effectiveness of the program. If an application failed to control the target weeds, try to determine why the failure occurred so you can avoid repeating the same mistakes. Be on the lookout for herbicide damage to desirable plants. In some instances, damage may warrant a change in application rate or an alternative herbicide.

DISEASE CONTROL

A plant disease is a harmful change in the growth of a plant. The causes of plant diseases may be broadly divided into two basic groups: abiotic and biotic. Abiotic (nonparasitic) diseases are caused by unfavorable growing conditions, such as too little or too much water or fertilizer, improper light, temperature extremes, or injury from machines or chemicals. Biotic (parasitic) diseases are caused by plant pathogens, such as fungi, bacteria, nematodes, viruses, and mycoplasmas that can multiply and spread from plant to plant.

DISEASE DEVELOPMENT—THE DISEASE TRIANGLE



The occurrence of a biotic disease requires that the disease triangle be complete. The components of the disease triangle are a causal agent (pathogen that is capable of causing disease), a susceptible host, and favorable environmental conditions for disease to develop. A disease will not develop unless all of these are present for a specific time.

Causal Agents (Pathogens)

The most common and severe diseases of turfgrasses are caused by fungi. Fungi are thread-like forms of plant life that are incapable of manufacturing their own food, and live off dead or living plant and animal matter. Fungi reproduce by forming spores or other microscopic structures. Fungi can be spread by wind, water, mowers, and other equipment, and infected plant parts such as grass clippings.

Susceptible Host Plants

Just as humans are more vulnerable to illnesses when they are weakened from fatigue or malnutrition, turfgrasses are more susceptible to infection by disease-causing pathogens when they are stressed. Drought-stressed turf is more susceptible to damage from dollar spot. Turf that is mowed too short is weakened and made susceptible to leaf spot. Fertilization is also an important factor in disease development. Dollar spot, red thread, and rusts are more severe on nitrogen-deficient turf; brown patch and Pythium blight are more severe on heavily fertilized turf.

Turfgrass species and cultivars vary in their susceptibility to diseases. Many grasses sold are resistant to one or more diseases.

Favorable Environmental Conditions

Light, temperature, and moisture influence not only the health of turfgrass plants and their ability to resist diseases, but the growth of pathogens. Moisture is necessary for the reproduction, spread, germination, and infection of disease-causing fungi. With some 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.

Fungi also have specific temperature ranges within which they are active. The fungi that cause snow mold are active only during cold weather, whereas the fungi that cause dollar spot and red thread are most active during warm weather.

DIAGNOSING TURFGRASS DISEASES

Fungal diseases are only one cause of turf loss. Disease control measures will do nothing to alleviate damage from other causes, such as insects or drought stress. Control of any turfgrass disease depends on accurate diagnosis. Disease management strategies that are effective against one disease may have no effect on, and may even worsen, another disease.

Nature of Disease Symptoms

Look for two types of disease symptoms in diseased turfgrass areas: symptoms in the turfgrass stand and symptoms on individual plants. Stand symptoms are the visible patterns of the disease within the site. They can appear as spots, patches, rings, or circles, or they may lack a pattern. For example, certain diseases never appear as rings, while others almost always appear as rings.

Symptoms to look for on individual plants include leaf spots, leaf blighting, wilt, yellowing, stunting, and root rot. Leaf spots can be great diagnostic clues, since leaf spots of different diseases are usually unique in shape, color, and size. Take note of the grass type that is affected, and whether surrounding weeds are also showing symptoms. Many turfgrass diseases caused by fungi do not affect weeds and affect only specific grass species.

Signs of the Disease

Signs of a disease are evidence of the pathogen that caused the disease. The "green stuff" on moldy bread, for example, is the sign of a mold fungus. The fungi that cause most diseases are microscopic. But with stripe smut, powdery mildew, and rust diseases, the spores of the causal fungi pile up in such numbers they become visible on grass blades as black, white, or orange powder. With the disease red thread, the fungus sticks together and forms pink or red antler-like threads. This sign is a typical diagnostic feature of red thread. When the causal fungus can be seen, its appearance is often the most important clue for disease diagnosis. Some fungi can only be seen in the early morning, or during periods of high moisture.

Environmental/Site Conditions

Environmental conditions at the onset of the disease problem are vital sources of information. What were the temperature and moisture conditions just prior to and during disease development? The nature of the disease site may provide valuable information. Air and water drainage, soil conditions, sun/shade, slope, and the nearness of other plantings or buildings all may play roles in the development of turf disease. Prior applications of pesticides and fertilizers can contribute to disease development, as can thatch accumulation and poor mowing practices.

DISEASE CONTROL METHODS

Managing turfgrass diseases involves altering conditions to favor the grass and inhibit the causal fungus.

Cultural Practices

The cultural methods or environmental changes needed to control a disease depend on the specific disease involved. For example, some diseases require leaf wetness for development. Reducing the period that leaves remain wet by switching to morning irrigation, removing dew, or reducing the amount/frequency of irrigation may reduce disease occurrence.

Improved air circulation and water drainage also discourage weed development. Reducing thatch, increasing sunlight, regulating fertilizer applications, and mowing properly are methods for reducing diseases and ensuring vigorous turf recovery from disease damage.

Resistant Varieties

Seeding with disease-resistant grasses is an excellent way to minimize turf loss from disease. Certain varieties of Kentucky bluegrass are resistant to leaf spot, a devastating disease on many Kentucky bluegrass turfs. When establishing new turf areas or renovating disease-damaged turf, select grasses resistant to the disease that damaged the existing stand and to diseases that are common in the area.

If a resistant variety or a particular grass species is not available, it may be possible to use another grass species that is resistant to a prevalent disease. For example, ryegrass may replace bluegrass in an area that has been damaged by a patch disease, or tall fescue may replace ryegrass in an area where Pythium blight is a problem. Disease severity can often be reduced by changing the grass that is being grown. It is a poor practice to continue to replant the same grass that has been killed by the same disease year after year.

In selecting grasses for turf establishment or renovation, it is preferable to use mixtures of different grasses, or blends of different varieties, rather than a single species. Using mixtures or blends produces a diverse population of grass plants that is often more successful in surviving stress and attack by disease.

DEVELOPING A DISEASE MANAGEMENT PROGRAM

Almost all the major turf diseases of Arizona home lawns and recreational areas are caused by fungi. Planning an effective disease management program involves, not only experience but selecting cost-effective disease control strategies. Following are some management ideas for planning a disease management program.

- Consider all aspects (the how, why, and when) of the disease problem before making a decision about control tactics. A change in weather conditions or cultural practices (e.g., changing irrigation schedule) often will reduce fungus activity, and promote turfgrass recovery from disease damage. Remember that more problems with turfgrass health are due to unfavorable growing conditions than to plant pathogens.

- Establish disease tolerance levels based on turf areas and the amount of disease that is acceptable. For example, on a golf course green very little disease damage can be tolerated on the putting surfaces. More disease can usually be tolerated, however, on golf course fairways and roughs. Athletic fields may need to be relatively disease-free to ensure their recovery from intense wear. In all areas where some amount of disease can be tolerated, the potential of a particular disease to kill large areas of turf must be kept in mind. Melting-out, Pythium blight, and the patch diseases can cause severe and disfiguring damage to turf. On the other hand, slime mold is unsightly, but does no permanent damage, and treatment is not necessary. Set up goals and priorities for the disease control program and try to adhere to them.

- Consider all avenues of disease management. Frequently, the only course of action considered by the turf manager is using a fungicide. Most disease situations on home lawns and landscape turf can be adequately managed without fungicides. Alterations in cultural practices, renovation with resistant cultivars or species, or even very simple procedures can help. Slime molds, for instance, are best controlled by spraying the turf with water from a hose to remove the fungus from the grass blades.

- Measure the cost-effectiveness of each procedure. Evaluate each disease control method in light of what you get for your investment. Determine the effectiveness of disease treatments and, when possible, consider alternatives such as overseeding with resistant grasses or changing irrigation or fertilization practices.

- Keep accurate disease records to help you develop a disease history of the turf area and anticipate outbreaks. Prevention is the key to good disease management. Implement preventive measures, whenever appropriate,

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SAMPLE TEST

QUESTIONS

1. Pesticides should be used as a(n) ______________ in turfgrass management, not as a substitute for good cultural practices.

2. When selecting a turfgrass cultivar for a specific site, you should consider the intended use of the turf. True or False?

3. A key aspect of maintaining vigorous turf is mowing at the correct height at regular intervals. True or False?

4. Thatch may provide favorable environments for disease and insect pests and may reduce the effectiveness of pesticides. True or False?

5. ______________, ______________ watering should be avoided (except during turfgrass establishment) because it promotes shallow root systems, which can lead to increased incidence of weeds and diseases.

6. Turf grown in shady areas is usually more vigorous. True or False?

7. The sampling technique of flotation/irritants/soil sampling is a method that uses water to sample arthropods associated with the thatch layer.

8. A postemergence herbicide is applied to growing weeds before they have emerged from the soil. True or False?

9. The most effective, long-term solution to minimizing weed problems is ______________________________.

10. The three components of the disease triangle are ____________________, ____________________, and ____________________.

ANSWERS

1. aid 2. true 3. true 4. true 5. light, frequent 6. false 7. flotation 8. false 9. proper turf maintenance 10. causal agent (or pathogen), susceptible host, favorable environmental conditions

CHAPTER 3 ORNAMENTAL PLANT MANAGEMENT AND PEST CONTROL STRATEGIES[1]

INTRODUCTION

Ornamental plants are grown for their aesthetic value, and therefore are more valuable to one person than to another. When ornamental plants are damaged in any way, their aesthetic value decreases. Various pests of ornamental plants can cause considerable damage when they occur in high enough populations. These pests include disease agents, weeds, insects, and mites. Other plant problems may stem from cultural mismanagement such as causing injury during transplant, or from environmental conditions such as too wet a climate for that particular plant. Most often, however, it is a combination of problems that leads to a plant disorder.

This chapter will cover the basic elements of ornamental plant selection and management. Plant management practices influence a plant's health, susceptibility to pest attack, and ability to recover from pest damage. Also covered will be the basics of diagnosing and managing pest problems caused by insects, mites, diseases, and weeds. Pest problems often occur when plant selection or plant management techniques are done incorrectly. A pest control strategy is then needed. Integrated pest management (IPM) is the use of various pest control tactics to form a strategy to reduce pest populations (or their damage) to an acceptable level. The benefits of an IPM strategy are many, including pest control with less probability of complications such as pesticide resistance or harm to nontarget organisms.

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[1]Much of the material for this chapter has come from the *Pesticide Applicator Training Manual; Category 3, Ornamental and Turf Pest Control*, written by Cynthia L. Brown and published by the University of Delaware College of Agricultural Sciences, 1990. Other sources include *Recertification Manual for Commercial Applicators: Ornamental Plant Pest Control; Category 3B*, compiled by Joy Neumann Landis and published by Michigan State University, 1989; *Ornamental Pest Control: Category 3A*, compiled by Donald C. Cress and published by Kansas State University, 1986; and various extension publications from The University of Arizona.

ORNAMENTAL PLANT MANAGEMENT

HOW A HEALTHY PLANT GROWS

To diagnose plant problems, it is necessary to understand how a healthy plant grows. The symptoms of pest damage appear when a normal plant process or function is disrupted.

A healthy root system is essential for optimum top growth. Roots will not grow in soil that lacks adequate oxygen or is hard and compacted. Root growth flourishes in soils that supply adequate oxygen, water, nutrients, and warmth. Stems are the framework that physically supports the leaf canopy and connects the roots and leaves. They also store food manufactured by the leaves. The primary function of leaves is to manufacture the sugars that all other parts of the plant require. The chloroplasts manufacture sugar and give the leaves their green color. The plant's flowers are for reproduction. Most plants have complete flowers that have both male and female parts and so are capable of producing fruits.

Proper plant growth depends on all plant parts functioning in balance with each other. Injury to the roots, for example, will lead to injury in the leaves. Continued injury to the leaves can lead to reduction in root growth.

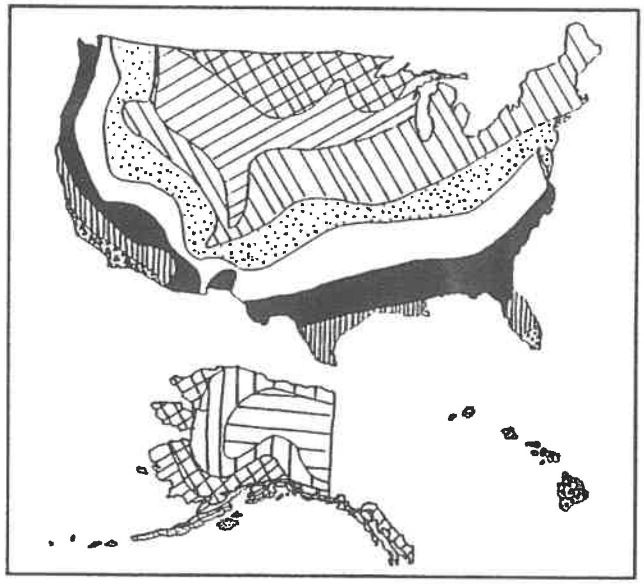
CULTURAL PROBLEMS

Plant disorders caused by cultural problems arise from the improper care of plants. Management practices such as plant selection, planting, watering, fertilizing, and pruning may cause plant problems if done improperly.

Landscape managers must plan and conduct activities that allow plants to remain healthy and growing. Some of these activities, and their effects on pest development, are described below.

Selection

Woody landscape plants such as Arizona ash, cottonwood, palo verde, acacia, and desert willow are generally selected for a variety of aesthetic, functional, and cultural reasons. Other factors should be considered, however, to ensure that plants thrive and remain attractive for a long period of time. A plant that is not suited to the soil, drainage, and exposure conditions found where it is planted, is much more likely to encounter serious insect and disease problems than one that is.



All landscape plants are assigned hardiness ratings that indicate the coldest zone in which they can thrive. Selecting hardy plants eliminates an important source of stress that increases plant susceptibility to insects and diseases. Any given area within a zone can have its own microclimate. For example, zone 8 conditions (average annual minimum temperature range of 10° to 20° F), may be created within a zone 7 (average annual minimum temperature range of 0° to 10° F) if a tree is planted beside a white brick wall (reflects heat and provides shelter) or within a fenced yard (provides shelter). The survivability of any plant varies with its microclimate.

Careful plant selection should also consider pest resistance. By selecting a resistant cultivar, the manager can reduce pest attacks and the costs of pest management.

For a plant to live successfully in Arizona throughout the year, it must be able to tolerate extremes of temperature as well as severe solar radiation and aridity. During the summer in southern Arizona, leaf surfaces in direct sunshine reach temperatures of 120° F or more, yet the same leaf may have to withstand a winter nighttime low temperature of 12° F for a few hours. Generally, those plants that can best withstand such extremes are those which are found growing naturally in the area. Plants from other parts of the country are severely stressed by these extremes and require extra care and attention if they are to survive.

Planting

Plant location is very important. Shaded locations cut summer stress for heat- and sunlight-sensitive plants. Eastern exposures or open areas are generally preferred for blooming plants. Southern or western exposures are subject to direct, intense sun—plus reflected heat and sunlight. Because walled areas of these hot exposures hold and build up additional heat, only very heat-tolerant plants can survive there. Also, consider draft and wind exposure when positioning plants whose foliage may be particularly subject to burn by hot, drying air movement.

Spring and fall are generally the best times to plant trees, although, if handled properly, trees can be planted any time of the year. Desiccation is one of the most common reasons new trees fail in the first season after planting. Any cultural procedure that reduces water loss, or increases water uptake, will improve the chances of transplant survival. New plantings should never be allowed to dry out, but they should not be overwatered either. Plant roots require oxygen in the soil for good growth. If soil is saturated with water for long periods, the roots die.

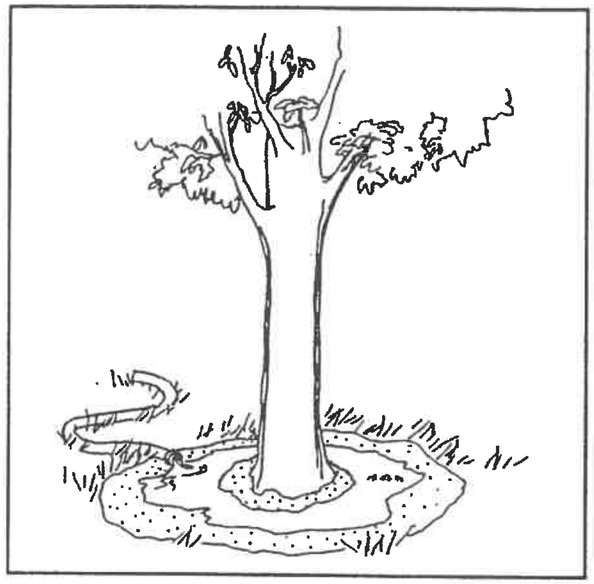
When a recently transplanted shrub or tree fails to grow and the cause cannot be associated with drought, excessive moisture, or insufficient roots, the plant may have been injured before planting. It may have become dehydrated while in storage or in transit, or it may have been subjected to unusually high temperatures.

To enhance drainage, woody plants should be planted at the same level in the soil where they were originally growing, or slightly above grade. Newly planted trees and shrubs can be mulched with shredded hardwood bark, compost, or a similar material; a 3- to 4-inch layer of mulch is usually sufficient for one season. Mulch should not be placed next to plant trunk or stem. Overmulching may suffocate the roots of shallow-rooted plants. It can also lead to crown rot and provide shelter for insects and rodents.

Remove injured or diseased branches that can serve as points of infection for many diseases. Wrapping new plants with tree wrap can provide protection from sunscald and rodent attack. To avoid girdling problems, tree wrap should be removed after one growing season.

Watering

Irrigation is a must in order to maintain good plant vigor during hot, dry summers. Proper watering year round to favor deep, extensive rooting is the key to summer hardiness. Be particularly careful not to overirrigate during cooler seasons. Too much water drowns roots needed to supply enough water and nutrients to the plant during its peak summer needs.



Encourage root growth beyond the canopy drip line. Newly planted trees must be watered well at the time of planting. Later waterings are based on plant needs. Apply water slowly to allow it to soak into the soil; wet the soil thoroughly to encourage development of a uniform root system; and water early in the day to prevent certain foliar diseases. Do not overwater. Plants with water-logged roots often contract root-rotting diseases.

Drought stress is a common problem in landscape plantings. Wilt is often reversible if sufficient water is supplied. However, if water is not supplied, a permanent wilt can result. In deciduous trees, water stress will kill back young stems and, eventually, large branches. Wilted leaves dry up, turn brown, and often remain attached to the plants for some time. Evergreens respond to drought by dropping older foliage or needles prematurely. Before deciding whether or not to irrigate, check the soil for moisture in the root zone, and not just at the soil surface. Quick summer showers may not supply adequate moisture to deep roots.

Scorch causes a marginal or interveinal browning of leaf tissues. It is a common problem on warm, windy days, when trees lose more water through their leaves than they can replace through their roots. Recently planted trees and root-injured trees often develop scorch symptoms first. Trees rarely die from scorch, but it may be a sign of potentially more serious problems.

Do not spray, wash, or get sprinkler water on hot, drought-affected plant foliage. The shock can cause foliage burn or leaf drop. Leaves are coolest during early mornings, so spraying or washing plants at that time of day is permissible. Generally it is better not to get water on the foliage of palms and cacti. Wetness can cause them to get rots.

Drainage water from evaporative coolers or swimming pool water should not be used regularly for irrigation because of its increased salt content. Occasional use on desert-adapted trees, shrubs, and grass normally causes no problem.

Fertilizing

Vigorously growing plants are more attractive in appearance and recover more easily from insect and disease infestation than plants that are weakened or growing slowly due to insufficient amounts of nutrients. Trees and shrubs can be fertilized in the spring or fall. Late summer fertilization is often discouraged on frost-sensitive plants because it can result in a flush of fall growth that may not have sufficient time to harden off before the first frost. Hardy trees and shrubs should be fertilized in late summer. A soil test is usually recommended before applying nutrients, especially if a soil fertilization program has been in effect. Stunting, yellow, mottled, or scorched foliage, or plant death can result from a nutrient deficiency. Plant symptoms can sometimes be used to recognize a nutrient deficiency, but this is complicated by the fact that virus diseases, overwatering, and high salinity, among other problems, can cause similar symptoms.

Fertilizing during hot weather should be done cautiously. The accelerated living processes of plants during hot weather use up nutrient reserves faster. However, rapid uptake of fertilizers by summer-active roots may result in fertilizer burn. Increase the fertilization frequency, but decrease the amount applied each time. Fall fertilization helps plants recover from summer exhaustion. Early spring (before budbreak) fertilization encourages strong growth to better withstand summer stress.

Most plants grow well in a soil with a pH range of 7 to 8.5. Some plants have very specific pH requirements and will become chlorotic if certain micronutrients are unavailable. In severe cases, the leaves curl and turn brown along the margins, or develop angular brown spots between the veins. Iron is most readily available to plants at a lower soil pH. The treatment for iron chlorosis is often an application of sulfur to temporarily lower soil pH and to enhance iron uptake.

Pruning

Pruning improves appearance, ensures plant health, and removes dead branches that become a safety hazard. When pruning trees, do not cut the central leader. Rather, thin out and help shape the tree or shrub in its natural form. Always remove dead, dying, and broken branches as soon as possible to minimize the chances of attack by insect and disease pests. Remove all crossing or rubbing branches to avoid bark wounds, which can serve as entry sites for insects and disease-causing organisms. Narrow-angle or V-shaped crotches are weak and should be removed before they become heavy enough to split the trunk below the crotch.

Pruning is best done when plants are dormant, although diseased and dead branches should be removed as soon as possible. Whenever possible, avoid pruning tender spring growth to prevent tearing new bark tissue and providing wound sites for pests to enter. Also avoid pruning during wet periods, particularly in the spring and fall, when diseases are active and can spread readily to other plants. The use of pruning paints or sealers may be ineffective and may encourage disease development.

Winter Protection

Plants injured by winter desiccation or low temperatures can be weakened and made more susceptible to infestation by insects and diseases the following year. The first step to avoiding winter damage is to select plants that are winter-hardy for your area. Avoid late-summer pruning, which can force soft, succulent growth that may not have time to harden off before winter. Water plants well before the soil freezes (if it does so in your area). Mulch can help keep soil moisture and temperature levels even, and prevent rapid and damaging changes. Carefully located windbreaks, burlap protection structures, or other insulating material can help protect plants from winter desiccation.

Salt Tolerance

Southern Arizona's dry climate, layered soils, and in some areas, high sodium levels often lead to soluble salt problems in the landscape. Poor watering practices and the use of salty irrigation waters during a warm, dry, and relatively long growing season can intensify the problem.

Symptoms of salt injury to plants often look like drought injury. In fact, salt damage is sometimes called physiological drought. Growth may simply appear stunted and dark blue-green, but in more severe cases plants show leaf burn, leaf drop, and twig die-back.

When watering, the following procedures will help prevent salt accumulation in plant root zones:

- Check soil moisture before applying water. Dig a small, 4- to 6-inch hole in the ground. If soil appears moist at this depth, do not irrigate until it's dry to the touch. Overwatering can aggravate chlorosis.

- Treat plants showing symptoms of lime-induced chlorosis (leaves have green veins and yellowing between veins) with special compounds containing sulfur, iron, and acidating materials.

Other Factors

The girdling of trees can cut off the nutrient and water supply to the upper parts of a plant and lead to the death of plant parts or entire plants. Girdling can be caused by lawn mowers, weed-eating devices, and other machinery. For this reason, turfgrasses and weeds around the bases of trees should be eliminated to reduce the need to use equipment near them. Wires and ropes used for stabilizing trees can cause girdling and should be removed after one growing season. Twine and burlap not removed at planting can eventually girdle a tree. Roots can also girdle plants. At the time of planting, the root system should be distributed in the planting hole and should not include any encircling roots.

Vertebrate animals of all kinds can cause considerable damage to plants. Girdling of stems by certain rodents and rabbits is common, especially during severe winter weather. Rabbits chew the bark of young plants, and deer eat the foliage, bark, and tender shoots of plants. The most common type of injury caused by pets is urine burn on shrubs. The urine of male dogs can cause browned or blackened areas on the lower parts of evergreens. The most effective method for preventing injury by animals is fencing, although repellents may work for some animals.

The construction of buildings, driveways, and sidewalks and the installation of steam, water, telephone, and gas lines can contribute to the slow weakening and death of trees, as a result of grade changes, soil compaction, mechanical injuries from equipment, and severed roots. The addition of as little as 2 inches of soil above the active root system of a tree can reduce soil oxygen enough to cause plant stress. Disturbing the roots of red maples, for example, will often result in their showing early fall color, and in the eventual death of branches, followed by death of the trees. If existing trees and shrubs are to be saved on a construction site, care and attention must be paid to avoid disturbing them. Remember that a tree's or shrub's root system extends well beyond the dripline of the plant.

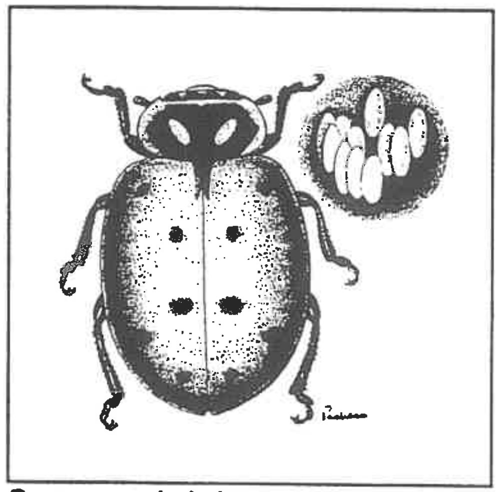
Injury to plants in a landscape can also be caused by air pollution, natural gas leaks, field effluent from septic tanks, de-icing salts, pesticides, and fertilizers.

INSECT AND MITE CONTROL

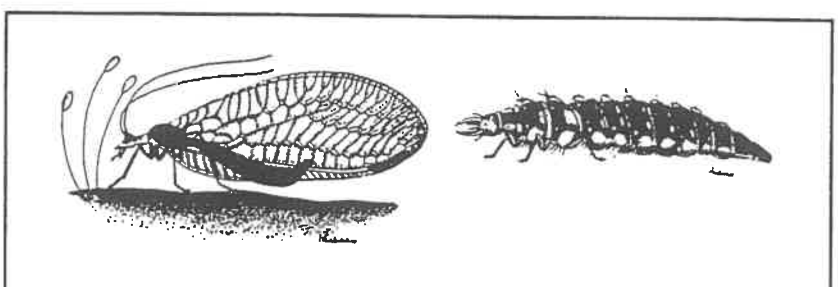
Many different kinds of insects and mites feed on trees and shrubs. Generally, the greater the variety of plants in the landscape, the greater the variety of insect and mite species encountered. The mere presence of an insect or mite on a tree or shrub does not mean there is a problem that has to be controlled with insecticides or miticides. Some plants require constant attention, while others are relatively free of insects and mites.

Inspection. Regardless of the situation, the surest way to prevent serious pest problems from occurring is to maintain a regular inspection schedule. This means carefully examining ornamentals for signs of damage or infestation on (and under) leaves, buds, flowers, branches or stems, crowns, and even in the root zone, when warranted. If plant numbers or planting areas are too large for checking each plant, systematically sampling a few representative plants in each part of the entire operation on a regular basis will, in most cases, be sufficient.

Natural Control. Parasites such as wasps, predators such as lady beetles, lacewings, and other organisms such as insect diseases play an important part in keeping most insects and mites under control during most years. These natural forces may break down during some seasons, especially when chemicals used to control other pest problems kill natural enemies. In these cases, the use of pesticides or other artificial control measures may be necessary.



Convergent lady beetle and eggs



Lacewing adult, eggs, and larva

Proper management of pests begins with knowing which insects and mites are most damaging in a specific area, which are likely to attack a particular kind of plant, and when they usually begin to cause damage. Once a suspected pest is identified, more can be learned about its life cycle, damage potential, importance, and control options.

ORNAMENTAL INSECTS AND MITES

Insect and mite pests of ornamentals can be divided into groups based on feeding site and type of damage caused. For discussion purposes, pests have been divided as follows: leaf-chewing insects, plant-sucking pests, gall-forming pests, root-feeding insects, and wood-boring insects. Grouping pests in this way can be useful in diagnosis and in the development of management programs.

Leaf-chewing Insects

Leaf-chewing insects, such as elm leaf beetles, flea beetles, and darkling beetles, have mouthparts that are adapted for chewing plant tissue. The long-term effects on plant health that result from the loss of foliage depend on the age and vigor of the plant, the extent of the feeding and how repeatedly it occurs, and the time of year. Many deciduous trees, for example, can tolerate up to 50% defoliation without serious effects. Some healthy trees can be completely defoliated in one season and not die. Repeated defoliation for several years in a row, however, can be fatal. Late-season defoliation of deciduous trees and shrubs is usually of less concern than early-season defoliation. Late in the season, the food necessary for growth has already been produced and stored, and the plant is shutting down for the winter. Evergreens can be seriously affected by heavy defoliation, because they replace only a portion of their total amount of foliage each year. Conifers usually die after one complete defoliation.

Plant-sucking Pests

Many different species of insects and mites have mouthparts adapted for sucking the sap from plants. Aphids, mites, white flies, and scales, for example, do not chew leaves, flowers, or stems, but rather injure plant tissues by sucking out plant juices. This usually results in the chlorosis or bronzing of leaves and a reduction in plant health and vigor. Sucking pests can also transmit disease-causing organisms.

Gall-forming Pests

A gall is an abnormal growth of 'eaf, stem, or twig tissue caused by the presence of a gall-making insect or mite. Most galls are produced during late spring on new growth, and do not cause serious damage to the host plant. The eastern spruce gall adelgid (an aphid relative), however, produces unusual purplish, pineapple-shaped galls that can retard growth, cause disfiguration, and in some cases, kill host trees. Oaks, ash, juniper, hackberry, pine, and oleander frequently have galls.

Under most circumstances, control of galls is not recommended. Most galls are produced by insects that move to the trees as new growth develops and can be controlled only by insecticides that cover the leaves when the eggs are being deposited. Once a gall is formed, pesticides will not control the pest.

Root-feeding Insects

A common root-feeding insect that attacks many plants is the white grub. Plants infested with white grubs will appear off-color and in general poor health. Newly transplanted stock may die before it can become established. When large numbers of grubs are feeding on the root system, even plants that are well established can die. Some insecticides are effective against the larvae if drenched into the soil that surrounds the roots.

Other beetle grubs, weevils, and borers may also attack the root system of ornamentals, causing root damage and deterioration of plant health.

Wood-boring Insects

Serious plant damage can be done by insects that spend at least part of their life cycle as internal feeders within woody plants. Any insect that feeds inside the trunk, branches, or roots of a plant is referred to as a borer. Borers are usually the immature stage of an insect, although some adult beetles bore into trees. The general life cycle of many borers starts in the spring, when eggs are laid on the bark. The eggs hatch and the larvae penetrate the bark, or tunnel underneath the bark and into the wood. Larvae usually molt several times as they develop and then pupate inside the plant. When the adults are ready to emerge, they eat through the bark to the outside of the tree. Exit holes made by the adults are often diagnostic clues of a borer infestation. Depending on the specific site of attack, internal feeding in woody tissues can stunt a plant's health, kill the plant by interfering with water and nutrient transport, or kill the plant by disrupting the production of new growth. Borers can also weaken the structure of a tree and increase its susceptibility to storm damage and disease.

The common borers are beetle larvae (flatheaded and roundheaded borers) and the bark beetles. The palo verde borer is another common wood-boring insect. A great many borers attack trees and shrubs. Some are specific to only one host, while others attack a variety of host species. Ash, birch, elm, lilac, locust, maple, poplar, palo verde, and fruit trees can be attacked by various boring insects.

Preventing borers requires the maintenance of healthy plants. Controlling borers in infested trees is difficult. It may involve pruning and/or using insecticides to kill adults before they lay eggs, or newly hatched larvae before they become established.

MANAGING ORNAMENTAL INSECTS AND MITES

Important methods for managing insects and mites on ornamental plants include proper plant selection and maintenance, cultural controls, sanitation, biological controls, and when necessary, chemical controls. IPM, or integrated pest management, is a strategy that employs all of the available methods of controlling pests. It also involves scouting and monitoring the pest population on certain plants.

Plant Selection and Maintenance

Borers are probably one of the best examples of how pests can be managed by proper plant selection and maintenance. Most borers are attracted to trees that are under stress or otherwise unhealthy. Some borer larvae cannot even complete their development in healthy trees. It is essential to keep trees healthy and vigorously growing. Select plants that are adapted to the growing conditions. An appropriate planting site and depth should be used, and proper watering, pruning, and fertilization provided. Other pests should not be allowed to reach levels that weaken trees and reduce their natural resistance to borers.

Certain species and cultivars of plants are more susceptible to pests than others. Using resistant plants can significantly decrease the maintenance necessary for those plants. Consider the history of an area. If previous plantings in a landscape or neighboring landscapes have been repeatedly damaged by a certain pest, select shrubs and trees that are resistant to the pest, or at least less likely to be affected by it, or non-host plants.

Carefully inspect new plants at the time of purchase and before installation in the landscape to ensure they are free of pests. A healthy tree with few bark wounds is less likely to have serious insect problems, and more likely to survive insect attacks, than a tree with wounds. Mowers and other maintenance equipment must be used carefully to avoid trunk and root injury. Mulching around trees will reduce the need to use equipment close to the trunk.

Cultural Controls

Pruning can be a useful method of insect control if an infestation is detected early and is restricted to certain parts of a plant. For example, if a borer has infested only a lateral branch and not the main stem, further spread of the insect may be stopped if the infested branch is removed and destroyed. Pruning and destroying branches infested with scale insects is sometimes helpful because they are relatively sedentary pests. Removing branches and twigs infested with tent caterpillar egg masses, or the caterpillars themselves, can help to reduce their numbers.

Sanitation

Sanitation includes a wide range of practices meant to remove a pest or a site of pest harborage from an area. For example, in early infestations of bagworms, the bags can be removed from trees and destroyed in the winter or spring (before the eggs hatch and before the leaves open and the bags are difficult to find).

For some pests, controlling weeds can remove an alternate food source or shelter. Remove fallen leaves and branches from the base of trees to discourage pest buildup. Two-spotted spider mites, for example, can develop on violets, chickweed, and wild mustard.

Biological Controls

Naturally occurring beneficial insects play an extremely important role in the natural control of many ornamental insects. For example, certain mite predators feed on destructive mites, and when abundant, keep the population of the pest mites in check.

Beneficial insects are available for purchase from many sources. Lacewings, lady beetles, and praying mantids are general predators that may be of use in certain situations but will not control many specific pest problems. The diversity and patchy distribution of ornamental plants and their associated pests, and the need for collective action to be taken over entire neighborhoods, will probably be major impediments to the widespread practice of introducing beneficial insects in many urban landscapes. Strategies should concentrate on promoting naturally occurring beneficial organisms by minimizing pesticide use, selecting pesticides that are least harmful to the beneficials, and applying pesticides in a manner that will be least detrimental to beneficials.

Bacterial insecticides can be used to control certain insect pests and to reduce the reliance on conventional insecticides. *Bacillus thuringiensis* (BT) is available as a commercially prepared bacterial disease that infects caterpillars, but is not toxic to people or higher animals. It can be used in control programs for gypsy moths, tent caterpillars, and other kinds of caterpillars on ornamental plants. Finally, birds, bats, and other animals can consume large numbers of insects.

Chemical Controls

Chemical controls for managing insects and mites on ornamental plants involve many different types of products and strategies. Pheromones may be used to attract an insect to a trap in order to monitor its life cycle or keep it from attacking a susceptible plant. Conventional insecticides and miticides, synthetic pyrethroids, botanicals, insecticidal soap, and horticultural oils are used in the landscape. Each type of material has specific uses, advantages, and limitations.

INSECTICIDE USE

Many factors affect the success of an insecticide application. Application timing, insecticide placement, pest resistance to pesticides, and tank mix conditions (i.e., pH and water hardness) should all be considered before making an application. Preventing phytotoxicity to the target plant is also a major concern.

Application Timing

To use chemicals effectively, you must know when a pest will be in a susceptible stage of growth. Applications should coincide with a period of peak pest susceptibility, which for many pests is brief. For many common serious pests, applying a chemical when populations are first getting established is important for effective management.

Brown scales on mulberry are a good example of how an insecticide application must be matched to the pest's life cycle. An effective time to control brown scales, and many other scales, is after the eggs have hatched and the insects are in the "crawler" stage. During the crawler stage, the insect is not under the protective shell and can be controlled using insecticides. Once the crawler stops moving and secretes a protective covering over itself, however, control become more difficult. You may have to look underneath the shells to determine if the crawlers have emerged.

Monitoring pest population may be necessary to determine when an insecticide application will be most effective. Pheromone traps are available to monitor the presence and emergence of many insects, including the adults of some borers. Traps can be placed in convenient locations in the area and checked periodically. Borer sprays can then be applied to trees after the adults have emerged, but before egg laying begins.

Read pesticide labels for instructions about the timing of insecticide applications. Monitor the conditions and the pest population where the chemical is to be used. If applied too early, an insecticide may dissipate by the time the main insect population is present. If spraying is delayed, the insects may have developed to a stage where they will be less affected by the insecticide, or they may have moved to an area within the plant where the spray cannot reach them. If insects have several generations in a season, or if weather conditions favor the hatching of eggs or the emergence of adults over an extended period, timing applications can be difficult. Multiple applications and/or the use of a residual insecticide may be necessary.

Pesticides vary greatly in their properties. Some insecticides have moderate residual activity on or in plants, and can provide control for extended periods. For other insecticides, the period of control is very short. Most miticides have considerable residual effectiveness for several days or more. Insecticidal soaps are effective only in liquid form, and leave no insecticidal residue behind on the application surface. The longer the treated plant surface remains moist, the longer the soap will keep its insecticidal properties. Making an application when slow drying conditions prevail, such as when it is overcast or in the early morning, late afternoon, or evening, will maximize the period of effectiveness. Understand the limitations of the product being used.

Insecticide Placement

An effective application of insecticide must give good coverage of the affected area and have good contact with the target pest. The dormant stages of some scale insects can be controlled by spraying horticultural oils. One theory is that the oil kills the scale by suffocation. In order for this suffocation to occur, however, the oil must completely cover the scale.

It is difficult to penetrate dense foliage, such as pyracantha, with foliar spray applicators. Dense foliage makes thorough and adequate coverage of the interior portions of a plant difficult. The leaf surface on which a chemical is sprayed will also affect placement of the insecticide. It may be difficult to keep material on waxy or hairy leaves, and a spreader-sticker or wetting agent in the spray mix may be needed. If an additive is used all the time, however, increased runoff and reduced deposit of spray material may occur on nonwaxy surfaces.

For some pests, only limited areas of a host plant need to be sprayed. For example, if treating for southwestern tent caterpillars in the spring, you may not need to spray the entire tree, but only the webbing of the nest. Whenever practical, insecticide applications should be confined to infested areas of plants, in order to minimize damage to beneficial organisms. Avoid using cover sprays over an entire landscape. Spray only those plants which are affected.

Systemic insecticides provide very good control of many insects because the chemical moves within the plant. Leafminers, for instance, can be controlled best with systemics that are absorbed by leaves and retained at high enough concentrations to prevent mining injury. Once absorbed by the plant, systemics cannot be washed off; their effectiveness is not reduced after a rain.

Contact insecticides are effective against a range of small and large chewing and sucking insects. Contact insecticides kill the pests they touch, and must be applied to a place the pest will contact in its normal habits. For pests, such as spider mites, coverage of the undersides of leaves is required if good control is expected. Contact insecticides are more susceptible than systemics to being washed off by rainfall and broken down by sunlight.

Any type of spray can be washed off a treated surface if rain occurs before the spray has dried. If sprays dry thoroughly, rain does not immediately remove a pesticide residue; the process occurs gradually over a period of time. Emulsifiable concentrate formulations are most resistant to washing off by rain or irrigation, wettable powder sprays are not as persistent, and dusts are readily washed off a treated surface.

Pest Resistance

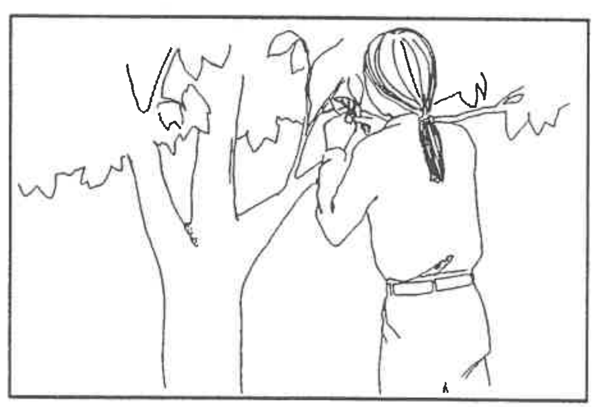
Pesticide-resistant populations of mites and other pests can develop in the landscape if the same chemical is repeatedly used to control them. To avoid the development of pesticide resistance, use pesticides only when necessary, spot-treat only infested areas, and rotate chemicals or chemical classes.

DEVELOPING AN INSECT MANAGEMENT PROGRAM

- You should be able to identify healthy plants in a landscape. Know their maintenance requirements, what pests commonly attack them, and what they normally look like when healthy. Processes such as fall needle drop and bark shedding can occur naturally to healthy plants, but be wrongly diagnosed as a pest problem.

- Establish the goal of your landscape management program. Is your goal to prevent any damage that is aesthetically displeasing, or is it to protect the health of the plants? The aesthetic injury level that is tolerated will vary according to the location of the plant and the purpose for which it is used. Some pests may not directly impact the health of the plant, but they become a nuisance or inconvenience when they, their frass or honeydew fall onto patios, picnic areas, or sidewalks. Total eradication of a pest is impractical, and essentially impossible.

- Manage plants in the landscape to minimize stresses. This will increase the plant's ability to repel pests and withstand pest attack.



- Monitor trees and shrubs for pests and beneficial organisms. Monitoring is a major component of integrated pest management (IPM) programs. Early detection of pests provides time to get a problem diagnosed while a potentially serious infestation is still minor, and before plants suffer major injury. Regular inspections and pheromone and other traps are used to monitor when a pest is first present in an area and how its population is changing. An IPM practitioner needs to know what to look for, where on the plant the pests are likely to be found, and when the pest is likely to appear.

- Correctly diagnose the problem. Many symptoms of insect damage can mimic those caused by disease or abiotic factors such as drought stress, frost injury, salt stress, fertilizer burn, or pesticide injury.

- Determine the significance of the pest and whether its presence warrants a control measure. Not all insects or mites found on plants are pests. Some may be incidental visitors, and some may be beneficials. On the other hand, some pests may be causing little damage at the moment, but the problem may become serious in a short time. The health of the plant, the specific pest involved, the severity of the infestation, weather conditions, and the time of year all influence whether or not control measures are warranted.

- Recognize that even when a pest is causing extensive damage, there may be no practical method for control. Many people feel an urgency to take remedial action immediately, but sometimes no action should be taken until the insect is in a vulnerable stage. Pesticides must be applied at the proper time to be effective.

- Do not apply pesticides that you know will not be effective (for whatever reason) just to satisfy a nervous client. Fully explain to the client why a pesticide would not be effective at a particular time, and offer alternatives such as removing the pest from the plant by hand, pruning infected branches, increasing plant vigor by adjusting water and fertilizer, or perhaps doing nothing at all until the pest can be treated effectively.

- Before applying an insecticide or miticide, consider the following points:

    - Is the pesticide labeled for use on the plant you want to protect, and is it likely to harm the plant under current conditions?

    - Is the pesticide labeled to control the insect or mite you wish to control?

    - Are you applying the pesticide at the proper time to control the pest?

  - Are label directions clear about using the pesticide for this purpose?
  - How and to what parts c. the plant is the pesticide to be applied?
  - Will the pesticide also kill beneficial organisms in this situation?
  - Do you have the equipment needed to apply the pesticide properly?

- Carefully appraise the site. Determine whether a pesticide can be applied safely to where you want to use it. Some trees should not be sprayed because the risk of spray drift onto people, automobiles, homes, yards, and other property is too great. Take note of sensitive animals. Look for pets, birds' nests, bird feeders, and bird baths. Consider the potential for runoff or spray drift into bodies of water.

- Use the signal word on the label to choose the insecticide that is the least toxic to humans. Protect yourself from pesticide exposure by wearing the appropriate clothing and equipment, particularly when overhead applications are made.

- Monitor weather conditions. Rains can move the pesticide off the treated surface. Temperature extremes can increase the chance of phytotoxicity from emulsifiable concentrate formulations and horticultural oils.

- Evaluate and record the success of control efforts. Avoid repeating what did not work.

DISEASE AND DISEASE CONTROL

Ornamental plants, like all other kinds of plants, are affected by many different diseases. Diseases can cause a general decline in the appearance and health of a plant, increase plant susceptibility to attack by insects and other pests, increase the likelihood of plant damage from winter injury and other stresses, and cause plant death. Abiotic diseases of ornamental plants are caused by noninfectious factors such as extremes in water or light, air pollution, soil compaction, and mechanical injury. Biotic or infectious diseases are caused by pathogens on or in the plant. This section will focus primarily on the diagnosis and management of biotic diseases on ornamentals.

DISEASE DEVELOPMENT

The development of a biotic disease requires that all parts of the disease triangle be present for a specific period of time. The disease triangle consists of a pathogen, a susceptible host plant, and favorable environmental conditions. A pathogen is a disease-causing organism. A pathogen will not infect a plant or cause plant disease unless the plant is susceptible and the environmental conditions are favorable.

Pathogens

Most biotic diseases of ornamentals are caused by fungi, bacteria, viruses, nematodes, and mistletoe. These pathogens vary in their form and the symptoms they cause. Understanding the factors that affect the development, reproduction, spread, and survivability of a pathogen is often essential for successful disease control.

Fungi are thread-like forms of plant life that live on dead or living plant and animal matter. Fungi produce seed-like structures of different shapes, colors, and sizes called spores. Individual spores are actually microscopic, but when present in large numbers, become visible as powder growth on infected foliage. Spore-producing structures, or fruiting bodies, are often apparent on infected tissues. Diseases are spread as spores and other parts of a fungus are carried from diseased plants to healthy plants by air currents, splashing or flowing water, insects, mites, birds, contaminated or infected plant parts, soil, workers' hands, clothing, tools, and equipment. Fungi overwinter in the soil, in plant debris such as fallen leaves, and in infected plant parts such as cankers. Fungi are the cause of most diseases of ornamentals, including phytophthora root and crown rot, Texas root rot, cankers, leaf spots, wilts, and blossom blights.

Bacteria are single-celled microbes that reproduce by dividing themselves. Bacteria only infect plants at the sites of wounds or natural openings. They are spread by splashing water, wind, equipment, animals, and soil. Diseases caused by bacteria include fireblight on pyracantha and pears, bacterial leaf spot on English ivy, crown gall on a variety of ornamentals, and bacterial leaf scorch on shade trees.

Viruses and mycoplasmas are much smaller than bacteria, and can exist and multiply only inside living cells. They are spread mainly by contact between plants, sucking insects (particularly leafhoppers and aphids), and contaminated tools. Mosaic (a mixture of dark and light green areas), flecking, and ringspotting are foliar symptoms typical of viruses. Stunting and other growth disorders can also be caused by viruses. 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 virus exists. Plant removal is often recommended to prevent spread of the virus to healthy plants. Fig mosaic is an example of a disease caused by a virus.

Nematodes are tiny roundworms that cannot be seen with the naked eye. They are found in the soil, and can be spread by soil, machinery, and infected plants. A few species of nematodes feed on leaves and shoots, but most feed on plant roots, causing stunting and poor growth. Close examination of roots may reveal browned areas, swelling, or a greatly reduced root system. Nematodes can be very difficult to control. A nematode analysis is usually required for a conclusive diagnosis. Be aware that not all nematodes are harmful, some feed on insect grubs and are beneficial.

Mistletoe is a parasitic plant that grows on living plants. It produces leaves, stems, flowers, and seeds, but no true roots. Without roots, it depends on its host plant for water and all minerals. The host plant eventually becomes less vigorous as a result of nutrient loss, lack of photosynthesis from shading, and loss of leaves. Limbs and branches swell at the site of mistletoe growth. Branches slowly and progressively decline and may die. Susceptible hosts include cottonwood, palo verde, and acacia. Pruning of infected branches 1 or more feet from the infected sites will help control mistletoe. Break off mistletoe flower stalks before seeds are produced.

Host Plants

Ornamental plants vary considerably in their resistance to diseases. Genetic resistance is a key factor that determines whether a plant is susceptible to attack from a particular pathogen. Stress also affects the susceptibility of plants to disease. Although some pathogens will attack vigorously growing and healthy plants, many attack and infect only plants that are stressed. A weakened tree, for example, is much more susceptible to cankers, wood decay, root rots, and certain wilts than a vigorously growing tree.

Plants may exhibit certain symptoms or growth characteristics if they are in decline or in a weakened condition. Some of the most common include

- late flowering, late leaf emergence, or early fall coloration compared to other trees of the same species in the same vicinity
- smaller than normal leaf size

- smaller than normal increase in shoot length
- excessive number of water sprouts

Environmental Conditions

The mere presence of a pathogen does not mean that disease will develop. Pathogens have specific moisture and temperature requirements for growth and infection. Disease-causing bacteria must have water to infect plants, reproduce, and spread. Most fungal spores need moisture to germinate and infect plant tissues. Many of the fungi that are responsible for root and crown rots need moisture to spread. Specific environmental conditions such as cool and wet soils, or a period of hot, dry weather, may be necessary to render a plant susceptible to infection.

DISEASES OF WOODY ORNAMENTALS

Diseases of woody ornamentals occur in four general locations on the plant: leaf and flower; twig and branch; root and crown; and vascular system. Common diseases within Arizona are discussed in chapter 4. Leaf and flower diseases include the fungal leaf spots and needle cast of conifers, anthracnose, apple scab, powder mildew, and rusts. Twig and branch diseases include Diplodia tip blight of pine, cankers, juniper blights, and fire blight. Root and crown diseases include the *Pythium* and *Phytophthora* rootrot and crown gall. Vascular wilt diseases invading the water-conducting tissues include Dutch elm disease, wetwood, and verticillium wilt.

Some of the common diseases that affect plants in the landscape are described below. The descriptions emphasize important principles about diagnosing and managing diseases of ornamental plants.

Leaf and Flower Diseases

Fungal leaf spots and ***needle cast of conifers.*** Leaf spots are characterized by brown or black spots randomly scattered across the leaf. The spots may or may not have the appearance of concentric rings, and the margin of a spot may be a different color than the center of a spot. Leaf spots are caused by many fungi that attack landscape plants. Infection may occur at any time, but disease is usually most severe on new, emerging foliage during rainy periods. Rain favors the production and spread of spores to unaffected foliage.

New spring infections are commonly caused by spores produced in spots on last year's leaves. The previous year's leaves should be removed before buds break in the spring. In the case of deciduous trees and shrubs, overthick growth should be pruned to allow for better air circulation and penetration of sunlight. Both will help foliage to dry quickly after rain, heavy dew, or overhead (sprinkler) irrigation. In the case of conifers, it is important to control weeds that surround the lowest branches. Weeds favor fungal infection of needles by inhibiting air circulation and increasing humidity. Fungicides are available, if needed, for controlling many leaf spot diseases.

Anthracnose is a common and unsightly fungus disease of shade trees. Typical symptoms are brown, dead areas that develop first along leaf veins. The dead areas often expand outward to the leaf margin, or merge and cause distortion of the leaf and eventual leaf drop. Badly distorted leaves look as if they were injured by a late frost. Severe shoot and twig blight can also occur as a result of cankers. Small, round, black fruiting bodies of the fungus are often apparent in infected canker and leaf tissue.

Control measures for anthracnose include pruning infected branches and dead twigs, removing fallen leaves and plant debris, improving air movement, avoiding overhead irrigation, and reducing the amount of shade around affected plants. Water and fertilize to stimulate plant growth and recovery from defoliation.

Powdery mildew. Many plants are susceptible to infection by powdery mildew fungi, but it is common on euyonomous hedges, roses, crepe myrtle, zinnia, and many herbaceous perennials.

Powdery mildew is most common in dense, shady areas where air circulation is poor. Disease development is favored by warm, dry days and cool, damp nights. Powdery mildew often appears rather suddenly and during wet weather it can spread rapidly among susceptible plants. It is often more of a nuisance than a threat to plant health. The amount of disease damage varies, depending on the degree of resistance of the plant cultivar, the health and vigor of the plant, and the weather conditions.

In the landscape, the best control is the use of powdery mildew-resistant cultivars. Improving air circulation around plants, increasing sunlight, and pruning diseased plant parts can help to reduce the severity of disease. Fungicides may be needed on some plants, although they are generally not used when powdery mildew appears late in the season.

Rusts are caused by numerous fungi that induce the formation of yellow, orange, red, brown, or black pustules on leaves, and sometimes on twigs and fruit. The pustules contain spores that can be readily spread by wind. Rusted leaves often turn yellow, die, and drop early. Cankers and galls may develop, and twig and branch dieback may also occur. If infection is severe, the plant may become stunted and susceptible to winter injury and other diseases.

Twig and Branch Diseases

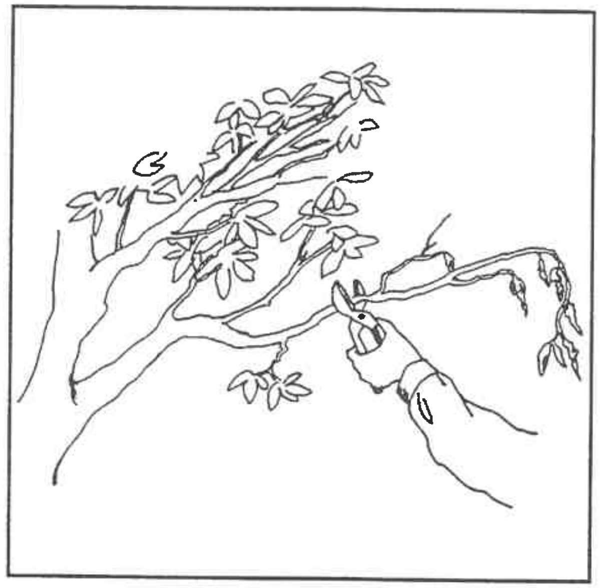
Cankers. On perennial trees and shrubs, cankers appear as sunken, dead areas surrounded by living tissue. Cankers usually have distinct margins between the dead and living tissue, and increase in size each year. Once a canker grows completely around (girdles) a branch, the parts above the diseased area usually die back.

Cankers can be caused by fungi or bacteria. Bacterial cankers usually begin as infections of leaves or flowers that spread down the petiole and twig, killing the shoot down to a major branch. Cankers then form on the large branch at the juncture with the dead shoot. Fungal cankers often begin as infections at twig and branch stubs left from breakage or pruning wounds. As the canker slowly grows year after year, callus tissue is killed back, causing concentric rings of callus to surround the canker and give it a characteristic "target" appearance. Fruiting bodies from canker-causing fungi often produce an ooze of orange, white, or brownish spores during rainy weather. Large cankers can weaken tree structure and increase a tree's susceptibility to storm damage. Some cankers found on woody ornamentals include Nectria canker on boxwood and Cytospora canker on mulberry.

Fire blight is a bacterial disease that occurs on many species of plants in the rose family. In the landscape, it is particularly serious on pyracantha and pears. In the spring and early summer, blossoms and leaves of infected twigs suddenly wilt, turn dark brown to black, then shrivel and die. The blighted leaves and twigs remain attached to the stems, which look as though they were scorched by fire. The tips of the dead stems are often bent into the shape of a shepherd's crook. The bark is shrunken, dark brown to purplish to black, and sometimes blistered, with gum oozing out.

Fire blight bacteria overwinter in cankers and can be spread by splashing rain, wind, honey bees and other insects, and contaminated pruning tools. Fire blight is most severe on fast-growing, succulent tissue. It can be particularly damaging if groupings of susceptible plants are near one another, such as cotoneaster in large ground cover areas.

In the landscape, the best control measure is the use of resistant varieties or species. Avoid heavy applications of nitrogen fertilizer in the spring. Prune during the dormant season at least 4" below the cankers. If pruning must be done during the growing season, cuts should be made at least 12" below the canker. Always disinfect pruning tools with alcohol or bleach between each cut. Remove suckers which develop on the trunk or main limbs, since they are very susceptible to fire blight infection. Controlling insect pests may help to control the disease.



Root and Crown Diseases

Root and crown rot. Many soil-inhabiting fungi can cause root rot in woody ornamental plants. Infected roots may appear darkly discolored, fall apart easily, and have a rotten appearance. If you gently pull on a rotted root, the external skin should separate entirely from its internal tissue. Stunting, yellowing, and loss of plant vigor are above-ground symptoms often associated with root rot. Leaves may wilt, even when the soil has adequate moisture. Unfortunately, by the time obvious symptoms become apparent above ground, a large part of the feeder root system is dead.

Pythium spp. and *Phytophthora* spp. are common and serious root-rotting fungi. They have a spore stage adapted to swimming in water that causes root rots, which are most severe in poorly drained soils. Roots that are killed in a waterlogged soil can serve as a site for infection. *Phytophthora* root rots will sometimes move into the basal part of a stem, turning the vascular tissue a brownish-black color that can be seen if the stem is cut.

Many root-rotting fungi attack plants that have been weakened by poor soil conditions, deep planting, drought, flooding, mower injury, winter injury, frost, or repeated defoliation by insects or diseases. Root rot can often be prevented by providing a plant with good growing conditions. Avoid planting trees and shrubs that are susceptible to root rot in poorly drained areas, or in areas that receive excessive amounts of water, e.g., under downspouts. Avoid over- or underwatering. Some plant varieties are resistant to certain root rots, but resistance can be lost if the plants are stressed by either too much or too little water. Once plants are damaged by root rot, they rarely recover and should be removed from a landscape. Before replanting in an area where a root-rotted plant was removed, try to improve the soil conditions. Soil treatment with a fungicide labeled for the causal fungus may be warranted. Fungicides are also available for soil drenching after planting. Buy disease-free plants with vigorous root systems.

Crown gall. A wide variety of woody and herbaceous ornamentals can be damaged by crown gall, which is caused by a bacterium. It is common on brambles, grapes, roses, fruit trees, willow, and many shrubs and vines. Crown galls are swellings that grow at or near the soil line or graft union, on roots, and on lower branches or stems. Young galls are spongy and light-colored; older galls are hard, woody, and almost black. Symptoms of infected plants may include: poor flowering, stunted growth, yellowing of foliage, and branch and root death. Bacteria infect the plants only at the site of a wound.

To reduce the occurrence of crown gall in the landscape, inspect plants at the time of purchase to ensure they are free of suspicious bumps. Highly susceptible plants should not be planted in sites where plants infected with crown gall were recently growing. The bacteria may persist in the soil for a year or two after a diseased plant is removed. Care should be taken to avoid wounding young plants near the soil line, when cultivating and transplanting. Protect plants from wounds and weakening caused by insect and mites. Severely infected plants should be removed and destroyed.

Vascular Wilt Diseases

Vascular wilt diseases are caused by pathogens (most commonly fungi) that invade the water-conducting tissues of plants and disrupt water movement. Symptoms of wilt diseases are most likely to become visible when a plant is under stress, particularly drought stress. Dutch elm disease is a wilt disease that has already killed most of the susceptible American elms. An important wilt disease of olives is verticillium wilt.

Verticillium wilt is considered the single most important disease of commercially cultivated and landscape planted olive trees. As a soil-borne fungus, verticillium initially invades the root system of olives when soil temperatures are cool. The fungus does not grow at temperatures above 86° F. After penetrating the roots, the fungus grows and moves through the plant in the water-conducting (vascular) tissues and eventually invades branches and twigs. This systemic invasion usually occurs from February to June. With the onset of high summer temperatures the fungus in inactivated. By then, unfortunately, the damage has been done and the trees begin to exhibit symptoms. The presence of the fungus in the vascular system interrupts and reduces the water movement from the roots to the leaves. Wilt symptoms are directly attributable to this impeded internal water flow.

Symptoms usually first appear in the spring near flowering time. Newer leaves roll inward and loose their deep green, waxy luster, and become dull gray and brown. Leaf drop and twig dieback may follow. Flower clusters on affected branches may die and remain attached and the bard on such limbs may become bluish. Individual branches, portions of trees, or the entire crown may die in one season. Tree death, however, rarely occurs. When cool weather returns, the fungus again becomes active and resumes its growth. In this way branches can be re-invaded each year during the spring season.

Wilt diseases are usually very difficult to control. Once verticillium wilt is suspected, the tree should be watered immediately to prevent moisture stress. Dead branches should be removed by pruning; and tools cleaned and sanitized between cuts. Severely infected trees should be removed. Do not chip, compost, or bury infected wood or plants. Avoid replanting the area with a susceptible tree or shrub, because the fungus is soil-borne and can persist for years. Conifers, oak, sycamore, and willow appear to have resistance to this disease.

DIAGNOSING DISEASE PROBLEMS

The effective management of any disease depends on an accurate diagnosis of the problem. This can be quite a challenge. There are six different perspectives that can help make your diagnosis easier and more accurate.

1. Close-up View

Look closely at symptoms and look for the direct evidence (signs) of a pathogen or insect. Examine leaves for spots or blotches. Some fungal leaf spots produce a target-like pattern of concentric rings. Bacterial leaf spots often have a water-soaked, yellow margin. Many fungal leaf spots have dark, pinpoint-sized fruiting bodies, while others show masses of spores. Look at trunks, branches, and twigs for cankers that vary in size and color, may be sunken or swollen, be oozing gum or sap, or show signs of the pathogen. Clusters of mushrooms or conks (fruiting structures of certain fungi) on the bark surface, particularly at the soil line, may indicate wood rot or decay. To identify wilt diseases, remove the bark and cut into the wood to look for vascular discoloration.

Be careful when using the close-up view–the part of the plant showing symptoms may or may not be where the problem began. Sometimes the most obvious symptoms are not the primary cause of the problem. For example, yellowing foliage or leaf drop may be the result of root rot that will only become apparent if the plant is dug up, and the root system examined. Or leaves may wilt because of a girdling canker that can only be found if the entire twig or limb is carefully examined.

2. General View

Stand back, and take a broader look at the affected plant(s). Take note of any pattern and whether other plants in the landscape are exhibiting decline or similar symptoms. Look for stress-promoting conditions. Is the site subject to extreme summer dryness, soil compaction from foot traffic, or crowding and shading from neighboring plants? Is the soil very wet? Excess soil water often causes root rot, followed by wilting. Finding a suspected pathogen may not be enough to accurately diagnose a problem and come up with a solution. For instance, powdery mildew may be easily diagnosed on a plant, but further observation may reveal that excessive shade and dampness are the real problem.

3. Time

How long has a symptom or a certain set of symptoms been present? When did symptoms first appear, and what activities have taken place? How long has the tree or shrub been there? If it was planted only a year ago, it may be an establishment problem. Records of plant appearance, cultural activities, and weather can be very useful when problems arise. Symptoms of winter injury, such as leaf stunting, wilting, and sparse foliage due to bud kill, will not be apparent until the following spring.

4. Knowledge and Experience

You need to look for certain problems on different types of plants in different situations. Pines, for example, are particularly susceptible to decline or death when soil compaction is combined with several successive years of dry weather. If you have a dead branch on a tree, you might expect fire blight if it is in the rose family or verticillium wilt if it is an olive. Collapse and death of palm heart fronds during warm, wet periods may indicate bud rot. With experience, you will become more familiar with disease problems.

5. Diagnostic Tests

This may involve a soil test, a nematode analysis, or the culturing and identification of pathogens. Representative sampling and careful handling of the sample are important because the diagnosis is only as good as the sample provided.

6. Questions

Ask questions about every imaginable event that happens on a regular and not-so-regular basis around the plant. For example, ask what the soil was like when the hole was dug (e.g., compacted, reddish tint), how much foot traffic there is near the plant, what natural events have occurred (e.g., storms with lightning, strong winds), whether a neighbor uses herbicides, when the plant was last watered or fertilized, and how much water or fertilizer was applied. Ask any question that may provide some sort of clue as to what may be harming the plant.

MANAGING DISEASES OF ORNAMENTALS

Managing plant disease means preventing infection or reducing the incidence or severity of disease. Once plants have a disease, they cannot usually be cured, but diseased parts can be removed, healthy parts can be protected, and the diseases can be suppressed.

A well-conceived disease management program requires some knowledge of the pathogen, the susceptible plant, and the cultural and climatic conditions that favor disease development. Since a great number of plant-decline problems are attributable to poor plant selection, chemical injury (salts, fertilizers, pesticides), mechanical injury (construction, mowing equipment), and poor cultural practices (poor planting, pruning, watering, or fertilizing; lack of winter protection), disease management must consider a total maintenance program.

Plant disease management tactics include selection of disease-resistant plants, cultural practices that promote plant health, sanitation to prevent the spread and survival of pathogens, and the use of chemical controls when necessary. Satisfactory control of most diseases requires the use of several tactics.

Plant Selection

Selecting disease-resistant species and cultivars is a cost-effective method of preventing disease development. Consider the history of an area. Avoid replanting the area with the same species or cultivar that was killed previously by a disease, unless modifications can be made to reduce the likelihood of its recurrence. Plant rotation, although impractical in many landscape situations, is an important method of disease control that can be used in flower beds. Inspect plants at the time of purchase to ensure they are disease-free.

Cultural Practices

Cultural practices that prevent disease development include the following:

- Determine the requirements of each plant and provide suitable conditions.
- Plant or renovate landscapes to minimize plant crowding. Overcrowding increases humidity beneath the plant canopy, which favors certain diseases. Thin out plants to promote air circulation.
- Set plants in the soil properly. Planting too deeply will increase the likelihood of root and crown rot.
- Prune the surrounding shade-producing vegetation, if the plants under consideration would benefit from an increase in sunlight.
- Improve and maintain the vigor of plants with proper fertilization and irrigation.
- Adjust soil pH and alleviate compaction, if necessary.
- Control insects that cause plant stress and increase plant susceptibility to disease, or that serve as vectors for disease-causing organisms.

Remember that improper cultural practices and conditions can encourage disease development. Watering plants lightly through overhead irrigation, especially late in the day, can leave foliage wet, and favor spore germination and plant infection. Overhead irrigation will also drip bacteria and fungi from infected leaves and branches onto lower plant parts.

Sanitation

Sanitation practices help to eliminate a pathogen, or restrict its development, survival, and spread.

- Rake and remove leaves that have fallen as a result of a foliar disease. These will provide a source of spores for infection the following spring if not removed.

- Prune out fungal or bacterial cankers. Disinfect pruning tools in 70% alcohol between cuts to avoid spreading the pathogen. Another commonly used mix is made by combining one part household bleach with nine parts water; the solution is more effective when a small amount of soap is added as a wetting agent. Pruning is best done in dry weather to minimize the spread of spores and bacteria.
- Remove infected plants from a plant bed, garden, or ground cover planting.

Chemical Controls

Pesticides can be used to protect plants from disease, or halt the spread of disease in an already-affected plant. Few diseases require regular spray schedules. Pesticides should be used only when a destructive disease is a known threat. Emphasis should be placed on preventing disease incidence, rather than relying on chemicals to control diseases after they develop.

An accurate diagnosis is required before a pesticide can be selected. When choosing a product, consider the following factors. Is the plant listed on the label? Is the pesticide labeled to control the disease? Do you have the equipment needed to apply the pesticide properly? What is the cost of application? What period of control can be expected? The pesticides most commonly used to control diseases in the landscape are fungicides that kill pathogenic fungi. Fungicides are discussed in more detail below.

Fungicide types

Broad-spectrum fungicides are toxic to many fungi, and are used to control a variety of diseases. Narrow-spectrum fungicides provide very good control of a few fungi, no control of many fungi, and in some situations, act as a stimulus for other fungi. Most broad-spectrum fungicides are protectant-contacts that prevent new infections and must be applied before the pathogen arrives. They are generally ineffective after infection has occurred. They are not absorbed by the plant, or translocated within the plant, but form a protective barrier over the surface of the plant to prevent infection. They will be washed from the sprayed plant surfaces over a period of several days, and new unsprayed/unprotected growth will emerge from buds. Contact fungicides must dry on the plant surface before being exposed to rain or overhead irrigation.

The effectiveness of protectant-contact fungicides is dependent on thorough coverage during application. The completeness of the fungicide barrier depends, in part, on how well the spray spreads and sticks to the plant surfaces. The best way to evaluate the coverage obtained by an application is to examine the sprayed surfaces after application. Hairy or waxy foliage is especially difficult to cover, and additives such as spreaders, stickers, and wetting agents are often included in the sprays. Most fungicides produced today are mixed with these types of spray additives by the manufacturer. Read labels to determine if additives are necessary.

Systemic fungicides are absorbed by, and translocated within, plants. Most systemics function primarily as protectants and cannot kill fungi that have established themselves inside a plant. Some may have "kickback" action and control fungi for a limited period after infection.

Timing fungicide applications

The scheduling of effective fungicide applications is not a simple task and cannot be readily standardized. Disease development is not governed by the clock or the calendar, but by temperature, relative humidity, soil moisture, and other environmental factors. Strict scheduling is made particularly difficult in the landscape because many different species of plants are present, each with its own set of disease problems. Timing, however, is one of the most important factors determining the effectiveness of a fungicide application. The timing of applications must be tailored to the plant species being grown, the diseases that are present, and the environmental conditions at the site.

Fungicides may be effective or necessary only under certain conditions, or at certain stages in the disease cycle. For example, fungicides are used against the fungus that causes apple scab during and immediately following rainfall. During drier periods, fungicides are not necessary to control the fungus because spores of the fungus are not germinating. Application timing may be based on the stage of growth of the susceptible plant. For example, only new pine needles are susceptible to diplodia tip blight. Preventive fungicides must be applied in early spring so the new growth is covered during the time when it is susceptible to infection. Fungicide labels often provide application guidelines based on plant growth (e.g., bud break or petal fall).

The frequency of fungicide application is influenced by the properties of the individual product, although weather conditions and the rate of plant growth affect the length of time a fungicide will provide protection. Many labels provide repeat application guidelines. Know the limitations and the requirements of the product you are using. Keeping records will help you develop disease management plans that can be adjusted and improved over the years. And recording general weather conditions and the occurrence of diseases helps you to anticipate certain problems. Knowing which diseases are present and when they are likely to occur will greatly improve the effectiveness of disease management strategies.

Resistance to fungicides

Recent experience with some fungicides (especially those with systemic action) indicates that fungicide resistance can be a problem. Using one fungicide or closely related fungicides year after year can increase the buildup of a fungicide-resistant population. For example, populations of benomyl-resistant fungi have been found primarily where benomyl was used regularly and exclusively for several years. Resistance has not been reported against broad-spectrum fungicides. In order to reduce the emergence of fungicide resistance, rotate classes of fungicides throughout a growing season, or every year.

WEEDS AND WEED CONTROL

Weeds are a constant problem in areas used for growing ornamentals. They can reduce the vigor and growth of ornamentals by competing for water, nutrients, and sunlight. Weeds detract from the appearance of a planting bed, and are hosts for disease-causing organisms. They also reduce air movement, which may increase the incidence of foliar diseases or frost damage, and they provide shelter and food for insects and rodents that attack ornamentals and invade buildings. In a landscape, any plants other than those actually planned for can be considered weeds. They may be woody or herbaceous, grass or broadleaf, annual, biennial, or perennial.

METHODS OF WEED CONTROL

Weed control in and around ornamental plants can be accomplished with or without the use of chemicals. Nonchemical weed control relies on hand-pulling, cultivation, and the use of mulch. Chemical weed control relies on the use of herbicides. Depending on the situation, each method has its advantages as well as its disadvantages. Both control strategies involve either destroying existing weed growth or preventing new weeds from developing. In many situations, a combination of both chemical and nonchemical methods produces the best results.

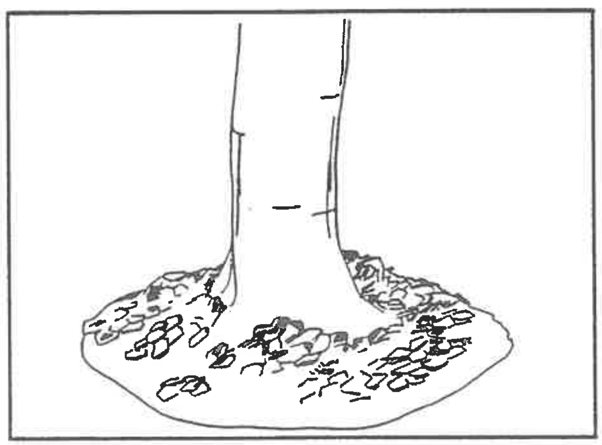
Nonchemical Weed Control

Nonchemical methods of weed control include hand-pulling, cultivation, and the use of mulches. These methods are often the most practical in plantings with a wide variety of species and in small ornamental beds, such as those around residential and industrial buildings. Nonchemical methods are often safer to ornamental plants than the application of herbicides.

Cultivation is done by hoeing, rotary tilling, and disking. Both cultivation and hand-pulling are labor-intensive, and because they remove only existing weeds, produce only temporary results. Cultivation works best when weeds are young, temperatures are high, and the soil is dry. Repeated cultivation is usually necessary to control perennial weeds, and to keep weeds from producing seeds.

There are disadvantages to some cultivation methods. Trees and ornamentals can be injured if equipment operators run into plants, or if deep cultivation is done in areas occupied by plant roots. Cultivation can also bring dormant weeds to the surface, and can chop heavily rooted perennial weeds into pieces that produce new plants.

Mulch is a layer of organic or inorganic material that is placed on the soil surface under and around desirable plants to control weed growth (among other things). Where a mulch layer is sufficiently deep or impenetrable, few weeds will grow. When a mulch is present, the need for hand-pulling, cultivation, and herbicides is greatly reduced. Mulches provide the best weed control in landscape situations, where herbicide use is frequently restricted by the presence of ornamentals.



Organic mulches commonly used in the landscape include shredded or chipped bark or root. They provide the greatest benefits to plant growth, but can be expensive to maintain since they last only one to three seasons. Fine-textured organic mulch is not effective for weed control because it provides an ideal medium for weed seed growth. Inorganic mulches such as marble chips, crushed rock, gravel, and landscape fabric provide a more long-term cover. A combination of landscape fabrics and organic mulch that allows water and air to penetrate, but excludes weeds, is usually the best cover for a landscape.

In addition to weed control, other potential benefits of mulch include

- water conservation because of reduced evaporation from the soil; this is especially important during dry periods
- maintenance of uniform soil temperature
- reduction of soil erosion by wind and water
- increased water absorption, percolation, and aeration with improved soil structure (organic mulch only)
- reduced crusting of the soil surface
- improved appearance of the landscape

Apply mulch when the soil has warmed sufficiently for active root growth. Applied before this, the mulch will keep the ground cool and root growth slow. If planting is done in the fall, the mulch should be applied immediately, so the soil will stay warm longer. Organic mulches are generally applied 3 to 4 inches thick to prevent weed growth.

Several potential problems can arise from using mulch. Weed seeds can be introduced into the landscape with hay, straw, and other mulch materials. Develop a reliable source that supplies mulch relatively free of weeds. Piling mulch around the stem or trunk of a plant can provide a favorable environment for many pathogens that cause stem rots. The bark on most woody plants must be dry or at least be able to readily dry after becoming wet. Too much mulch can also injure plants by limiting soil aeration or by keeping the soil too moist.

The repeated application of layer after layer of organic mulch can cause the decline and death of shallow rooted shrubs and large trees if the mulch forms a dense crust that cannot be penetrated by water and oxygen. Without oxygen, roots will die. Use of coarse mulch materials will help alleviate this problem. If an ornamental plant can root readily, it may initiate roots in the mulch layer, but these will be susceptible to winter injury. To avoid this problem, fresh mulch should be applied only after the existing mulch is nearly decomposed and has been lightly incorporated into the soil. A shallow raking will help break up any dense barrier formed by mulch.

Mulch materials may move out of a planting bed in runoff water if they are used on steep slopes or placed on top of plastic mulch. When using certain mulches such as wood chips, sawdust, straw, and shredded bark, an addition of fertilizer is required to prevent a nitrogen deficiency in growing plants. Mulches can also affect pH. For example, oak leaves may lower soil pH (make it more acidic), and limestone and marble chips may raise soil pH (make it more alkaline).

Chemical Weed Control

Herbicides are an effective and economical method of controlling weeds in ornamental plantings. When herbicides are used, they should be combined with nonchemical controls whenever possible. The success of chemical weed control depends on what type of herbicide is used, where it is placed, when it is applied, and what environmental conditions prevail at the time of application. The first step in implementing a chemical control program is to identify the weeds.

Herbicides can be classified into three categories, depending on when they are used. Preplant herbicides are used before planting; preemergence herbicides are used before or after planting, but before weed seedlings emerge; and postemergence herbicides are used after weeds have emerged. A herbicide must be selected on the basis of the particular weed-ornamental plant situation.

Preemergence herbicides. Preemergence herbicides are commonly used in ornamental plantings. These are applied to the soil and are active on germinating seedlings before they emerge through the soil surface. Preemergence herbicides are used in plantings of woody ornamentals, ground covers, bedding plants, and vegetable gardens.

Plant tolerance. Ornamental plants vary widely in their tolerance of herbicides. Because of this, a herbicide should be used only in plantings of species listed on the product label. Since beds of ornamentals usually contain several different species, special care must be taken to avoid applying a herbicide to plants for which it is not labeled. Herbicides can cause severe damage to those ornamentals not listed on the label. The age of a plant and the time since transplanting can influence plant tolerance to herbicides and other pesticides.

Soil preparation. Although the activity of some herbicides may not be affected by plant residue on the soil surface, most preemergence herbicides will provide better weed control when applied to a clean soil surface. Material on the soil surface (established plants, leaves, mulch, etc.) can intercept the herbicide and reduce the amount that reaches the soil. Tilling the soil can eliminate weeds and improve herbicide distribution.

Herbicide incorporation. A preemergence herbicide will not be effective if it remains on the surface of the soil. It must be moved into the soil profile by water (rainfall or irrigation) or a mechanical procedure to the depth where weed seeds are germinating. Some herbicides are lost quickly from the soil surface, and must be incorporated immediately after their application. Other herbicides are resistant to degradation and can remain on the soil surface until it rains without losing their activity. Some herbicides should not be mixed into the soil with cultivation, although most will perform more consistently if they are incorporated either mechanically or with irrigation when rainfall does not occur within seven days of the application. Cultivation deeper than two inches will reduce the effectiveness of most herbicides. Read the herbicide label for incorporation instructions.

Soil type and organic matter. Herbicides can be bound to soil particles in varying degrees, depending on the herbicide, the amount of organic matter in the soil, and the soil texture. Some herbicides will provide inconsistent or poor weed control in certain soils. Those herbicides which are tightly bound to soil particles may require higher rates when applied to fine-textured soils, or soils with high levels of organic matter.

Spectrum of control. No preemergence herbicide is effective against all weed species. If a chemical kills all but one weed species, that species will multiply. This results in a shift in weed population. Eventually, weed control with that product becomes ineffective. Some herbicides are better at controlling broadleaf weeds; others are most effective at controlling grasses. Rotating chemicals and combining herbicides help ensure control of a broad spectrum of weeds.

Postemergence herbicides. Postemergence herbicides can be used in ornamental plantings if handled with great care. The two types of foliar herbicides are contact and systemic (translocate). Contact herbicides cause a rapid kill of green areas that are sprayed. This can include tree bark that is thin or green. Since there is little movement of the herbicide into the plant, uniform coverage of the weed with the spray solution is required. Contact herbicides generally provide excellent control of annual species. Perennials frequently resume growth from unaffected rootstocks.

Systemic herbicides are moved in the plant to areas that are not directly contacted by the spray. These herbicides often act slowly, but can kill underground roots of perennial weeds. The more leaf area of the weed that is present at the time of application, the more herbicide will be absorbed by the weed. To allow herbicide movement throughout the entire root system, weed roots should be intact and not broken up by cultivation.

Preventing herbicide injury to plants. Although herbicides can be useful tools for managing weeds, improper application can result in injury to trees and other ornamentals. Selective herbicides may have a relatively small margin of safety. The margin of safety is the difference between the rate of chemical that is required to control weeds and the rate that is toxic to the desirable plant. Misapplication that results in a higher herbicide rate than stated on the label may lead to plant injury and is illegal.

Herbicides should not be applied over exposed roots or be allowed to contact injured root or stem tissue. Avoid using residual herbicides where trees are growing in a depressed area that prevents water from draining away from the tree. Granular materials should not be applied when the foliage of ornamentals is wet. Each granule contains a relatively high concentration of herbicide, and water on the foliage could cause granules to stick to the leaves and inflict localized injury.

The majority of herbicide injury occurs due to drift of postemergence herbicides onto sensitive, nontarget plants.

DEVELOPING A WEED MANAGEMENT PROGRAM

Weed control in a landscape can be divided into a three-part program:
(1) eliminate weeds prior to planting, (2) prevent weed growth, and
(3) eradicate weeds as they appear.

Eliminate Weeds Prior to Planting

One of the most common mistakes in ornamental plantings is the lack of preplant planning. Many times a little preplant planning will help avoid problems later. Weeds, especially the difficult-to-control perennials, should be eliminated from the landscape bed prior to planting. This can be done in a number of ways.

- Herbicides can be used to kill existing weeds. Systemic herbicides will be the most effective against perennial weeds. Translocating herbicides are often the herbicides of choice, because they are very effective against perennials, and the treated area can be planted soon after application.
- Rotary tillage before planting will kill annual weeds and some weakly rooted perennial weeds.

- Mulches and landscape fabrics will kill many existing weeds, including perennials. Large weeds may lift plastic mulch before the energy reserves in the roots are completely used, and weeds can grow out of the planting holes cut in the materials.

Prevent Weed Growth

If you spend the time to clear an area of weeds, take measures to prevent weed growth from seed, and prevent weed encroachment from surrounding turf, roadsides, and other areas.

- Use weed-free planting stock.
- Apply a preemergence herbicide that is labeled for the plants in the landscape. Always read the label to check for the sensitive species. (Preemergence herbicides that must be incorporated are usually easier to apply before planting.)
- Keep an intact mulch layer.
- Properly manage ornamental plants. If desirable plants are properly managed, they may shade or crowd out many weeds. For example, most annual weeds do not usually become established in dense ground cover plantings.

Eliminate Weeds in Existing Plantings

Eradicate weeds that escape the previous procedures before they are well-established. Areas must be monitored and the status of control efforts should be recorded.

- Hoe or hand-pull weeds. Pull weeds whenever you see them in a bed. If weeds are pulled before they become established, even perennials can be killed. Do not let weeds go to seed.
- Apply a postemergence herbicide that will selectively kill the weeds. Some postemergence herbicides can be sprayed directly over certain types of ornamentals, and will kill the weeds without harming the desirable plants. Others are nonselective and must be used with great care. Follow label directions to prevent injury to desirable plants.
- Use sponge applications, wick applicators, coarse sprays, or shields to help protect ornamentals from herbicides. Monitor weather conditions to maximize control of weeds, and to prevent off-site movement of herbicides due to wind and rain.

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SAMPLE TEST

QUESTIONS

1. Plant management practices influence a plant's ________________, ________________________________, and ________________________________.

2. To diagnose plant problems, it is necessary to understand how a plant grows/dies/thinks.

3. Avoid pruning plants during wet weather because ____________ may be spread.

4. Certain species and cultivars of plants are more susceptible to pests than are others. True or False?

5. ____________ can be a useful method of insect control if an infestation is detected early and is restricted to certain parts of the plant.

6. Naturally occurring ____________ insects play an extremely important role in the natural control of many ornamental insects.

7. Pesticide application should coincide with a period of ____________________, which for many pests is brief.

8. The effective management of any disease depends on a ________________ of the cause(s) of the problem.

9. Pesticides can be used to ____________ plants from disease, or halt the ____________ of disease in an already-affected plant.

10. The first step in implementing a chemical weed control program is to ____________ the weeds.

ANSWERS

1. health, susceptibility to pest attack, ability to recover form pest damage 2. grows 3. diseases 4. true 5. pruning 6. beneficial 7. peak pest susceptibility 8. accurate diagnosis 9. protect, spread 10. identify

CHAPTER 4 BENEFICIAL ORGANISMS AND MAJOR PESTS WITHIN ARIZONA[1]

INTRODUCTION

In this chapter, we identify the **major** beneficial organisms and pests within Arizona. The insects and related pests, weeds, and diseases listed are only the **major** pests, and do not include all the pests in the state. The manual provides the following information: for **beneficial organisms**, descriptive physical characteristics, life cycles, and types of pests they control; for **insects and related pests**, descriptive physical characteristics, life cycles, types of damage or problems caused by the pest, and types of control of the pest. The information supplied for **weeds** includes descriptive physical characteristics, favorable conditions, and types of control of the pest. Information on **pathogens** includes descriptive physical characteristics of symptoms and damage, the cause of the problem, and types of control of the pest.[2] If there is a category of information (e.g., favorable conditions, cause, control) missing for a specific pest, we were unable to find information of that nature for that specific pest.

BENEFICIAL ORGANISMS

Beneficial organisms have always been an important part of pest management, but recently these organisms have started to receive more substantial recognition for their contribution to pest prevention and control. The beneficial organisms (generally predators and parasitoids) discussed in this chapter are considered to be good biological control agents. Generally beneficial organisms, unlike chemicals, are quite selective in what they target. As a result, nontarget organisms are seldom harmed. Biological control is not a new concept, but has probably been around (and known about) since the beginning

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[1]Persons contributing to information in this section include George Brookbank, Gary Cramer, Richard B. Hine, David Kopec, Dave Langston, Terry Mikal, Oscar Minkenberg, Carl Olson, and Jimmy Tipton, The University of Arizona; Ed Minch, Arizona Department of Agriculture; and Jerald Wheeler, ACRE, Inc.

[2]The information found in this chapter dealing with physical characteristics, life cycles, types of damage, and control measures of all the pests has been taken directly and indirectly from various sources. All sources used are listed in the References and Additional Information section at the end of this chapter.

of agriculture. In the United States, use of beneficial organisms was well developed by the late 1800s.

Beneficial organisms are usually present in the environment naturally. It is important, therefore, for pesticide applicators to be able to identify these organisms and, at the very least, try to protect them and integrate them into a pest control strategy. Beneficial organisms (also known as natural enemies) range from predatory mites, entomophagous fungi, and braconid and ichneumonid wasps to ground and rove beetles.

Biological controls have both advantages and disadvantages. Disadvantages include: (1) the effectiveness of the biological control may be somewhat unpredictable due to environmental factors such as rainfall and temperatures, which may affect the organisms development and (2) biological controls often take a longer time to effectively control the pest than do chemical controls. Advantages of using biological controls include: (1) they generally do not harm nontarget organisms (including humans) or the environment and (2) there is no resistance buildup against them.

A few common beneficial organisms naturally occurring in the Arizona environment are described below.

Assassin Bugs: Assassin bugs (family Reduviidae) are primarily predators, but some are parasitic. There are several species of assassin bugs and they range in size from 3/8 inch to 2 inches long. They are generally brown- or black-colored. They have long, slender heads with large, protruding eyes, long beaks, and legs armed with sharp spines. Upon capturing its prey, the predator pierces it, injects a paralyzing venom, and withdraws the prey's body fluids. Adults lay their eggs in soil. Assassin bugs overwinter as adults, nymphs, or eggs. *(See color plate, page 3.)*

Target: Aphids, bedbugs, bees, caterpillars, Colorado potato beetles, fly larvae, Japanese beetles, leafhoppers, Mexican bean beetles, and other reduviids.

Big-eyed Bugs: Big-eyed bugs are found mostly in thatch and feed on chinch bug nymphs. Adults big-eyed bugs resemble chinch bugs, but have larger eyes, wider bodies and more rapid movement. They are grayish in color, with tiny black spots on the head and thorax. Adults are about 1/4 inch (6 mm) long and hibernate in plant debris for the winter. Several generations are produced each year. *(See color plate, page 3.)*

Targets: Aphids, chinch bug nymphs, leafhoppers, and mites.

Lacewings: Lacewings (families Chrysopidae and Hemerobiidae) adults have two pairs of delicate lace-like wings. Green lacewings (Chrysopidae) lay eggs on the end of a thread of silk to protect them from predators; the brown lace wings

(Hemerobiidae) lay eggs directly on leaves. Adult green lacewings are green or yellow-green in color and are about 3/4 in (1.9 cm) long with golden eyes; the adult stage feeds only on pollen or honeydew. The larval stages prey on many types of soft-bodies insects and eggs of even more insects and mites. The larvae are very active and resemble an small alligator. They are yellowish gray with brown marks and tufts of long hair. They are approximately 3/8 inch long. They have hollow tusks which they use to pierce their prey and suck out body fluids. After they pupate for about 2 weeks, the adults emerge and mate. Three to four generations are produced each year. Lacewings pass the winter in the pupal stage in cocoons. *(See color plate, page 3.)*

Targets: Many soft-bodied insects, such as aphids, caterpillars, mealybugs, mites, scale insects, whiteflies, and the eggs of insects and mites.

Ladybugs: Ladybugs (family Coccinellidae) are small orange beetles with black spots. The larvae have the opposite coloring: they are black with orange spots. The larvae are about 1/2 inch long and are usually covered with spines. The eggs are yellow. Only one generation occurs each year. Eggs are laid in the early spring, producing larvae that feed for several weeks, pupate, and then emerge as adults. The adults feed through the fall, then either lay eggs and die or hibernate over winter, emerging in spring to deposit eggs. Both the larvae and adults prey on soft-bodied pests. *(See color plate, page 3.)*

Target: Aphids, beetle grubs, mealybugs, scale insects, spider mites, thrips, various small larvae, whiteflies, other soft-bodies pests, and insect eggs.

Minute Pirate Bugs: Minute pirate bugs *(Orius tristicolor)* are small, 2 to 5 mm (1/2 to 3/4 inch), in length, elongate-oval, and somewhat flattened. They are generally black with whitish markings. These bugs may be caught outside and transported into the greenhouse to help control thrips. *(See color plate, page 3.)*

Targets: Chinchbugs, mites, moths, thrips, wheelbugs, and whiteflies.

Parasitic Wasps: Parasitic wasps (superfamilies Ichneumonoidea and Chalcidoidea) are miniwasps that parasitize many insects. These tiny wasps jab their ovipositors into insects and insect eggs, and place one of their own eggs inside (or sometimes just near) the organism being parasitized. The Chalcid wasps are 1/32 in. long and are either metallic black or golden colored. The Ichneumon wasps are generally slender and have a long abdomen. Their formidable looking ovipositor is used for placing eggs. *(See color plate, page 3.)*

Targets: Chalcid wasps target aphids, beetle larvae, butterflies, mealybugs, moths, and scales. The Ichneumon wasps prey on moth and butterfly larvae.

Spiders: Spiders (order Araneae) can be extremely abundant. Spiders range in size from almost microscopic to nearly 4 inches in size (about 9 cm). All spiders are predatory and have mouthparts equipped with hollow fangs and venom glands. When a spider bites, venom from the glands is injected into the body of its prey. The venom of most spiders is only mildly toxic to humans and not life-threatening. The primary function of the venom is to kill or paralyze prey organisms and begin digestion of prey tissues. Some adult spiders will hibernate through the winter, but it is usually the eggs that pass the winter months. Spiders are one of the first predators to emerge in the spring. The primary food of most spiders is insects.

Targets: All insects.

PESTS

We wish to emphasize, again, that these are the **major** pests within the state. Pests which may be a major problem in only a small section of the state may not be included. Contact local experts for more information on specific pests in your area.

If a pest falls into both the turf and ornamental plant categories, it is described in detail in both the turf and ornamental plant sections. For example: annual bluegrass (*Poa annua*) is a problem in turf and in ornamentals. Annual bluegrass is described in detail under Turf and also under Ornamentals. Information, such as management and control practices, may be different for the two situations (turf and ornamental), so we have chosen to go into detail for both situations.

See box on next page for further information on category breakdowns.

In describing control measures for the pest, we have purposely not used trade or chemical names of pesticides. Pesticides that can be legally used today may be taken off the market, or lose registration, next year. Therefore, we have chosen not to include specific names. Contact your local authority for information on specific pesticides.

Many pests do not fit nicely into specific categories. For example, many pathogens are below ground (root) pathogens when moisture is limited; however, many of these same pathogens may express themselves in above ground situations (bud and flower or twig and stem) when moisture is not limited. Many of the insects and related pests may be problems in both larval and adult stages. Weeds may be cool-season plants (e.g., in southern part of the state) and warm-season plants (e.g., in northern part of the state). Due to these types of complications, we have separated the pests into the following categories:

Insects and Related Pests: Turf--**Above Ground** and **Below Ground**.
Ornamentals--**Leaf-chewing**, **Plant-sucking**, **Gall-forming**, **Root-feeding**, **Wood-boring**.

Weeds: First divided into **Cool-season** or **Warm-season** (these terms refer to the time of year these plants are a problem to pesticide applicators, not to the C_3 and C_4 photosynthetic pathways of these plants), then divided into **Grassy** and **Broadleaf** (not all plants in the grassy category are grasses; some, such as nutsedge, are not grasses or broadleaves, but fall more into the grassy category).

Diseases: **Above Ground** and **Below Ground**.

Please be aware that your pests may fall into different categories than those presented here. For example, a pathogen we have assigned to the Below Ground category may be an Above Ground pest in your area. Categories presented here are meant to provide general direction.

TURF INSECTS AND RELATED PESTS

ABOVE GROUND (including thatch)

Ants: The harvester ant (*Pogonomyrmex* spp.) and the native southern fire ant (*Solenopsis xyloni*) are both found in the Southwest. They not only damage turfgrass, but also sting when disturbed. Harvester ants are 1/4 inch long and reddish brown or black. The native southern fire ant is about 1/8 inch long and red with a black abdomen. *(See color plate, page 4.)*

Life cycle: Winged males and females swarm from parent colonies, pair off, and mate. The female (queen) locates a suitable nesting site and lays eggs. The colony is thus formed–the worker ants care for the nest and young and gather food, while the queen's sole function is to lay eggs.

Damage: Ants will invade any sunny, well-drained turfgrass area. As the colonies of ants grow, the harvester ants make a large mound with bare circular areas around it and trails through the turf. The native southern fire ants make small mounds. The ant galleries in the soil disturb the roots, dry the soil, and cause the grass to thin out. Native southern fire ants, when disturbed, will repeatedly sting whatever it is that disturbs them.

Control: Ants may be controlled with the use of baits or by treating individual mounds with insecticidal drenches or granules. If anthills are numerous, a broadcast treatment of the entire area may be needed.

Bermudagrass Stunt Mites: Bermudagrass stunt mites (*Eriophyes cynodoniensis*) are a serious pest of bermudagrass on golf courses. This mite was first discovered in the United States in a bermudagrass lawn in Phoenix. These mites are worm-like in shape, creamy white to yellowish, and barely visible with a 10x to 20x lens. Several generations occur during the season.

Life cycle: Mites are active primarily during late spring and summer. These mites are 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. They require only 5 to 10 days to complete their development from eggs to adults. After hatching, they pass through two nymphal instars, molt, and become egg-laying adults in 7 to 10 days.

Damage: Damage is caused by mites that feed under the leaf sheaths. The first signs to appear are a slight yellowing of the leaf tips and a twisting of the leaves, with the margins rolling upward and inward. Stem internodes are shortened, resulting in a stunted, rosetted, or tufted appearance. With heavy infestations, the grass turns brown and dies. When infestations are allowed to persist, the grass may thin out, allowing weeds to invade.

Control: To detect this pest 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 a 10x to 20x hand lens or dissecting microscope. Look for mites and spherical, transparent eggs.

Well-fertilized lawns are more attractive to mites than starved grass. The mite *Stenotarsonemus spirifex* is a natural enemy of the bermudagrass stunt mite.

Chinch Bugs: Chinch bugs (*Blissus* spp.) are a problem on St. Augustine grass in Arizona. The first symptoms of a chinch bug infestation are patches of dead grass in sunny areas. Chinch bugs are small, white and black insects that suck sap from grass. This insect has piercing-sucking mouth parts, which it inserts into the plant to extract plant juices and insert toxins. The combination of the toxins and the extraction of plant juices may kill or severely damage grass plants. The false chinch bug (*Nysius raphanus*) may invade lawns after desert annuals die in the spring, but generally causes little problem. *(See color plate, page 4.)*

Life cycle: Adults are approximately 1/5 inch long. They are black with white wings folded over their back, which gives them the appearance of having a white cross on their back. In the spring, the overwintering adults emerge and move to the growing grass plants, where they feed and begin mating. Females lay about 200 eggs over a 3- to 5-week period. Nymphs begin feeding on the grass within 2 weeks, and change in color from yellow to red to orange-brown and then to black at maturity. In the summer, the nymphs molt about 5 times to become adults. They continue to feed on plant sap, then produce a second generation of bugs in the summer. In autumn, adults of the second generation hide in grass clumps and leaf litter to survive the winter. When the weather warms in the spring, they leave this shelter and search for food.

Damage: Most of the damage is caused by the nymphs as they suck plant juices from young grass. An infestation of chinch bugs shows up as yellow patches in the turf. Injured grass turns yellow, then brown, as feeding continues. Chinch bugs concentrate their feeding at the edge of the dead patch.

Control: There are several biological controls for chinch bugs. Infection by the fungus *Beauveria* causes a disease in which white fungal threads may fill the body cavity of the bug, causing death in about 3 days. The big-eyed bug, which looks similar to the chinch bug but lacks the white cross and has large eyes, preys on chinch bugs. The nematode *Steinernema carpocapsae* also attacks chinch bugs.

Cultural control methods that help prevent chinch bugs include keeping lawns healthy with proper watering and fertilizing, and aerating the soil when it becomes compacted. Some resistant varieties of grasses are available. Several pesticides are available that help control chinch bugs.

Cutworms: Cutworms (family Noctuidae) are the larvae of night-flying moths two to three times larger than sod webworm moths. Cutworms in general are plump and dull grayish or brownish in color. Many have variations in color patterns. Adults are dull-colored and have a wing span of 1-1/4 to 1-1/2 inches. *(See color plate, page 4.)*

Life cycle: Adult moths lay their eggs at night on the turfgrass surface. The larvae feed at night, hiding in the thatch and soil during the day. The number of generations each year varies with the location. Cutworms overwinter either in the larval or pupal stage. Up to 5 generations can occur in a year.

Damage: Larvae are active summer feeders and may cause noticeable foliar damage to fine bentgrass turf. The larvae feed at night on grass blades, which they chew off close to the base of the plant. More significant damage may occur when birds tear up the turf searching for larvae. All grasses are susceptible to cutworm attack.

Control: A healthy turf will generally withstand cutworm damage. Use of a pyrethrum irritant to move cutworms to the soil surface may help determine the extent of infestation. Treat when 5 or more cutworms are found per sq. yd.

Bacillus thuringiensis (BT) may be an effective biological control for some species of cutworms. This pest often requires chemical control measures on putting greens. If chemical treatment is decided on, it may be necessary to remove the thatch. Water thoroughly (some people prefer to add a little detergent to the water) to drive the worms to the surface, and apply the pesticide. Generally, treatment is most effective if applied in the late afternoon or early evening.

Flea Beetles: Adult flea beetles (*Chaetocnema ectypa*) are black and very small, about 1 millimeter (1/25 inch) long. The larvae live in the soil and are not usually seen. Flea beetles generally attack dichondra. *(See color plate, page 4.)*

Life cycle: Little is known of the life cycle of this flea beetle. Adults appear to be active from May through October in warm areas. Observations indicate that one generation is completed in about a month. The larvae are thought to develop on the roots of plants. Adult beetles jump readily when disturbed—hence the name "flea beetle."

Damage: Adult flea beetles feed on the upper surfaces and skeletonize the leaves. When enough of the leaf is eaten away, the leaf turns brown. Injury may be localized or spotty, and damaged areas are often assumed to have been caused by lack of water or fertilizer burn.

Control: Close inspection of infested plants will reveal the small, shiny, black beetles sitting on the leaves. Moving the open palm of the hand lightly over the surface of the plants will cause the beetles to jump about, and some will light on the back of the hand or arm and can thus be readily seen.

Leafhoppers: Leafhoppers are small, generally less than 1/4 in. They are pale-colored (often green, yellowish, or grownish gray) insects that suck plant sap. They are very abundant and can be found on nearly all species of plants. Adults as well as nymphs feed on plant sap. *(See color plate, page 5.)*

Life cycle: There may be 2 or more generations of leafhoppers a year, and they may become numerous.

Damage: These insects suck the sap from leaves and stems, and the plant becomes yellow and spotted. In severe infestations, the lawn or turf appears scorched or wilting from drought.

Control: Insecticides that help control leafhoppers are available.

Rove Beetles: Rove beetle (*Osorius planifrons*) adults are 1/8 to 1-1/4 inches long. They are usually brownish or black colored. They have unusually slender bodies and extremely short wing covers. They eat mites, beetle larvae, aphids, and small worms.

Life cycle: Nocturnal adults are active during warm weather. Rove beetles may overwinter as larvae, pupae, or adults, and produce several generations each year.

Damage: These beetles make small holes and mounds of dust on turf. On golf course greens, soil excavated from holes creates a poor putting surface.

Control: There are certain pesticides registered for use on turf that help to control the rove beetle.

Sod Webworms: Sod webworms (family Acrolophidae) are the larval stage of several species of *Lepidoptera*. These larvae vary in color from greenish to beige, brown, or gray, depending upon the species. When mature, they are 3/4 inch long, and most have characteristic dark, circular spots scattered over their body length. As the larvae mature, they construct tunnels or burrows through the thatch, sometimes extending into the soil. The adults are commonly seen flying in jerky, short flights from place to place as you walk through the grass, and near lights at night. They are usually dull-colored with a wing span of 1-1/4 to 1-1/2 inches. Although there are several species of sod webworms, damage is similar. *(See color plate, page 5.)*

Life cycle: In spring, when the weather warms, the overwintering caterpillars begin feeding on the grass. When the webworm caterpillar is full-grown, it forms a pupa. Moths begin flying in April or May in the warmer areas of the state and breeding continues through October. The moth lives for only a short period to mate and lay eggs in the grass. The caterpillars build silken tunnels at ground level or in the thatch layer, which they stay in during the day; they feed at night. In autumn, the second-generation caterpillars remain in their tunnels to hibernate through the winter.

Damage: Damage first appears as small, brown areas in the grass. The turf often has a ragged appearance. Feeding and consequent damage occurs only at night, when the larvae feed on the grass blades. If feeding is extensive during dry weather, the plants may be killed. While all grasses are susceptible to attack, bentgrasses and blue grasses are most susceptible to injury—especially new turf.

Control: Use of a pyrethrum irritant to move the sod webworms to the soil surface may help determine extent of infestation. Treat turf when 15 or more worms are found per sq. yd.

Biological controls include the nematode *Steinernema carpocapsae*, which attacks sod webworms. A slow-working, but effective fungus that also attacks webworms is

Beauvaria bassiana. *Bacillus thuringiensis* (BT) may also be effective. Pyrethrum or rotenone, botanical poisons, paralyze webworms on contact. Insecticidal soaps may help to control sod webworms, and there are several pesticides that can also be used. Preventive treatments are suggested for newly planted turf.

Cultural controls include reducing the habitat for sod webworms by reducing thatch to 3/4 inch or less, and by planting resistant perennial ryegrasses and fescues, when they are commercially available. Maintaining adequate nutrient and moisture levels also helps.

Vegetable Weevils: The vegetable weevil (*Listroderes costirostris*) larvae are small, green, legless grubs about 3/8 inch long. Adults are brownish or grayish weevils or "snout" beetles about 3/8 inch long. Wing covers are very rough or punctate with sparse, short setae (hairs). A light, V-shaped marking is prominent posteriorly on the wing covers. The adults do not fly. Both larvae and adults are very slow and sluggish in movement. Vegetable weevils attack various species of turf. *(See color plate, page 5.)*

Life cycle: Vegetable weevils are active only during the winter and spring months. No males are present, and females produce young without mating. Both adults and larvae feed at night. Occasional adults can be seen during the day, but usually hide among plant foliage or in other dark places. Larvae hide in the soil beneath the plants during the day.

Damage: Damage first appears as small holes in the leaves, but in the case of heavy infestations, the leaves may be skeletonized or completely removed leaving only the bare stems. Since the adults do not fly, infestation of new areas usually takes place very slowly, and damage is usually localized or spotty.

Control: To help detect the presence of these weevils irritate soil with pyrethrum solution. Maintain a lush turf as these weevils attack stressed turf. Insecticides effective against vegetable weevils are available.

BELOW GROUND

Billbugs: Billbugs (*Sphenophorus phoeniciensis* and *S. venatus*) look much like white grubs, except they are smaller and do not have legs. Larvae are white, 3/8 inch long, and have a yellow to brown head. They are fat with the tail end somewhat larger than the head end. Larvae feed on the roots and stems of grass, often cutting the stems off at the crown so they are easily pulled up. Adult beetles feed on the blades of grass. Adults have a large snout or "bill," are 1/4 to 1/2 inch long, and vary in color from cream to brown to black. Bermudagrass and zoysia are frequently attacked by billbugs. *(See color plate, page 4.)*

Life cycle: Billbugs generally overwinter as adults in the turf or sheltered areas nearby. In spring, they begin to move about, and are commonly observed wandering around on driveways and sidewalks. In May and June, adults lay eggs in cells cut near the crown of the grass stems. These eggs hatch in about two weeks. Larvae feed within the grass stem for a time, and then burrow down the stem to feed on the crown. Later, they move to the root zone, feeding on roots and rhizomes. Larvae are abundant from mid-July to mid-August. After completing development, they pupate in small cells in the soil and soon emerge as new adults. New adults are abundant in late September and October, when they are again frequently found in considerable numbers on driveways and sidewalks. As winter approaches, the adults seek shelter in turf and other protected areas.

Damage: Damage to turf by the larvae is similar to that caused by white grubs (i.e., areas of grass begin to turn brown due to root damage). Turf is easily pulled out by hand, with the stems breaking off at the crown. A good indication is the presence of fine, white, sawdust-like material left by larvae feeding in the root zone. The adults eat small holes in the blades of grass. The area around the holes may turn yellow, and the grass may have a speckled appearance.

Control: If more than 1 grub per sq. ft. is found in border areas where grass turns from green to brown, then the turf should be treated. Turf labeled insecticides are available. Beneficial nematodes or a botanical poison such as rotenone provide quick, but temporary, control. While milky spore disease, caused by *Bacillus popilliae*, may provide long-term control in most climates, control may be very limited in soils at lower elevations in Arizona, where it is too hot for this microbe to survive.

Frit Flies: Adult frit flies (*Oscinella frit*) are about 1/16 inch long, shiny 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. Frit flies attack various species of turf.

Life cycle: 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.

Damage: 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 to be most susceptible. All grasses are susceptible, with bentgrass and bluegrass most susceptible to injury.

Control: To detect the presence of frit flies, 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. Water well to maintain a lush turf as these flies attack stressed areas of turf. Effective insecticides are available.

Ground Pearl Scales: Ground pearl scales (*Margarodes* spp.) are the immature stage of scale insects. A few days after hatching, the tiny nymphs attach themselves to the roots of grasses—primarily bermudagrass and centipede grass in the

Southwest. With piercing mouthparts, they suck nutrients from the grass, and secrete around themselves a pearl-like shell. Shells are yellowish purple, varying from pinhead-size to nearly 1/4 inch in diameter. *(See color plate, page 4.)*

Life cycle: Ground pearl scales overwinter in cysts. Females mature in late spring, emerge from the cysts, and soon secrete a waxy coating that covers their bodies. They deposit eggs within this waxy coat. Eggs hatch in late summer, and the young crawlers start feeding on grass roots. At least 1 year, and probably 2 or more years, is required for a complete cycle from egg to adult.

Damage: These sucking insects attack grass roots, essentially removing all the juices. The turf turns yellow, then brown, and eventually may die and leave irregular circle-shaped dead spots.

Control: Since pearl scales can occur as deep as a foot in the soil, control can be difficult. There are pesticides available, however, which can be effective. Wet the soil to a depth of at least one foot. Do not scalp the turf when mowing, and raise the cutting height to about 1-1/2 inches during late summer. Water and fertilize the turf to maintain good grass vigor.

White Grubs: White grubs are the larval or grub stage of several species of beetles (*Cyclocephala* spp.). These beetle larvae are usually C-shaped, and can be found feeding on the roots of grass. They may be 3/4 to 1-1/2 inches long and have three pairs of legs. They are typically cream-colored with a brown head and a dark area at the posterior end, where the body contents show through the skin. White grubs feed on grass roots and most complete their development in 1 year (some May beetles require 2 or 3 years). *(See color plate, page 5.)*

Adults of white grubs are commonly called May beetles, June beetles, or June bugs. They are 3/4 to 1 inch long and are yellowish-brown in color with a reddish head.

Life cycle: Eggs of *Cyclocephala* spp. are laid in July and August, the adult beetle selecting the best grass available to deposit its eggs. Young grubs begin feeding on the grass roots within 1 or 2 weeks. Feeding goes on until fall, when the grubs burrow deep into the ground to overwinter. In the spring, the grubs burrow upwards to the grass roots and resume feeding until late May, when they transform to the pupal stage. Adults begin emerging from the ground about the first week in June or sooner.

Damage: Areas of grass begin to turn brown due to root damage. Usually the turf can be rolled back like a rug to reveal the white grubs. All grasses are susceptible to white grubs damage; however, bermudagrass and rye grass seem to be the most susceptible.

Control: Examine the soil around the grass roots. Dig in brown areas of grass near the edge of healthy green grass. If more than 1 grub per sq. ft. of area is found, the turf should be treated. Apply a turf labeled insecticide after eggs have been laid in late July or early August.

TURF WEEDS[3]

COOL-SEASON GRASSY

Annual Bluegrass. Flowering plant. a. Spikelet. b. Grain.

Annual Bluegrass: Annual bluegrass (*Poa annua*) is a winter annual or perennial that can persist in closely mowed turfs for many seasons. It is apple green in color and produces hundreds of whitish green seedheads at all mowing heights. Seedhead production persists, even at the extremely close mowing heights of a putting green. It grows well on compacted soils under moist and shaded conditions, and frequently occurs in dense patches. Seedheads are produced throughout the growing season, but are particularly abundant during midspring. *(See color plate, page 7.)*

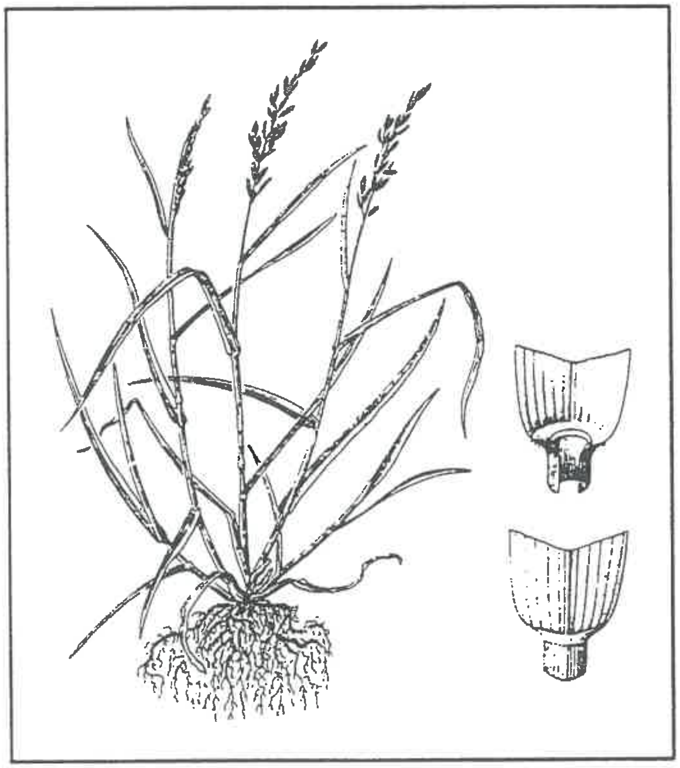
Favorable conditions: Management practices encouraging the persistence of annual bluegrass include excessively close mowing, shallow, frequent irrigation, poor soil drainage, improperly timed fertilization, aerating or dethatching during primary periods of annual bluegrass germination, use of heavy equipment causing soil compaction, and allowing the site to be shaded.

Control: Maintain a dense turf. Annual bluegrass requires strong light for seed germination. A dense turf may shade the soil surface enough to keep annual bluegrass from germinating. Reduce soil compaction with coring. Increase mowing height and frequency. Remove grass clippings when annual bluegrass seedheads are present. There are a variety of herbicides and growth regulators that can be applied at certain times of the year to obtain control of annual bluegrass. A preemergence herbicide can be used with some success when applied in the fall at low elevations

[3]Illustration of tall fescue by Jim Converse, reprinted with permission, from *Turfgrass Pest Management Manual: A Guide to Major Turfgrass Pests and Turfgrasses*, edited by Arthur H. Bruneau, the North Carolina Extension Service. All other illustrations by Lucretia B. Hamilton reprinted from *An Illustrated Guide to Arizona Weeds* by Kittie F. Parker, by permission of The University of Arizona Press, copyright 1972.

(3,500 ft. and below), or in the spring at higher elevations. Plant growth regulators can be used after the poa plant has germinated and is visible. Do not apply a plant growth regulator for annual bluegrass control during cold-temperature periods.

Tall Fescue: Tall fescue (*Festuca aurundinaceae*) is a cool-season perennial grass. It has been distributed as a seed contaminant in uncertified seed lots of other turf species. Tall fescue appears as a clumpy, coarse-type grass. It is often found in Kentucky bluegrass lawns at higher elevations (4,500 ft. and above), and occasionally at low elevations, where it may have established in overseeded bermudagrass lawns, when ryegrass was planted in the fall at low elevations. *(See color plate, page 9.)*


Tall fescue.

A wide leaf blade, coarse-edged leaves, and its rapid elongation rate make this plant a weed in Kentucky bluegrass, ryegrass, and bermudagrass lawns.

Favorable conditions: Most plants are introduced as a seed contaminant. Tall fescue tolerates close mowings. Cool temperatures in the spring and fall favor seed germination.

Control: Where possible, raise the mowing height of the competing grass; on bermudagrass lawns, maintain a low mowing height and decrease irrigation which will favor the bermudagrass; spot treat persistent plants with a nonselective herbicide when the leaves are tall and lax; for infested Kentucky bluegrass lawns, a selective herbicide is available for control—a fall application is recommended.

Wild Barley: Wild barley (*Hardeum leporium*) is a low-growing annual grass, which germinates in the fall. Throughout the fall, winter, and early spring, the plant will maintain a prostrate (low-growing) profile. In March and April, a coarse flower head will appear, with stiff bristles 3/4 to 1-1/2 inches long. The seed is then dispersed by physical means and by wind. After this, the plants wither and die. *(See color plate, page 10.)*

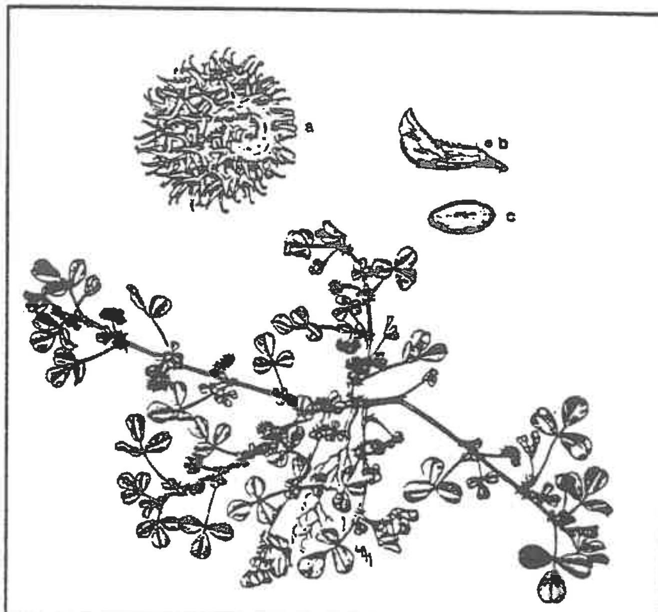
Favorable conditions: Found mostly in weak turfs, or open ground areas in the landscape. Plants originate from seed every year.

Control: If wild barley is found in irrigated lawns, maintain normal mowing and accepted fertilizer practices. Mow off seed heads, collect debris in catch bag, and dispose of off-site. Prevent germination in the fall by using a preemergence herbicide. Small wild barley plants in open areas can be hoed.

Wild barley. Flowering plant. a. Spikelets. b. Floret with long bristle.

COOL-SEASON BROADLEAF

Bur Clover: Bur clover (*Medicago polymorpha*) is a bright green, nearly hairless annual, sometimes a winter annual, which reproduces only by seeds. The weak stems branch from the base, and spread or lie on the ground. The leaves are alternate and divided into 3 leaflets, which arise from a common point at the end of the leaf stalk. The leaflets are somewhat wedge-shaped, with toothed edges and indented tips. There are a pair of stipules with long, irregular teeth where the leaf stalk joins the stem. The small, yellow, pea-like flowers are borne 3 to 5 in a cluster near the end of short



Bur clover. Plant with flowers and pods; the leaves are trifoliate. a. Pod, spirally coiled, with prickles. b. Flower, pea-like. c. Seed.

stalks. *(See color plate, page 7.)*

Favorable conditions: Poor soil and lack of competition favor this plant. Once established, bur clover will withstand mowing.

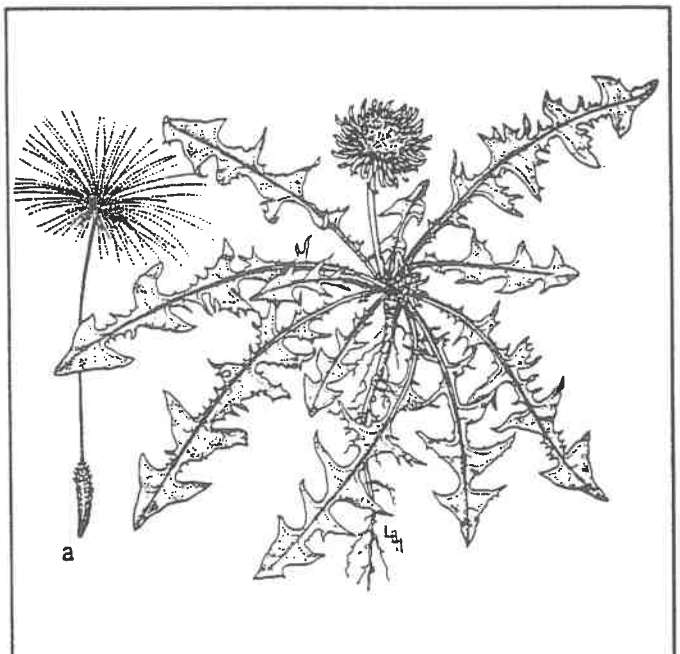
Control: Some pre- and postemergence herbicides can effectively control bur clover.

Common Chickweed: Common chickweed (*Stellaria media*) is a creeping winter annual with small, pale green leaves, and petioles that have a line of hairs on one side. Its smooth stems branch and take root, enabling the plant to spread over large areas, and completely crowd out turfgrasses. The white, star-like flowers appear during cool seasons. *(See color plate, page 7.)*

Favorable conditions: Common chickweed grows best during cool, wet weather in shady places. It does not tolerate hot, dry conditions. It is very shade-tolerant. Poor fertility in turf and lack of competition favor this weed.

Control: Maintain a dense, vigorous turf. Water infrequently. Some postemergence herbicides are useful in controlling common chickweed.

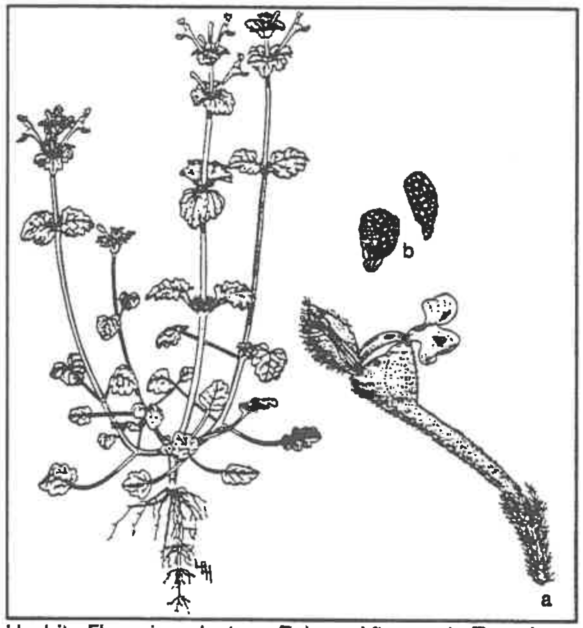
Dandelion: Dandelion (*Taraxacum officinale*) is a low-growing perennial common throughout the entire United States. Its roots are thick, fleshy, and often branched. Dandelion stems never elongate and produce a basal rosette of leaves. The leaves are simple, but are deeply lobed, with the lobes pointing back toward the stem. The bright yellow flowers are borne on single stalks. Dandelions often regenerate from pieces of root or stem. When mature, dandelion seeds develop a pappus and are transmitted through the air over large distances. *(See color plate, page 7.)*



Dandelion. Tufted perennial plant with taproot. a. Achene with tiny curved teeth on upper margins, and long, slender beak topped by umbrella-like tuft of whitish hairs.

Favorable conditions:
Dandelions thrive in weak, thin turf.

Control: Maintain a dense, healthy turf. Remove grass clippings when dandelion seed heads are present. Spot-treatments with post emergence herbicides can be very effective, especially if combined with a good preemergent program.

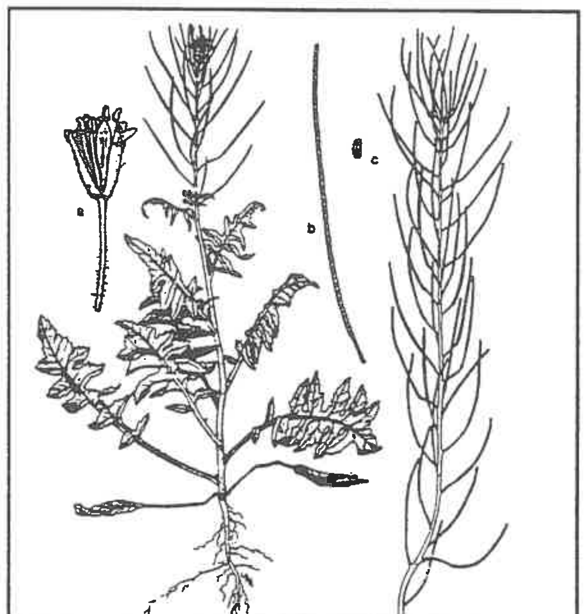


Henbit. Flowering plant. a. Enlarged flower. b. Two views of seed-like nutlets.

Henbit: Henbit (*Lamium amplexicaule*), a member of the mint family, is a very common winter annual that reproduces by seed. Stems are 4-sided and grow primarily upright, but can root at the lower nodes. Henbit branches freely from the base stems, which are square in cross section and green or purple in color. Leaves are rounded, coarsely toothed, hairy, and deeply veined. They are opposite on petioles in the lower portion of the stem. The upper leaves are sessile or clasping the stem. Flowers are in whorls in the axils of the upper leaves. Petals are pink to purple and fused into a two-lipped tube. *(See color plate, page 8.)*

Favorable conditions: Poor soil and lack of competition favor this plant.

Control: Henbit is very difficult to control. It is often troublesome in newly seeded turfs. Fallowing before seeding can help minimize weed competition. Some pre- and postemergence herbicides are effective.



London rocket. Plant in flower and in fruit. Also, fruiting branch. a. Flower. b. Fruit or seedpod. c. Seed.

London Rocket: London Rocket (*Sisymbrium irio*) is one of the more common mustard weeds found. It is a bright green, fleshy annual or winter annual. Its stems are usually much branched from the base. It has a coarse taproot and reproduces by seeds. Leaves are divided and 1 to 8 inches long. Small, yellow flowers are borne on slender stalks in small clusters at the stem tip. The flower stems elongate as the seedpods mature, so there are many, very narrow pods below the flower clusters. *(See color plate, page 8.)*

Favorable conditions: London rocket is usually found in moist soils. It is one of the first weeds to appear, and usually disappears in hot weather, except in moist, shaded places.

Control: Some pre- and postemergence herbicides are effective.

Malva (Little Mallow): Little mallow (*Malva parviflora*) is a stout, bushy annual or biennial, branched and spreading from the base. It is 1 to 3 feet high, has a short thick taproot, and reproduces by seeds. The large, soft leaves are alternate, almost circular, and often have a red spot at the base. They usually have 5 to 7 shallow lobes with toothed edges. The leaves are 2 to 5 inches wide on stalks 4 to 10 inches long. The inconspicuous, bluish or pinkish flowers are nearly stalkless, forming small clusters at the base of the leaf stalks and at the top of the plant. Normally, this plant will grow upright in a globe shape, but will grow laterally when mowed regularly. *(See color plate, page 8.)*

Little Mallow. Leafy plant. a. Normal flower. b. Flower unopened, when temperatures are low. c. Fruit surrounded by enlarged sepals. d. Carpel with seed enclosed.

Favorable conditions: This plant is often found on moist, loamy soil.

Control: Hand-pull or hoe when practical. Some pre- and postemergence herbicides are effective.

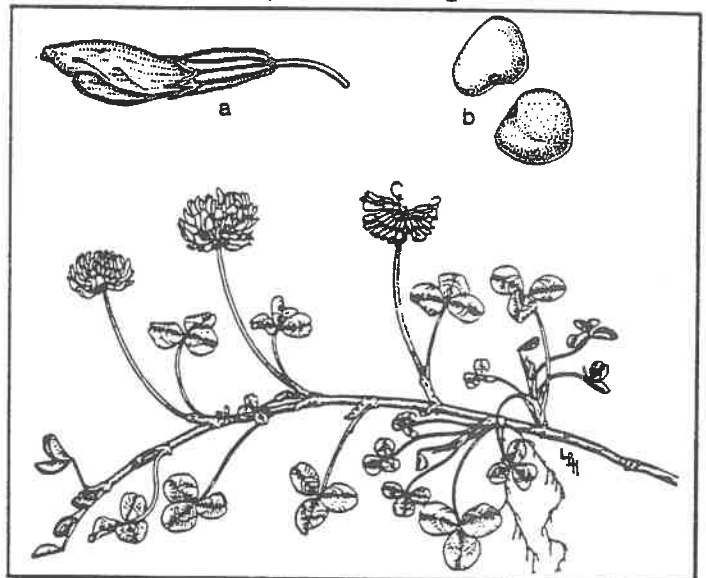
Red Stem Filaree: Red stem filaree (*Erodium cicutarium*) is an annual or biennial that reproduces by seed. It has hairy, low, spreading or prostrate stems. Leaves are alternate and pinnately compound. Flowers are pink to purple and are borne on conspicuous stems. *(See color plate, page 9.)*

Red stem filaree. Branch with flowers and fruits. a. Basal rosette of young plant. b. Flower. c. Single fruit with seed enclosed and corkscrew-like "tail."

Favorable conditions: Lack of competition by turf favors this plant.

Control: Hoe or pull out the rosettes as soon as they can be recognized.

White Clover: White clover (*Trifolium repens*) is a hairless perennial that roots along its runners and remains summer dormant at lower elevations (3,500 ft. and lower). The leaflets have a white band across the mid-section. White flowers are borne in globe-like heads, which are white or pink tinged. The flowers attract honeybees when in bloom. *(See color plate, page 9.)*



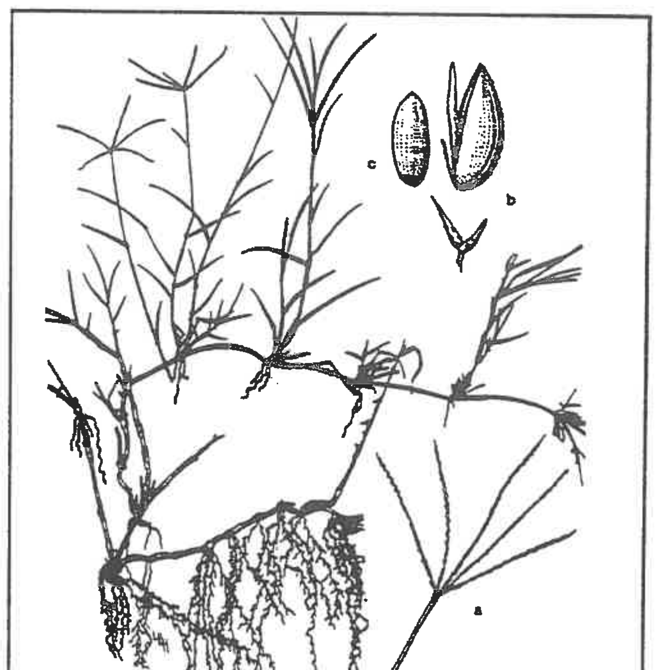
White clover. Prostrate branch rooting at a node, with stalked heads of flowers; the compound leaves are trifoliolate. a. Flower. b. Two views of a seed.

Favorable conditions: This weed competes with turfgrasses in moderately to intensely managed lawns. White clover prefers partially shaded areas.

Control: To help control this weed, increase mowing height and decrease irrigation, when and where possible. Broadleaf weed control herbicides are available that are effective against white clover.

WARM-SEASON GRASSY

Bermudagrass: Bermudagrass (*Cynodon dactylon*) is a warm-season perennial found throughout much of the United States. It is fine- to medium-bladed and low-growing, producing both rhizomes and stolons. Bermudagrass is extremely aggressive and one of the most rapidly growing grasses commonly found in turf. It has a



Bermudagrass. Plant showing rhizomes. a. Enlarged inflorescence. b. Spikelet, with glumes detached below. c. Grain.

deep root system that provides tolerance to drought, but is particularly troublesome in moist soils. The seedhead of bermudagrass is a whorl of three or four racemes with small, one-flowered spikelets. Bermudagrass is the principal turfgrass species used in the southern United States, but can become a troublesome weed when it invades other turfs such as bluegrass. *(See color plate, page 7.)*

Favorable conditions: Bermudagrass is a prolific seed producer when not mowed.

Control: Use pre- and postemergence herbicides.

Crabgrass: Crabgrasses (*Digitaria* spp.) are annuals which persist well under most turf conditions. They are coarse-bladed and light or apple green. Crabgrasses are highly competitive in turf, and their spreading growth habit tends to minimize recovery by turfgrass species. Crabgrasses can germinate throughout the entire growing season, after soil temperatures have warmed in the spring. Germination occurs after each irrigation or rainy period, thus requiring persistent control. Once established, seeds can remain viable in the soil for many years. *(See color plate, page 7.)*

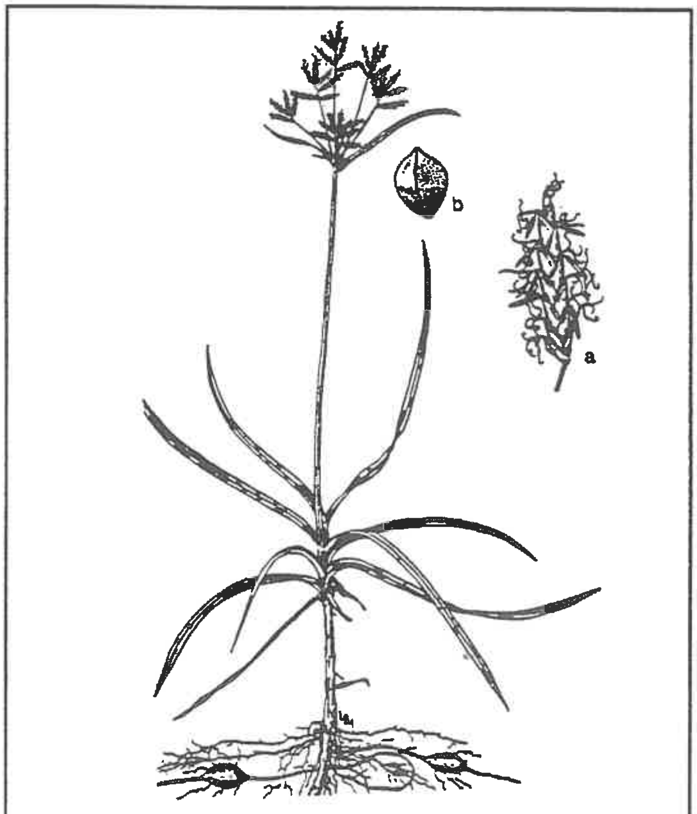
Large crabgrass. Plants with finger-like inflorescences. a. Spikelet. b. Spikelet side view. c., d. Two views of grain or floret

Favorable conditions: Crabgrass is often found in thin, open turf. Factors that favor crabgrass include improper mowing, summer fertilization, and light, frequent waterings.

Control: Maintain a dense, healthy turf. Crabgrass is frequently controlled with preemergence herbicides if applied when soil temperatures approach 55° F (the temperature at which crabgrass germinates). If it is too late in the year for preemergence herbicides, some postemergence herbicides are effective.

Nutsedge (Yellow and Purple): Yellow nutsedge (*Cyperus esculentus*), when well established, is considered a serious weed problem, and is difficult to eradicate. Yellow nutsedge can be spread in balled-and-burlapped nursery stock, and can be a problem in field-grown nursery stock, lawns, and landscape plantings. It is a perennial herb, reproducing by seeds and weak thread-like rhizomes, terminated by hard tubers. The stems are erect, tall, and triangular. Near the base of the triangular stem, a cluster of 3-ranked, grass-like leaves arise, which are often longer than the stem. The flower stalks are pale green w h umbels that form yellowish to golden-brown spikelets. Yellow nutsedge is found at both low and high elevations. *(See color plate, page 8.)*

Purple nutsedge (*Cyperus rotundus*) closely resembles yellow nutsedge, but the mature stems are usually longer than the basal leaves. The leaves are generally darker in color than yellow nutsedge and appear below the flowering heads. Leaves are between 1 and 5 inches long, and are about the same length as the flower stems. The spikelets are dark brownish purple. Purple nutsedge produces small round tubers (nutlets), generally 1/8 to 1/4 inch in size. Purple nutsedge is readily found at lower elevations (below 3,000 ft.), and less frequently at higher elevations.



Purple nutsedge. Flowering plant, showing underground stems with nutlets or tubers at tips. a. Spikelet in flower. b. Achene.

Favorable conditions: Nutsedges are found on moist, poorly drained sites.

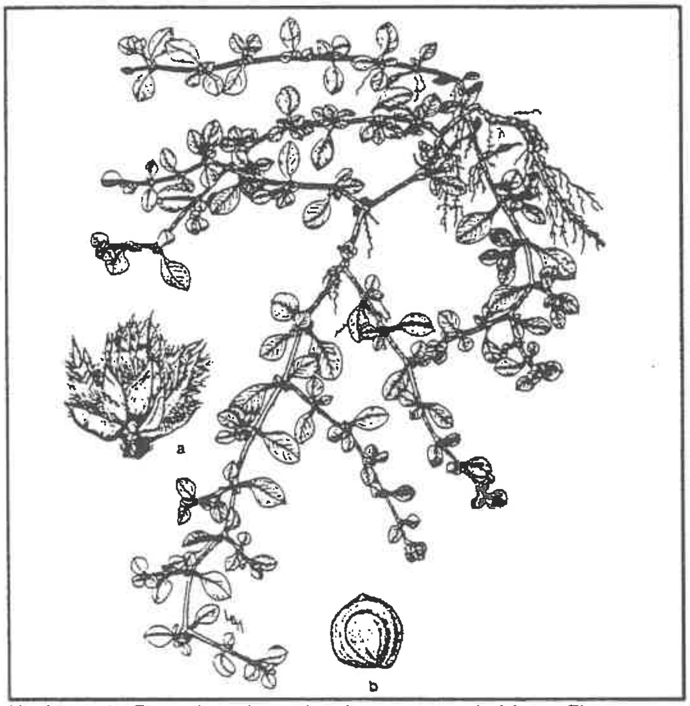
Control: Maintain a vigorous turf. Avoid mowing close to ground level to help keep nutsedge out of the turf. However, once nutsedge is present in the turf, frequent, close mowings will help slow its spread, if the turf can withstand this as well. Improve drainage. Pull up single plants and repeated regrowth when practical. Postemergence applications of an arsenate herbicide or certain new compounds are effective. Note, however, that only certain turfgrasses are tolerant.

WARM-SEASON BROADLEAF

Khakiweed: Khakiweed (*Alternanthera pungens*) is also known as creeping chaffweed. This is a perennial weed that reproduces both by seeds and from thick woody vertical roots. Seeds germinate in late spring. This weed has prostrate stems with dark glossy leaves 1/2 to 1-1/2 inches long, scattered with short hairs. The leaves appear opposite on the stems, often with one leaf larger than the other. Stems are hairy. Small, papery flowers appear along the stems at the base of the leaves. *(See color plate, page 8.)*

Favorable conditions: Khakiweed is a very competitive weed in southern Arizona, crowding out even bermudagrass. It forms dense mats, eliminating surrounding vegetation. It is moderately drought-tolerant, and remains low to the ground.

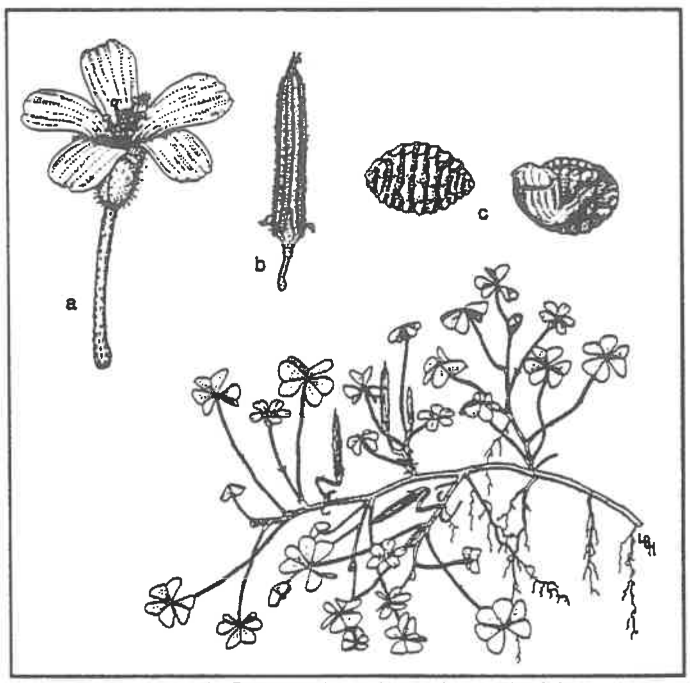
Control: Hoe young khakiweed plants in May when they appear; repeat application of postemergence herbicides are otherwise necessary. Established stands of this weed will increase in size from underground roots. Raise mowing height during spring and early summer.



Khakiweed. Flowering plant, showing prostrate habit. a. Flower cluster. b. seed.

Oxalis (Woodsorrel):

Oxalis (*Oxalis* spp.) is a perennial or annual, with hairy stems weakly branched at the base. These may root at the nodes. With leaflets in groups of three, oxalis can be easily mistaken for a clover. The leaves are heart-shaped. The middle leaflet, however, is not borne on a short stalk. The flowers are small, with five conspicuous, bright yellow petals. As the flowers mature, cucumber-shaped seedpods are formed. When dry, the seeds may scatter for several feet in all

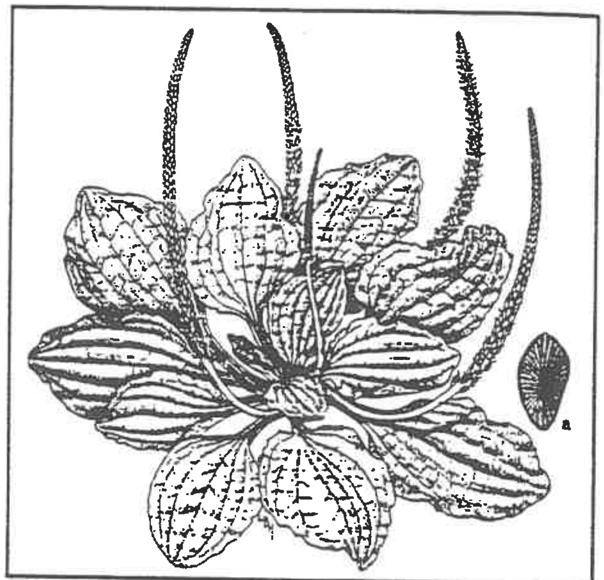


Creeping woodsorrel. Prostrate branch, rooting at the joints. a. Flower. b. Seedpod. c. Two views of seed.

directions. Woodsorrel occurs extensively throughout the United States, and is a very common turf weed. *(See color plate, page 8.)*

Favorable conditions: Oxalis can be found on dry or moist soils, and usually prefers shaded areas. It is often found where turf is thin.

Control: Hand-weed areas with only a few Oxalis plants present. Maintain a dense, vigorous turf. Oxalis, in the past, has been difficult to control with herbicides; however, certain new pre- and postemergence herbicides are effective.



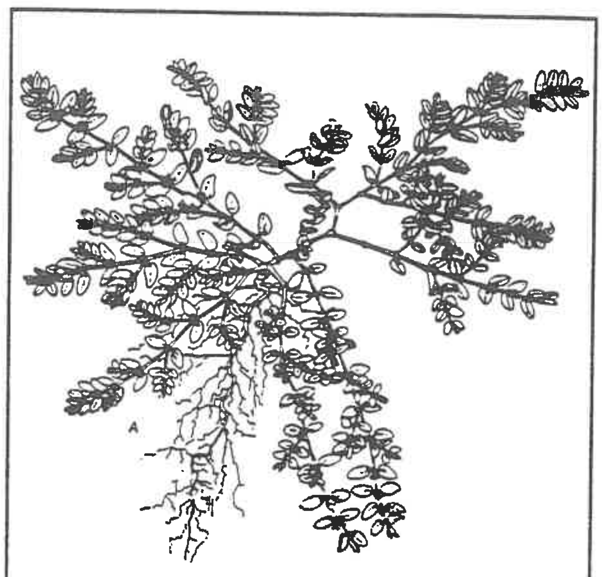
Broadleaf plantain. Leafy plant with elongated flowering and fruiting spikes. a. Seed.

Plantain: Plantains (*Plantago* spp.) are low-growing perennial plants found throughout much of the United States. These species form basal rosettes of leaves, with flowers borne on a leafless stem. Plantains are common weeds in turf.

Favorable conditions: Plantains invade weakened and poorly managed turf.

Control: Maintain a healthy turf.

Prostrate Spurge: Prostrate spurge (*Euphorbia humistrata*) is a low-growing summer annual that usually appears in midseason. It branches freely from the base. The reddish or green, prostrate stems form a mat-like growth, which often chokes out desirable turfgrasses. When the stems are broken, they emit a milky juice. The leaves are opposite, and vary in color from a pale reddish green to a dark green, but usually have a conspicuous maroon blotch. They are smooth or sparsely hairy, toothed especially near the tip, and unequally sided at the base, with a short petiole. Flowers are very small, pinkish white, and borne in the leaf axils. The fruit, a 3-lobed capsule,



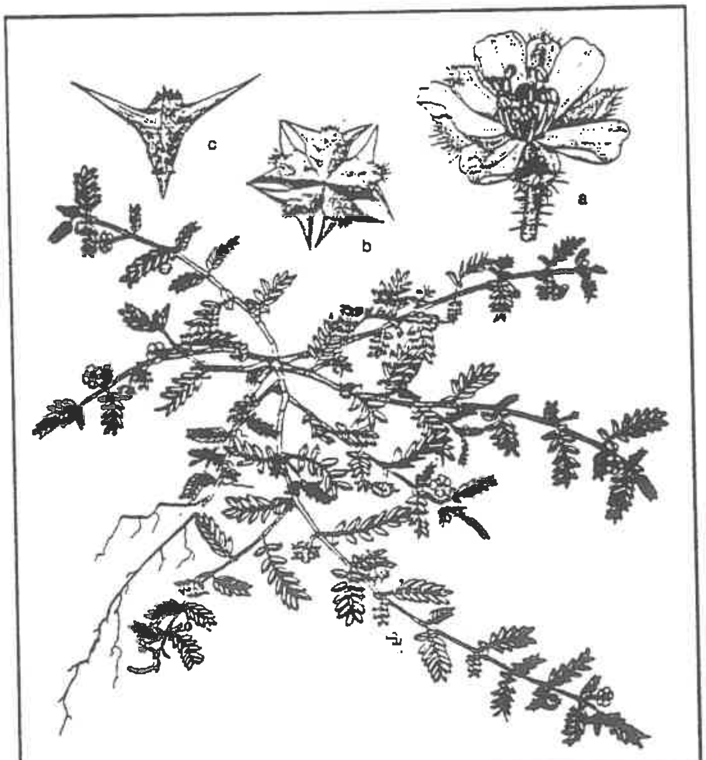
Prostrate spurge. A. Prostrate plant.

develops rapidly. There are several other species of spurge in Arizona that have a prostrate (low-growing) habit. *(See color plate, page 9.)*

Favorable conditions: Prostrate spurge is often found on thin, undernourished turf that suffers from periodic drought stress. High soil temperatures, such as areas along sidewalks and driveways, favor this weed.

Control: Maintain a dense, healthy turf. Since prostrate spurge germinates when soil temperature reaches 60° to 65° F, apply preemergence herbicides at this time. Postemergence control may also be possible.

Puncturevine:
Puncturevine (*Tribulus terrestris*) is a prostrate, silky-haired annual which reproduces by seed. It has a shallow taproot. The branching stems radiate out from the root for 1 to 8 feet, and can form a dense mat several feet in diameter. The leaves are opposite, divided into 4 to 7 pairs of oblong leaflets 1/8 to 1/2 inch long. The bright yellow flowers are solitary on short stalks. The seedpod consists of a cluster of 5 flat, spiny burs, which break apart at maturity. These burs can be very painful if stepped on. *(See color plate, page 9.)*



Puncturevine. Prostrate plant with flowers and fruits, or burs. a. Flower. b. Fruit or seedpod, a cluster of 5 bony burs or nutlets. c. Single bur or nutlet containing 2 to 5 seeds.

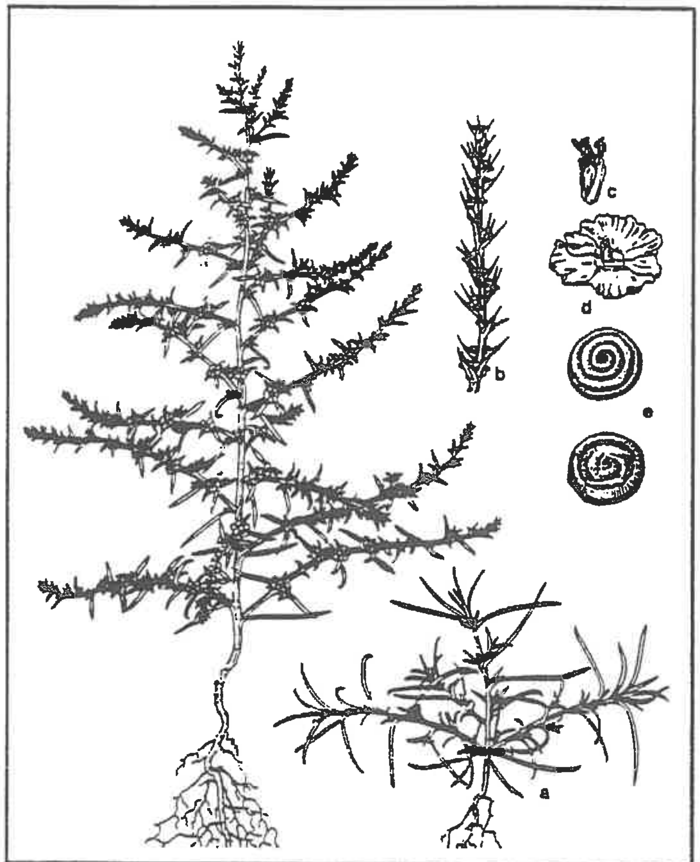
Favorable conditions: Puncturevine often invades thin turf. This weed prefers dry, or droughty soils.

Control: Maintain a dense, actively growing turf. Reduce soil compaction. Hoe scattered plants, making sure you cut off the plant below the crown. Hoeing and disposal of the plant should take place before the seeds mature. Pre- and postemergence herbicides may be effective.

Russian Thistle: Russian thistle (*Salsola iberica*), or tumbleweed, is an intricately branched, bushy annual. It has ridged, prickly stems and can grow to a height of 6 feet. It reproduces by seed. At maturity, the dried plant breaks at ground level and rolls along the ground, scattering seed. The seedlings are fleshy and tender, with alternate, narrow, pointed leaves. These leaves drop off and are replaced with short, stiff, spiny leaves. *(See color plate, page 9.)*

Favorable conditions: Russian thistle is often found on dry, sandy soils.

Control: This weed is easily spread, since it scatters seeds as it rolls along the ground. One plant may produce thousands of seeds. Furthermore, the seeds remain viable for many years. Diligent hoeing or hand-pulling may be necessary to culturally control this plant. If tumbleweeds get piled up along a fence, collect and burn them (if allowed in your area), or otherwise dispose of them, to keep the seeds from being further scattered. Some pre- and postemergence herbicides are effective at controlling Russian thistle.



Russian thistle. Plant habit. a. Seedling. b. Part of fruiting branch. c. Flower. d. Fruiting calyx. e. Seed.

TURF PATHOGENS

ABOVE GROUND

Brown Patch: Brown patch is commonly found on St. Augustine grass, bentgrass, and tall fescue in the Southwest. Areas of turf infected with brown patch consist of irregular, brown areas, which may range from several inches to many feet in diameter. Centers of the spots may recover, resulting in rings of diseased grass that resemble pearl scale damage. Green plants within the infected turf have leaf spots that are irregularly shaped, bleached areas, surrounded by a darker margin (easily confused with dollar spot). After drying, the leaf spots will turn straw-like in color. Leaves and sheaths turn olive green, wilt, become light brown, and die. Stems, crowns, and roots also may be infected. All of the symptoms may appear simultaneously. In light attacks, roots and crowns usually are not involved, and plants recover. All lawn grasses are susceptible. *(See color plate, page 11.)*

Cause: Brown patch is caused by the soil-inhabiting fungus *Rhizoctonia solani*. This fungus may survive on soil organic matter and thatch. The fungi are active as fine threads (hyphae) that survive in the soil, or in and on the turf. Resting structures (sclerotia) composed of hard masses of fungal threads are resistant to adverse conditions and are impossible to control with fungicides. Sclerotia are the chief overwintering structures.

The disease is favored by excessive thatch and mat, high temperatures (75° to 90° F), high humidity (80% to 100%), and soft, lush growth due to excessive nitrogen. The disease is most common in the summer months and in warm, inland areas. A cold, wet-weather (40° to 60° F) form of the disease occurs infrequently. Poorly drained soils, thatch, excessive nitrogen, and night irrigation lengthen the period of leaf wetness and promote infection.

Control: Reduce shading and improve soil aeration and water drainage. Water when needed to a depth of 4 to 6 inches, if possible. Check this with a soil probe, since water may not be penetrating due to excess thatch, unfavorable soil type, or too rapid application of water. Water in the early morning, not in late evening or at night. Avoid excessive nitrogen fertilization that results in soft growth of the foliage. Sharpen mower blades. Dull blades fray the edges of cut blades and allow the fungus hyphae to enter. Remove and dispose of clippings from infected areas or whenever conditions are conducive to disease development. Fungicides are more effective when used preventively, but will also stop the disease's progress.

Dollar Spot: Dollar spot is commonly found on bermudagrass and bentgrass in the Southwest. Dollar spot affects the appearance of turf, but seldom kills the turf. Most turf will recover from dollar spot injury, once conditions are favorable for vigorous, healthy growth. On closely mowed grasses (e.g., bentgrass golf greens), dollar spot appears as small, round, bleached-out or straw-colored spots ranging in size from a quarter to a silver dollar. Individual spots seldom exceed 2 inches in diameter, but may become so numerous that they merge into large, irregular, sunken patches. On turf of taller grass heights (1 to 3 inches), dollar spot appears as mottled, straw-colored patches 4 to 6 inches in diameter. These patches may merge and become quite large. *(See color plate, page 11.)*

Individual grass blades develop a lesion that is first chlorotic, then water-soaked, and finally bleached-out or light tan in color. The lesions may be up to an inch in length, usually span the width of the blade, and are characteristically bounded on either side by reddish-brown bands. This is especially true on Kentucky bluegrass leaves.

Cause: Dollar spot is caused by fungi of the genera *Lanzia* and *Moellerodiscus*. These fungi are spread by equipment, foot traffic, animals, water, or wind, and often enter plants through cut leaf tips. The presence of dollar spot may indicate a nitrogen deficiency in turf. Warm days, cool nights, and high humidity favor these fungi. Dry soils, thatch buildup, and inadequate amounts of nitrogen and potassium also favor these fungi.

Control: Provide sufficient nitrogen and potassium to maintain a healthy turf. Avoid late afternoon and evening watering. Prune trees and shrubs, to allow light penetration to the turf. Preventive fungicides are effective at controlling dollar spot in areas where it has occurred before. Other fungicides are available that help control dollar spot once it is established.

Grease Spot: Grease (sometimes called fire ring) spot is characterized in Arizona by the appearance of reddish brown spots with grass blades at the edge appearing greasy. The term "grease" comes from the fact that leaf blades turn dark in color, become water-soaked, mat together, and appear slimy. The disease usually starts as small (approximately 2 inches in size) blotches, which may eventually coalesce to form large circular to irregular patches of dead grass. Quite often, especially in bentgrass greens, the centers of these circular areas are not damaged initially and give a doughnut effect. Also, dead grass in the form of steaks often appear and follow low areas where water accumulates. Injury is most noticeable in early morning when humidity is highest. The bordering edge of a circular spot or group of spots often takes on a reddish color, hence the alternate name of "fire ring."

Cause: Grease spot is caused by *Pythium aphanidermatum*. Disease development is enhanced by hot, humid weather or during a hot spell by excessive irrigation or poor air circulation over the diseased areas.

Control: Since abundant moisture is a prerequisite for the development of this disease, overwatering during periods of high temperatures should be avoided. Greens and lawns should be well drained and free from low spots where water may accumulate from rain or irrigation. Grease spot is extremely difficult to control with fungicides, although a few instances of good control have been reported.

Gray Snow Mold: Gray snow mold appears after the snow melts. Spots that vary in color from gray, or light yellow, to dark brown form on annual bluegrass, Kentucky bluegrass, perennial ryegrass, fescues, or bentgrasses (i.e., cool-season grasses). Most spots are between 6 to 12 inches in diameter. Upon inspection of the turf, a dark gray fungal growth or light tan to dark brown hard rings of fungus (called sclerotia) may be seen. Gray snow mold usually requires snow cover, and is worse when snow falls on unfrozen turf or turf not hardened off by repeated frosts. *(See color plate, page 11.)*

Cause: *Typhula* spp. fungi cause gray snow mold.

Control: Mow to normal height for winter (do not mow to a shorter height). Avoid overstimulating growth and/or discouraging winter hardiness by overapplying nitrogen in the fall. Preventive fungicides are effective and should be applied during late fall.

Leaf Spot: Leaf spot commonly infects bermudagrass, St. Augustine grass, tall fescue, and ryegrass in the Southwest. It is also commonly found on Kentucky bluegrass at higher elevations (4,800 ft. and above). It first appears as small, dark purple or black spots on the leaf blade, which become oval spots with buff-colored centers, surrounded by a dark brown to dark purple margin. Stolons and rhizomes are often infected and show the same symptoms as found on the leaves.

Cause: Leaf spot is primarily caused by the pathogen *Bipolaris sorokiniana*, which is favored by dry periods alternating with prolonged cloudy, wet weather, and moderate temperatures. This pathogen produces spores, which are spread by turf equipment, foot traffic, wind, water, and infected grass clippings.

Control: Fertilize to maintain a vigorous, but not lush, turf. Avoid a thick thatch. Water infrequently but deeply in the early morning. Mow grass frequently, so that no more than 1/3 of the blade is removed at one time. Avoid high rates of nitrogen fertilizer on cool-season grasses in the spring (fall fertilization favor cool-season grasses). Avoid scalping. Use resistant cultivars when possible, and apply fungicide when necessary.

Melting-Out: Melting-out is a disease of the leaves and crowns of turf plants and if conditions are right serious damage to the root system may occur. Patches of turf die slowly and have a dried or droughty appearance. These patches have indefinite borders and a melting out effect is observed. These dead areas often have clumps of live grass interspersed, but if control is not implemented rapidly, they will die also. Melting-out is more of a problem in the lower elevations of the state. *(See color plate, page 11.)*

Cause: Melting-out is caused by fungi of the genera *Helminthorsporium* and *Curvularia* in Arizona. Both genera are usually found together in diseased turf and probably work in conjunction with one another. The most important condition contributing to development of this disease is moisture stress on the plant because of improper watering or poor water penetration due to soil compaction. Quite often the disease occurs directly over soil hard pan or compaction areas in the turf. Both genera of fungi attack weakened plants.

Control: To help control melting-out, use a spading fork or other coring equipment to punch holes in the turf showing melting-out symptoms. Do not turn the soil. This will create channels for water penetration. Bermuda grass turfs should be renovated during dormancy in the winter, and small amounts of sand added to encourage water penetration and drainage. Maintain a vigorous turf with proper applications of water and fertilizer.

Pink Snow Mold: Pink snow mold (also known as fusarium patch) is a fungal disease which attacks the same cool season grasses as gray snow mold. Pink snow mold develops either with or without the presence of snow cover. Without snow cover, pink snow mold occurs as reddish brown spots, ranging in diameter from 1 to 8 inches. Were snow occurs, circular spots are found from 2 to 3 inches, or 1 to 2 feet in diameter; are tan, white, gray, or reddish brown. Shortly after snow melt, the pink growth of the fungi can bee seen at the edge of the spot. Hence the name "pink snow mold."

Cause: *Fusarium* spp. of fungi cause this disease.

Control: Avoid overapplications of nitrogen fertilizer in the fall. Preventive fungicides are often necessary to protect high-value turfs.

Powdery Mildew: Powdery mildew occurs mostly on cool-season grasses. As the name suggests, infected leaves have a white, net-like film over the surface—this is the fungus itself. Later, the turf will appear yellow (chlorotic), with black resting bodies appearing on the leaf. Powdery mildew occurs during the fall seasons, mostly at elevations above 4,500 ft. on Kentucky bluegrass, fine-leaf fescues, ryegrass, and occasionally on tall fescue. It occurs most frequently when temperatures are cool and skies are cloudy. *(See color plate, page 11.)*

Cause: Powdery mildews are caused by fungi in the genus *Erysiphe*. These fungi are transmitted to infected plants by wind and mechanical means.

Control: Decrease shading through selective pruning of surrounding ornamentals or plant resistant cultivars. Curative fungicides are effective.

Slime Molds: Slime molds are harmless, but unsightly organisms that suddenly appear over the grass surface during warm weather, following heavy rains or watering. Watery white, gray, black, or cream to yellow, slimy masses grow over the grass blades in round to irregular patches (1 inch to 2 feet in diameter) that shade otherwise healthy grass. The masses soon dry to form unsightly bluish gray, grayish white, black, white, or yellow powdery growths that are easily rubbed off. The grass blades beneath are healthy or somewhat yellow after being shaded. The affected patches of grass do not normally die or turn yellow, and signs of the mold usually disappear within one to two weeks. The mold will often reproduce in the same location each year. *(See color plate, page 12.)*

Cause: *Mucilago crustacea*, *Physarum cinereum*, and other species of *Physarum*, *Mucilago*, *Fuligo*, and *Stemonitis* cause slime molds on turfgrasses. These organisms are not parasitic on turf, but rather feed on decaying organic matter, fungi, and bacteria in the thatch layer and soil. Warm, moist weather and high soil moisture favor these molds, which are spread by air currents, water, shoes, and turf equipment.

Control: Control measures are usually unnecessary, since slime molds soon disappear when left alone. The process can be accelerated, however, by raking, brushing, or mowing the affected area, or by hosing down the area with water. If slime molds are abundant and become unsightly, some fungicides can be used to control them.

BELOW GROUND

Necrotic Ring Spot: Necrotic ring spot is a root pathogen which infects Kentucky bluegrass turf. It forms symptoms similar to summer patch disease (i.e., declining turf which appears to die from lack of water), however, the symptoms usually appear during the cool-wet weather seasons. Symptoms can thus appear in late summer and in mild winters at elevations above 4,500 ft. The patches from necrotic ring spot are usually 12 inches or greater.

Cause: Necrotic ring spot is caused by the fungi *Leptosphaeria korrae* and *Leptosphaeria narmari*.

Control: Control thatch buildup during early fall. Effective fungicides are available.

Pythium Blight: The infection process, symptom development, and spread of pythium blight occur rapidly, and large areas of turf can be destroyed within 24 to 48 hours after the onset of disease-favorable weather. Round to irregular, dark, water-soaked, greasy or slimy, sunken patches of matted grass, up to 6 to 12 inches wide, develop rapidly in hot or cool, very wet, calm weather. Waterlogged soils and a moist thatch layer, along with high relative humidity (90% or greater) and daytime temperatures in the 80s or 90s with warm nights (above 70° F) provide ideal conditions for warm-weather pythium blight. There are pythiums that do well in cool weather also, but their symptoms and occurrences are not as well known.

Diseased areas quickly fade from reddish brown to light brown as the grass dies. The disease often appears in elongated streaks, following water drainage or mowing patterns. White to straw-colored spots, without a reddish brown border, form in the grass blades, causing them to twist and collapse. A fluffy, white to purplish gray, cobwebby mold may cover blighted grass when the air is saturated with moisture. Pythium is a major problem on bermudagrass overseeded with ryegrass during the fall seeding period. *(See color plate, page 11.)*

Cause: Pythium blight is caused by several species of *Pythium* fungi. These fungi survive well in thatch, infected leaves and roots, and soil. The two most important criteria for disease occurrence are poor soil drainage and a wet turfgrass canopy. Excessive nitrogen favors the disease.

Control: Improve surface and subsurface drainage wherever possible. Avoid overwatering, thick thatch, excessive nitrogen fertilization, and compacted soil. Avoid mowing or walking on wet turf. Several fungicides are available to help control pythium blight. Do not seed cool season grasses (or overseed ryegrass into bermudagrass) when temperatures are high. For highly valuable turf, a preventive spray program using a systemic fungicide, applied prior to the onset of hot, humid weather, is recommended. Contact fungicides can be used on less valuable turf.

Spring Dead Spot: Spring dead spot is the most serious disease of bermudagrass in the transition zone between southern and northern grasses. The disease usually appears 3 or 4 years after planting in turf that has been fertilized heavily with nitrogen. Sunken, circular patches 1 to 3 feet in diameter are dead when the bermudagrass resumes growth in the spring. The disease occurs in the same spots for several years, and weeds often invade the spots. High nitrogen fertilization and excessive thatch increase the severity of the disease.

Cause: The fungus *Leptosphaeria narmari* is known as the causal agent in California and *L. korrae* in Australia. In other areas the causal fungi are uncertain.

Control: Do not apply excessive amounts of nitrogen. Raise mower heights to 1 or 1-1/2 inches and reduce thatch buildup by power raking. Fungicides are available that provide good control. Apply the fungicides in the fall to areas that had the disease the previous spring.

Summer Patch: Summer patch disease is a fungal disease which attacks the root and crown tissue of Kentucky bluegrass, annual bluegrass, and fine-leaf fescues. Its only symptom is declining turf which appears to be dying from lack of water. No distinct symptoms on turf foliage appear. The fungus enters the plant roots in the spring when the temperatures are cool. When the air and soil temperatures increase in late spring/early summer, the fungus increases its growth on roots and crowns, decreasing the ability of the plant to take up water. Sunken spots may appear, resulting in large areas of blighted turf. There are no distinct foliar lesions.

Cause: Summer patch is caused by the fungus *Magnaporthe poae*. The fungus can subside in the thatch when it is not active.

Control: Actions which may discourage summer patch establishment include raising mower height, improving aeration in fall, reducing traffic, and irrigating deeply and infrequently. Corrective fungicides are available.

ORNAMENTAL INSECTS AND RELATED PESTS

LEAF-CHEWING

Caterpillars: Caterpillars are the larval stage of moths and butterflies. They are smooth, hairy, or spiny worm-like creatures with 3 pairs of legs near the head and several pairs of prolegs (false legs) in the middle and rear of the abdomen. Their mouthparts are adapted for chewing plant tissue. They generally confine themselves to tissue that is soft and succulent. Noticeable caterpillars found in Arizona include cutworms, grapeleaf skeletonizers, orange dog caterpillars, tent caterpillars, and many other species. *(See color plate, page 5.)*

Life cycle: After hatching, caterpillars go through as many as 11 stages of development (instars). At the end of each instar, caterpillars must molt to make room for their larger body size. Caterpillar populations often fluctuate greatly from year to year due to environmental conditions and to control by natural enemies such as birds, rodents, diseases, and other insects.

Damage: During the first instar, caterpillars may feed as leafminers between the upper and lower surfaces of leaves; or as skeletonizers, eating only one leaf surface. As the caterpillars increase in size in later stages, they require more food, devouring entire leaves.

Control: In general, caterpillars are foliage feeders, and most can be controlled by similar methods. After determining the time of day or night when a ceratin species is feeding, many caterpillars can be picked off by hand. Stepping on them at this point is very effective. If necessary, several insecticides are available for caterpillar control. Care should be taken in applying these materials to give a thorough coverage of the foliage, particularly those areas being eaten by the caterpillars. Do not use any material on plants not mentioned on the label. Timing applications to treat the caterpillars when they are small is important. Close observation and a knowledge of the insect's life habits will indicate the proper time and location of an insecticide application.

Flea Beetle: Flea beetles (*Chaetocnema ectypa*) are shiny, black beetles, about the size of a pinhead. Some species have yellow or white markings. They are very active and jump like fleas when disturbed. *(See color plate, page 4.)*

Life cycle: Adults overwinter in the soil and in garden debris and emerge in early spring. Females lay eggs near the bases of plants. These hatch in about one week, and the larvae feed on the roots of plants for 2 or 3 weeks before pupating and emerging as winged adults to attack foliage.

Damage: Many tiny holes in leaves are a sign of flea beetles. These insects can destroy small plants rapidly. Flea beetle larvae also weaken plants by feeding on the roots.

Control: Flea beetles prefer hot and dry conditions, so make the microclimate around the vulnerable plants somewhat cool and moist. Sprinkle the plants during the hottest part of the day. Space plants close together so that the leaves touch; this will create a more humid environment.

Beneficial nematodes will control flea beetle larvae in the soil. Dusting the plant or the ground around it with diatomaceous earth may help control this beetle. Insecticides are available which help control the flea beetle.

Leafcutter Bees: Leafcutter bees (*Megachile* spp.) are gray with white bands encircling the abdomen. They are 1/2 to 3/4 inch long. The females have scopae (pollen-collecting hairs) located only on the ventral surface of the abdomen rather than on the hind legs as in most other pollen-collecting bees. The female cuts circular pieces of foliage usually from roses and use the disks as a lining and plug for her egg cells. The bees are solitary insects, but they make numerous cells in hollowed out twigs and other protected places. *(See color plate, page 6.)*

Life cycle: Some leafcutter bees build their nests by tunneling into rotten or solid wood, or into the ground, but most species use the hollow stems of a plant. Several Arizona species have discovered that polyurethane foam roofs can be excavated and provide excellent insulation for developing young. When the female bee has excavated a tunnel, she cuts leaf disks and lines the bottom. She then deposits a paste of pollen and honey in the nest and lays an egg on this material. Next she seals the cell with more leaf disks and repeats the foregoing process until many cells have been produced. The eggs hatch and the resulting larvae develop on the stored food, pupation occurs, then new bees emerge from their pupae and chew out of their respective cells.

Damage: Leafcutter bees cut circular pieces of foliage out of leaves—usually roses.

Control: The work of leafcutter bees is usually little more than a curiosity, and thus seldom requires control measures to be taken.

PLANT-SUCKING

Aphids: Aphids are a common problem on many species of plants. They are small (1/16 to 1/8 inch long), soft-bodied, somewhat pear-shaped, winged or wingless insects with needle-like mouthparts that are especially adapted for sucking sap from a plant. Aphids are usually green, black, brown, red, or pink, but may be almost any color. They have a pair of long, slender antennae on their head and two tube-like projections near the rear of their abdomen. They change very little in form during their life cycle, the young resembling the adults, except being smaller in size. *(See color plate, page 5.)*

Life cycle: The life cycle of aphids can be either simple or somewhat complicated, depending on the species. In a relatively simple case, an egg overwinters on a branch or stem and hatches in the spring, producing a wingless creature, called a stem mother. The stem mother gives birth to a large number of living, wingless, female young. Several generations may occur in this fashion, but at some point winged males and females are born. These migrate to another host, mate, and deposit eggs for the winter. This life history may vary with each of the 50 or more different species of aphids, sometimes involving alternate host plants, sometimes multiple host plants, and sometimes different forms of aphids for different generations.

Damage: Aphids suck the juices from leaves, fruits, and stems of plants. They generally move on the undersides of the leaves, causing the leaves to curl around them as they feed. They may carry pathogens from one plant to another. They also excrete a sticky substance that makes the leaves appear wet and dripping. This substance, called honeydew, can serve as a site for sooty mold, and also attracts ants. Aphid feeding can destroy leaves and cause succulent stems to wilt. If an aphid colony is large enough, it can stunt a plant's growth. When feeding on the bark of woody plants, however, aphids themselves usually cause little or no harm.

Control: Because they are slow-moving, soft-bodied insects, aphids are easily controlled with chemical sprays. Generally, the use of chemicals is warranted only if populations are large. There are many parasites and predators of aphids that can help keep aphid populations down. Three of these are *Lysiphlebus* spp., a wasp-like insect that deposits eggs in the aphid's body, and the ladybugs *Adalia bipunctata* and *Hippodamia convergens*. For very light infestations, spraying the infested plants with a forceful stream of water every few days, or using an insecticidal soap, may provide sufficient control. In some cases, cultural practices such as proper pruning, fertilizing, and watering play an important role in preventing or suppressing an aphid infestation.

White Flies: White flies have a far greater economic impact on citrus fruit crops and on greenhouse-grown ornamentals than on ornamental plants grown out of doors. Where outdoor plants are concerned, white flies are much more abundant in the southern portions of the United States than in the northern portions. The adults are tiny, white, and moth-like. Their wings are generally covered with a powdery substance. Adults vary in size from 1/32 to 1/8 inch. The nymphs are flat, oval, legless, and yellow in color. *(See color plate, page 6.)*

Life cycle: Cone-shaped eggs are laid by the adult females on the lower leaf surface. The eggs are initially light yellow, but those of many species turn gray as incubation proceeds. The eggs are oval and are attached to the plant by a stalk. They require 1 to 3 weeks to hatch, depending upon the season. The young nymphs crawl about on the lower leaf surface for several hours and then settle to feed. After settling, the juveniles remain fixed in the same position until they grow to maturity. The nymph has a flattened, scaly form, and the nymphal period lasts 3 to 4 weeks. The most distinctive feature of the nymph is the fringe of waxy material that projects radially from its body. At the end of the nymphal stage, the "pupa" (there is no true pupal stage) appears. The insect spends this stage within a case which is fixed to the leaf, and from which the adult appears. On any infested leaf, white flies may be found in all stages of development. There are several generations each year. The insect overwinters in either the nymphal or "pupal" stage.

Damage: Damage to plants is primarily caused by the white flies sucking the juices from leaves, buds, and stems. Heavy feeding results in yellowing and drying of the leaves, and stunting of the plant's growth. As important as direct feeding injury is, the greater damage is caused by the honeydew produced by the nymphs. The honeydew covers the leaves and results in sooty mold fungi colonizing on the leaves. White flies may also carry viruses from one plant to another.

Control: Light infestations may be controlled with insecticidal soap. Botanical poisons such as pyrethrum and ryania are generally effective controls, as are insect predators such as green lacewings and ladybugs. Some pesticides are available to help control white flies. It is important to direct spray to the undersides of the leaves, since that is where the insects are located. The addition of a little liquid soap can help the insecticide penetrate the wax layer covering the insect. Avoid using soap during the heat of the day, though, as leaf burn may result. Be prepared for insecticidal failures, particularly after use of the same materials for an extended time, since white flies are notorious for developing insecticide resistance.

GALL-FORMING

Galls: Galls are growths on plants. They may be simple lumps, or they may have a complicated structure. Some galls are brightly colored. Galls form on leaves, twigs, and branches. *(See color plate, page 6.)*

Life cycle: Some galls form when insects (certain wasps, midges, and aphids) or mites feed on or lay eggs in leaves, stems, and twigs. While feeding or laying eggs, these insects inject a toxin that stimulates rapid and abnormal cell growth. Galls may also develop as a response to infection by any of several kinds of fungi, bacteria, and viruses. Galls caused by fungi and bacteria are usually most numerous in wet years.

Damage: In most cases galls are unsightly, but not damaging to the plant, although small plants may be stunted. The water and nutrient circulatory system of a small plant may be disrupted by the galls.

Control: Pruning off gall-infested growth usually takes care of the problems. If galls are especially unsightly and numerous, you can control (with pesticides) the insects or pathogens that are causing them.

ROOT-FEEDING

Palo Verde Borers: In the southwestern United States, there are 3 species of *Derobrachus* encountered. The common urban species *D. geminatus* is found throughout southern Arizona. It is often associated with exotic plants such as elm, Mexican palo verde, rose, privet, and olive. The adults of this species fly at dusk and are readily attracted to lights. *(See color plate, page 6.)*

Life cycle: The female, after mating, may return to her emergence hole and enter to lay eggs. It is common to find several size ranges of larvae near trees. Larval development is thought to require 3 years. Adults normally emerge in late June through July to early August.

Damage: Larvae damage the roots, but seldom severely. However, in severe cases, the green bark of Mexican palo verde turns yellow.

Control: Borers like the palo verde borer that work in the trunk area and/or roots are difficult to control with insecticides. Consider taking good care of plants with proper fertilizers and watering intervals to allow the plants to compete with the wood borers. If plants are old, removal might be the most practical solution.

WOOD-BORING

Cypress Bark Beetles: Several species of bark beetles, all of the genus *Phloeosinus*, attack trees of the families Cupressaceae and Taxodiaceae. These two families include cypress, juniper, redwoods, and certain other cedar-like trees. *These beetles are generally cylindrical, 1/25 to 1/3 in. long, and are reddish brown to black in color.* *(See color plate, page 6.)*

Life cycle: The biology and life history of these pests are quite similar to those of pine bark beetles. The beetles usually overwinter beneath the bark of the host tree as larvae, pupae, or adults, depending on the species involved. In the spring, the adult beetles tunnel their way to the bark surface, emerge, and fly in search of other trees to attack. The adult (in some species the female, in others the male) initiates the egg-laying gallery after first tunneling through the bark. Mating usually occur in the gallery. Eggs are laid on the sides of the gallery in characteristic patterns for each species. When feeding is completed, the larvae pupate in the inner or outer bark. Emergence from the tree and initiation of a new generation follows. There may be 6 or more generations each year, depending upon species and geography.

Many newly emerged cypress bark beetles have the curious habit of feeding on the twigs of cypresses and certain other plants in the above 2 plant families. Twigs are usually attacked between 6 and 12 inches from their tips.

Damage: During feeding, the adult beetle hollows out, or deeply grooves, slender twigs which then break easily in the wind. The dead tips, called flags, often remain on the trees for long periods of time, making them unsightly. Flagging, if caused by cypress bark beetles, is not an indication that the tree is declining in health. It does indicate that somewhere in the area a dead or dying cedar-like tree is serving as a breeding place for the beetles. Flagging may continue for many months each year.

Flathead Beetles/Borers: Flathead beetles (*Chrysobothris* spp.) and their larvae are the most important pests of newly set shade trees in the Southwest. There are several species of borers belonging to this group, that are very common, attacking practically all kinds of trees. Generally, only stressed trees are attacked. The larvae of flathead beetles are medium to large, yellowish white, legless grubs, with a pronounced flattened enlargement of the body (thorax) just behind the head, which bears a horny plate on both the upper and the undersides. The adults are often beautifully colored or metallic, boat-shaped beetles, 1/3 to 1 inch long, with the wing covers usually roughened like bark. *(See color plate, page 6.)*

Life cycle: The winter is passed as grubs or borers. These are of different sizes, from 1/2 to 1 inch in length. The larger, nearly full-grown borers will be found 1 to 2 inches (or less, in the warmer parts of the state) deep in the wood of the tree. In the spring, they change to yellow pupae, and later to beetles. These are sun-loving insects, and will be found in greatest numbers on the sunny sides of trees. The female beetle lays her yellow, disk-like, wrinkled eggs in cracks in the bark of trees, nearly always selecting a tree that is unhealthy, or a spot on the healthy tree where the bark has been injured. The eggs are laid from May to August, and most of the borers become adults by fall, completing their life cycle in only 1 year.

Damage: Typical injury consists of rather shallow, long, winding, oval galleries packed with frass beneath the bark, usually on the south or southwest side of the tree. Areas of the bark become entirely undermined. Some species kill trees by mining beneath the bark.

Control: Trees that have been taken from the nursery and set in situations exposed to the sun should be protected, at least during the first season, by completely wrapping them in paper from the ground to the lowest limbs. Massive pruning that suddenly exposes previously shaded bark to the sun may cause sunburn, which will encourage these borers. Good nutrition and adequate water will help keep trees in healthy condition and resistant to flathead beetle attack.

Giant Palm Borer: The giant palm borer (*Dinapate wrighti*) is an extremely large beetle in the family Bostrichidae. This borer was first found in the Phoenix area in 1987 and has been found in other locations since then. It is thought that this borer will become more of a problem in Arizona over the next few years. Adult borers are large, black beetles 1-1/4 to 2 in. (30 to 50 mm) long with a 1/2 to 5/8 in. (12 to 15 mm) diammeter . Juveniles are cream-colored, soft, grub-like larvae with large black mandibles. They are 1 to 2 in. (25 to 50 mm) long with a 5/8 to 3/4 in. (15 to 20 mm) diameter.

Very little is known about this borer, and more information is needed. If you encounter this insect, please contact the Entomology Department at the University of Arizona.

Life cycle: Larvae live and feed in the trunks of palms for 3 to 9 years before emerging as adults. Adults emerge June through September, with peak emergence in July. Adults fly to palms at night, where females burrow into the crown, mate with males, then lay eggs in the burrow.

Damage: Tall palm trunks may snap in high winds due to extensive damage caused by larval feeding. Exit holes (3/4 to 1 in. (18 to 25 mm) diameter) in the trunks of living palms indicate emergence of the adult beetle. Another indication of infested palms is the presence of frass located at the base of the emerging fronds in the bud region.

Control: At this time, there are no chemical controls known. There is some evidence that this borer attacks stressed trees; therefore, maintain healthy trees with proper plant management such as proper planting, irrigating, and fertilization.

ORNAMENTAL WEEDS[4]

COOL-SEASON GRASSY

Annual bluegrass. Flowering plant. a. Spikelet. b. Grain.

Annual Bluegrass:

Annual bluegrass (*Poa annua*) is a winter annual or perennial that can persist for many seasons. It is apple green in color and produces hundreds of whitish green seedheads at all mowing heights. It grows well on compacted soils under moist and shaded conditions, and frequently occurs in dense patches. Seedheads are produced throughout the growing season, but are particularly abundant during midspring. *(See color plate, page 7.)*

Favorable conditions: Management practices improperly encouraging the persistence of annual bluegrass include shallow, frequent irrigation, poor soil drainage, timed fertilization, aerating soil during primary periods of annual bluegrass germination, use of heavy equipment causing soil compaction, and allowing area to be shaded.

Control: Annual bluegrass requires strong light for seed germination. Reduce soil compaction. Pull individual plants. A variety of herbicides are available which can be applied at certain times of the year to obtain control of annual bluegrass.

COOL-SEASON BROADLEAF

Bur Clover: Bur clover (*Medicago polymorpha*) is a bright green, nearly hairless annual, sometimes a winter annual, which reproduces only by seeds. The weak stems branch from the base and spread or lie on the ground. The leaves are alternate and divided into 3 leaflets, which arise from a common point at the end of the leaf stalk.

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[4]All illustrations by Lucretia B. Hamilton reprinted from *An Illustrated Guide to Arizona Weeds* by Kittie F. Parker, by permission of The University of Arizona Press, copyright 1972.

The leaflets are somewhat wedge-shaped, with toothed edges and indented tips. There is a pair of stipules with long, irregular teeth where the leaf stalk joins the stem. The small, yellow, pea-like flowers are borne 3 to 5 in a cluster near the end of short stalks. *(See color plate, page 7.)*

Bur clover. Plant with flowers and pods; leaves are trifoliate. a. Pod, spirally coiled, with prickles. b. Flower, pea-like. c. Seed.

Favorable conditions: Poor soil and lack of competition favor bur clover.

Control: Some pre- and postemergence herbicides can effectively control bur clover.

Malva (Little Mallow): Little mallow (*Malva parviflora*) is a stout, bushy annual or biennial, branched and spreading from the base. It is 1 to 3 feet high, has a short, thick taproot, and reproduces by seeds. The large soft leaves are alternate, almost circular, and often have a red spot at the base. They usually have 5 to 7 shallow lobes, with edges toothed. The leaves are 2 to 5 inches broad, on stalks 4 to 10 inches long. The inconspicuous, bluish or pinkish flowers are nearly stalkless, in small clusters at the base of the leaf stalks, and at the top of the plant. *(See color plate, page 8.)*

Little Mallow. Leafy plant. a. Normal flower. b. Flower unopened, when temperatures are low. c. Fruit surrounded by enlarged sepals. d. Carpel with seed enclosed.

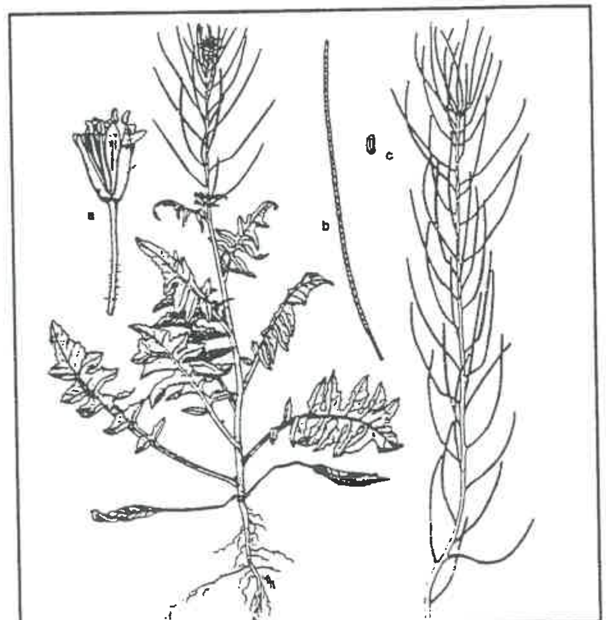
Favorable conditions: This plant is often found on moist, loamy soil.

Control: Hand-pull or hoe when practical.

Mustards: While mustards (family Cruciferae) in general cause problems in the Southwest, London Rocket (*Sisymbrium irio*) is one of the more common mustards found. It is a bright green, fleshy annual or winter annual. Its stems are usually much branched from the base. It has a coarse taproot and reproduces by seeds. Leaves are divided and 1 to 8 inches long. Small, yellow flowers are borne on slender stalks in small clusters at the stem tip. The flower stems elongate as the seedpods mature, so there are many, very narrow pods below the flower clusters. *(See color plate, page 10.)*

Favorable conditions: London rocket is usually found in moist soils. It is one of the first weeds to appear, and usually disappears in hot weather, except in moist, shaded places.

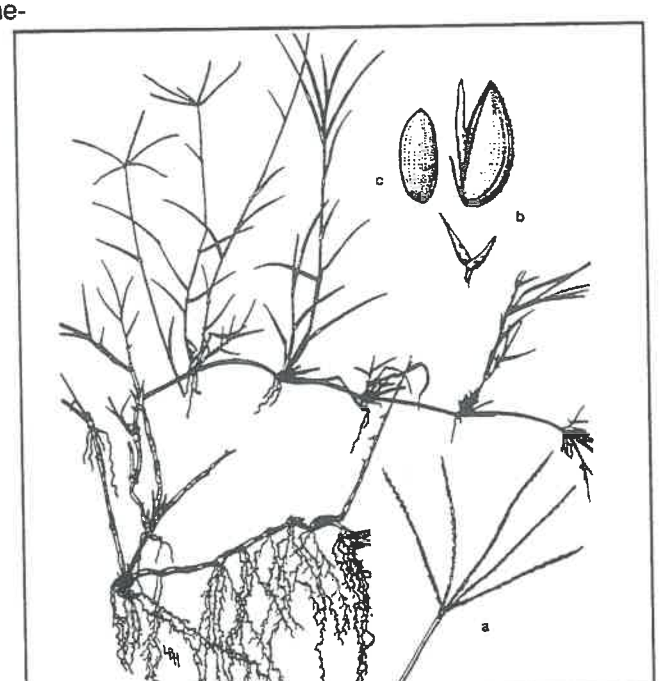
Control: Some pre- and postemergence herbicides are effective.



London rocket. Plant in flower and in fruit. Also, fruiting branch. a. Flower. b. Fruit or seedpod. c. Seed.

WARM-SEASON GRASSY

Bermudagrass: Bermudagrass (*Cynodon dactylon*) is a warm-season perennial found throughout much of the United States. It is fine- to medium-bladed and low-growing, producing both rhizomes and stolons. Bermudagrass is extremely aggressive and one of the most rapidly growing grasses. It has a deep root system that provides tolerance to drought, but is particularly troublesome in moist soils. The seedhead of bermudagrass is a whorl of 3 or 4 racemes with small, 1-flowered spikelets. *(See color plate, page 7.)*

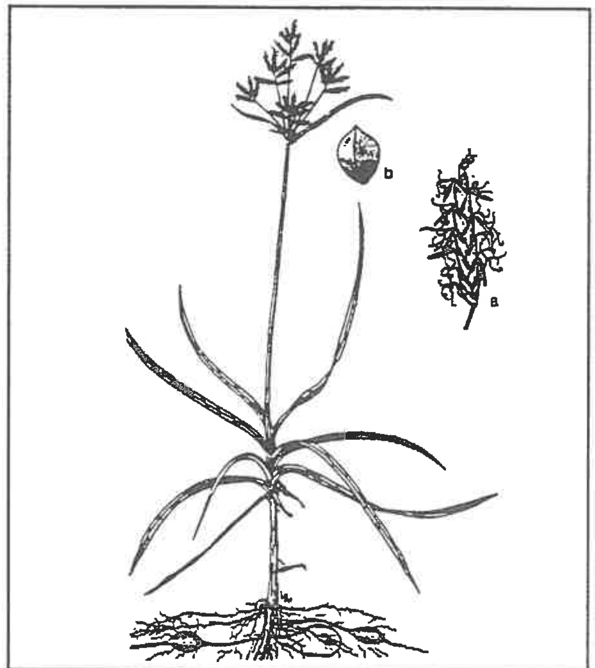


Bermudagrass. Plant showing rhizomes. a. Enlarged inflorescence. b. Spikelet, with glumes detached below. c. Grain.

Favorable conditions: Bermudagrass is a prolific seed producer.

Control: Nonselective, translocated herbicides work well at controlling Bermudagrass in open areas, whereas selective, translocated herbicides work better in planted areas.

Nutsedges: Yellow nutsedge (*Cyperus esculentus*), when well established, is considered a serious weed problem and is difficult to eradicate. Yellow nutsedge can be spread in balled-and-burlapped nursery stock and can be a problem in field-grown nursery stock, lawns, and landscape plantings. It is a perennial herb, reproducing by seeds and weak thread-like rhizomes, terminated by hard tubers. The stems are erect, tall, and triangular. Near the base of the triangular stem, a cluster of 3-ranked, grass-like leaves arise which are often longer than the stem. The flower stalks are pale green with umbels that form yellowish to golden brown spikelets. *(See color plate, page 8.)*



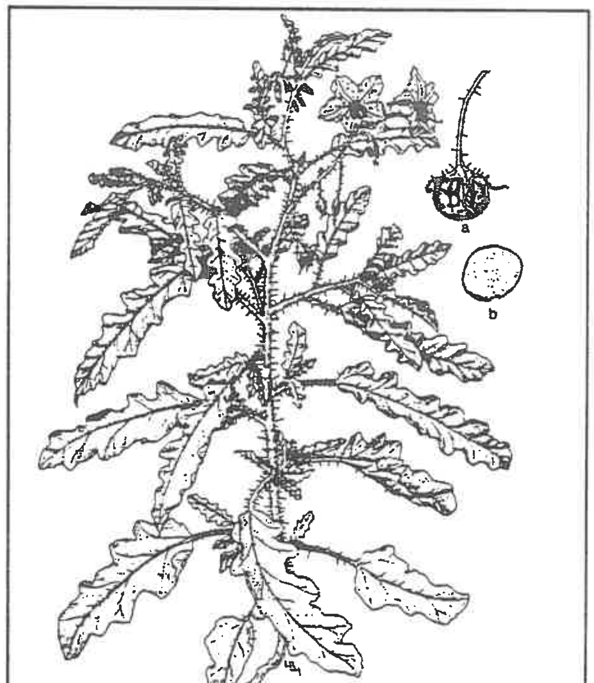
Purple nutsedge. Flowering plant, showing underground stems with nutlets or tubers at the tips. a. Spikelet in flower. b. Achene.

Purple nutsedge (*Cyperus rotundus*) closely resembles yellow nutsedge, but the mature stems are usually longer than the basal leaves. The leaves below the flowering heads are between 1 and 5 inches long, and are about the same length as the flower stems. The spikelets are dark brownish purple.

Favorable conditions: Yellow nutsedge is found on moist, poorly drained sites.

Control: Improve drainage. Pull up single plants when practical (be sure to pull up the "nut." Herbicides are available, depending on the particular nutsedge.

WARM-SEASON BROADLEAF



Silverleaf nightshade. Spiny plant with flowers and seedpods. a. Mottled seedpod. b. Seed.

Nightshade: Silverleaf nightshade (*Solanum elaeagnifolium*) is an upright, silvery perennial, usually prickly, 1 to 3 feet high. It reproduces by seeds and by deeply penetrating or creeping rhizomes. The surface of the entire plant is covered by densely matted, tiny star-like hairs, which give it its characteristic silvery color. Slender, yellowish spines may or may not be present on the stems, leaves, and flower stalks. Leaves are alternate, lance-shaped, and the margins are usually wavy. The flowers are bluish purple. The berry-like fruit is orange or yellow when mature. *(See color plate, page 10.)*

Favorable conditions: This plant prefers growing on moist sandy soil and will readily invade disturbed places.

Control: Pull up plants when practical.

Oxalis (Woodsorrel):

Woodsorrel (*Oxalis* spp.) is a perennial or annual, with hairy stems weakly branched at the base. These stems may root at the nodes. With leaflets in groups of three, oxalis can be easily mistaken for a clover. The middle leaflet, however, is not borne on a short stalk. The flowers are small, with five conspicuous bright yellow petals. As the flowers mature, cucumber-shaped seedpods are formed. When dry, the seeds may scatter for several feet in all directions. Oxalis occurs extensively throughout the United States. *(See color plate, page 8.)*

Creeping woodsorrel. Prostrate branch rooting at the joints. a. Flower. b. Seedpod. c. Two views of seed.

Favorable conditions: This plant can be found on dry or moist soils; usually prefers shaded areas.

Control: Hand-weed when practical.

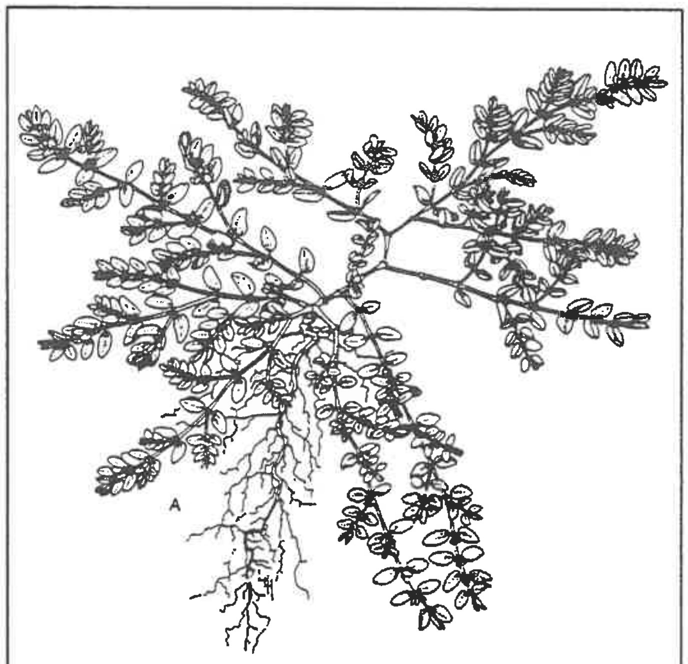
Pigweed: There are many species of pigweed which cause problems in the Southwest. Pigweeds (*Amaranthus* spp.) are usually bushy, branched annuals, but some species are more erect, while others may be prostrate. Leaves are alternate, oblong, or lance-shaped. They reproduce by seed. *(See color plate, page 10.)*

Favorable conditions: Pigweed is often found on dry, sandy soil.

Control: Hoe or hand-weed plants before they set seed.

Pigweed (Palmer amaranth). Flowering plant and flowering branch. a. Basal leaf. b. Male flower showing stamens. c. Female flower. d. Seed.

Prostrate Spurge: Prostrate spurge (*Euphorbia humistrata*) is common in landscape plantings and nurseries. It is a low-growing summer annual that usually appears in midseason and branches freely from the base. The reddish or green prostrate stems form a mat-like growth. When the stems are broken, they emit a milky juice. The leaves are opposite, and vary in color from a pale reddish green to a dark green, but usually have a conspicuous maroon blotch. They are smooth or sparsely hairy, toothed, especially near the tip, and unequally sided at the base with a short petiole. Flowers are very small, pinkish white, and borne in the leaf axils. The fruit, a 3-lobed capsule, develops rapidly. *(See color plate, page 9.)*



Prostrate spurge. A. Prostrate plant.

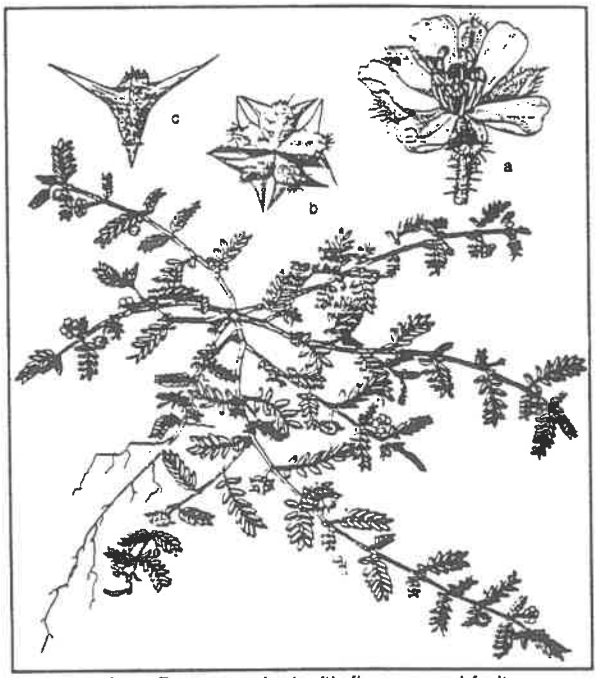
Favorable conditions: Prostrate spurge is often found on dry, gravelly or sandy soils.

Control: Hand-weed before it sets seed. Planting dense bedding plants may discourage its presence. Some preemergence herbicides are available. Apply the herbicide before soil temperature reaches 60° to 65° F, since spurge germinates at these temperatures.

Puncturevine: Puncturevine (*Tribulus terrestris*) is a prostrate, silky-haired annual, which reproduces by seed. It has a shallow taproot. The branching stems radiate out from the root for 1 to 8 feet, and can form a dense mat several feet in diameter. The leaves are opposite, divided into 4 to 7 pairs of oblong leaflets 1/8 to 1/2 inch long. The bright yellow flowers are solitary on short stalks. The seedpod consists of a cluster of 5 flat, spiny burs, which break apart at maturity. These burs can be very painful if stepped on. *(See color plate, page 9.)*

Favorable conditions: Puncturevine is often found on dry or droughty soils.

Control: Hoe scattered plants, making sure you cut off the plant below the crown. Hoeing and disposal of the plant should take place before the seeds mature.

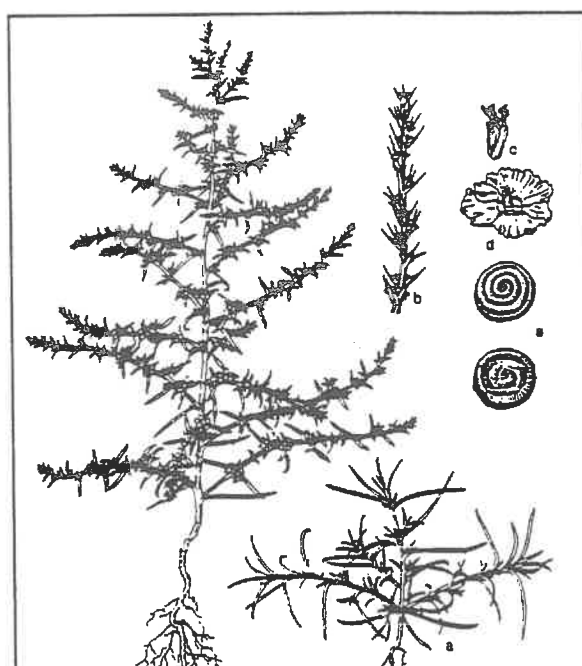


Puncturevine. Prostrate plant with flowers and fruits, or burs. a. Flower. b. Fruit or seedpod, a cluster of 5 bony burs or nutlets. c. Single bur or nutlet containing 2 to 5 seeds.

Russian Thistle: Russian thistle (*Salsola iberica*), or tumbleweed, is an intricately branched, bushy annual. It has ridged, prickly stems and can grow to a height of 6 feet. It reproduces by seed. At maturity, the dried plant breaks at ground level and rolls along the ground, scattering seed. The seedlings are fleshy and tender, with alternate, narrow, pointed leaves. These leaves drop off and are replaced with short, stiff, spiny leaves. *(See color plate, page 9.)*

Favorable conditions: Russian thistle is often found on dry, sandy soils.

Control: This weed is very difficult to control, since it scatters seeds as



Russian thistle. Plant habit. a. Seedling. b. Part of fruiting branch. c. Flower. d. Fruiting calyx. e. Seed.

it rolls along the ground. One plant may produce thousands of seeds. Furthermore, the seeds remain viable for many years. Diligent hoeing or hand-pulling may be necessary to culturally contro' this plant. If tumbleweeds get piled up along a fence, collect and burn them (if allowed in your area), or otherwise dispose of them, to keep the seeds from being further scattered. Decomposed granite may seal the soil well enough to prevent seed germination.

ORNAMENTAL PATHOGENS

ABOVE GROUND

Cytospora Canker: Cytospora canker often affects poplars and willows and has been associated with the decline and or death of many ornamental trees in landscapes, windbreaks, and recreational areas. Circular or irregular-shaped cankers first appear on young trees as brown, slightly sunken areas in the smooth bark of branches and trunks. As the canker enlarges, the outer bark may become black, brown, gray, reddish brown, or yellow. The inner bark turns black and may have a foul, salty odor. Symptoms include peeling bark and branch die-back. Cankers frequently start at wound openings. *(See color plate, page 12.)*

Cause: Cytospora canker is caused by the fungus *Cytospora chryosperma*. This is an opportunistic fungus. Once a tree has been weakened by other stresses, this fungus infects weakened tissue quickly and massively. Spores are spread by splashing rain or sprinkler water, wind, insects, birds, humans, and pruning tools.

Control: Remove all dead and dying branches of affected trees. Do not prune trees when bark is wet, as the fungus spreads this way. Clean pruning tools between cuts with household bleach. Remove and bury or burn (if allowed) cut twigs. Fertilize plants and water deeply (10 to 12 in.) during hot, dry weather to keep plants growing vigorously. Avoid physically or chemically injuring the bark. No fungicides are available to treat this disease.

Fire Blight: Blossoms, leaves, fruit spurs, and young fruits on new shoots afflicted by fire blight suddenly wilt and turn dark brown or black, as if scorched by fire. The afflicted parts die but still cling to the twigs. Shoots are shrunken and brown to black, and the tips often curl downward to resemble shepherd's crooks. Dead, slightly sunken, discolored cankers with sharp, often cracked margins form on the twigs, branches, and trunk. *(See color plate, page 12.)*

Severe fire blight can girdle and kill branches, major limbs, or entire plants. Susceptible trees and shrubs include cotoneaster, quince, loquat, pear, pyracantha.

Cause: Fire blight is caused by a bacterium, *Erwinia amylovora*, that overwinters at the living margins of cankers, mostly on the branches and trunk. The bacterium is spread principally by insects (mostly honey bees, flies, and ants), splashing water, wind, and contaminated pruning tools in warm, moist, spring and summer weather. Infection commonly follows hail or other injuries. Fire blight bacteria overwinter in living tissue and become active again in the spring when temperatures are above 65° F. Rain, heavy dews, and high humidity favor this bacterium.

Control: Grow resistant varieties where available. Avoid overfertilizing and overpruning, which stimulate excessive growth. Provide good soil drainage. Carefully cut out root suckers and water sprouts, and prune blighted twigs and branches 6 to 12 inches below any sign of infection. Prune in the dormant season, and disinfect tools between cuts with 70% rubbing alcohol. Spray weekly with a bactericide, starting in early bloom and continuing through early summer, or until the onset of hot, dry weather. Under susceptib'э trees, a 6-inch organic mulch reduces the incidence of fire blight and prolongs tree life.

Mosaic: Symptoms of mosaic vary, depending on the cause, plant species, cultivar, age, and time of year. They often disappear in hot weather. With most mosaics and a few ringspots, the leaves may develop a light and dark green, yellow, or ivory mottle. With most ringspots and a few mosaics, ring, watermark, oakleaf, or other line patterns may form along the leaf veins. Leaves are often pale green, yellow, or bronze, as well as stunted, distorted, or curled. Affected plants may grow slowly, decline in vigor, and have sparse foliage and dieback in the upper branches. *(See color plate, page 12.)*

Cause: These diseases are caused by viruses and mycoplasmas. Most are spread by propagation of infected plants or by insects or nematodes. A few are spread by root grafts with nearby trees, or by infected seed and pollen.

Control: Start with disease-free plants form a reputable nursery. Propagate only from plants that are known to be healthy. Destroy severely diseased trees and shrubs.

Palm Rot: Palm rot symptoms are the collapse and death of fronds from the growing point during warm, rainy periods.

Cause: Palm rot is caused by the fungus *Phytophthora palmivora*. Spores from diseased palms are spread by rain and wind.

Control: The crown and bud portions of the palm can be sprayed or drenched twice a year with a copper fungicide as a preventive. Applications should be made in May or June and again in November or December.

Powdery Mildew: Powdery mildews are diseases that affect a large number of plants. The severity of the disease depends on several factors, including the variety, age, and condition of the plant, when the plant is infected, and weather conditions during the growing season. Typical signs of this disease appear on newly developing leaves as individual, white, powdery spots which may continue to grow, and eventually cover the entire leaf surface. Young plants are most vulnerable to the disease, especially those grown in heavy shade. Powdery mildew rarely kills the plant, but weakens it and damages it aesthetically. Many deciduous plants are susceptible. Affected parts may be dwarfed, distorted, and curled. If the disease is severe, the leaves often turn yellow, wither, and drop prematurely. *(See color plate, page 13.)*

Cause: Powdery mildews are caused by over 1,000 species of fungi—primarily *Microsphaera* spp. and *Oidium* spp. These fungi live largely on the outer surface of the host plant, and obtain their nutrients from the plant by means of small, root-like organs that penetrate the outer or epidermal layer of the plant. They can feed upon any green tissue—leaves, green stems, flower buds, and green fruit—and are easily spread by wind and splashing water. Powdery mildews are most severe on crowded plants growing in the shade, where air circulation is poor.

Control: Prune affected plant parts if possible. Select plants resistant to powdery mildew where available. Improve air circulation and soil drainage. Reduce shade if possible. Several fungicides are available for control of powdery mildew. Be sure to spray all plant surfaces, including upper and undersides of leaves. It may be necessary to treat not only the infected plant, but also those nearby to eliminate the fungi. Since most of the mildew fungus is external to the plant, this is one of the few diseases that can be easily controlled after infection has occurred.

Sooty Canker: Sooty canker or branch wilt is a common disease that attacks a variety of plants (including mulberry, oleander, ash, wisteria, sycamore, fig, walnut, citrus, and cottonwood) in the Southwest. Plants affected with sooty canker generally produce smaller-than-normal leaves. Leaves on the affected branches wither and die in midsummer, and remain attached late into the winter. Symptoms on limbs first appear as brownish, moist areas on the bark. As the disease develops these areas crack and split revealing a black, dusty mass of fungal spores. The fungus progressively infects other limbs until the main trunk becomes infected, at which point the plant usually dies.

Cause: Sooty canker is caused by a fungus (*Hendersonlula toruloidea*), which enters the plant through a wound. Pruning wounds, mechanical damage, frost injuries, and sunburned bark all provide entry points for this fungus. Sunburned bark provides the most common entry. Sooty canker can spread from infected plants to healthy ones by spores carried by wind, rain, insects, birds, or pruning tools.

Control: Small infected branches should be removed as symptoms appear. Do not summer-prune limbs larger than 1 to 1-1/2 inches in diameter. Removal of the large limbs may cause further sunburning. Heavy pruning should be postponed until winter. Prune at least 4 inches (12 inches is better) below the active infection. Treat pruning wounds and cankers with certain fungicides. Reapplications may be needed. Disinfect pruning tools before moving to another susceptible plant.

Wetwood or Slime Flux: This disease is poorly understood and it is unclear whether or not this is one or two diseases. Symptoms consist of water-soaked, discolored areas at or below branch crotches and trunk wounds, with chronic bleeding of sap. Wilting and dieback of branches may occur. Water-soaked wood with large number of bacteria is discolored and dead. Liquid may seep out of cracks and wounds and run down the bark. The liquid, because of contamination with microorganisms, becomes dark in color, sticky, and odoriferous. Fermentation of tree tissues may increase pressure and toxin production within the infected tree. Normally, the disease, under Arizona conditions, is not observed in young trees. This is probably due to the fact that in the sapwood and heartwood of normal, young, actively growing trees, bacteria and fungi are rare. Susceptible hosts in Arizona include ash, elms, cottonwood, mulberry, and mesquite.

Cause: A number of diverse bacteria, including *Erwinia* spp., are thought to be the cause of this disease.

Control: Holes may be drilled to tap the pressure point. Drill a 12 mm hole at an upward angle below the bleeding and insert a plastic hose snugly and permanently into the first inch or two of the hole. This reduces internal pressure and facilitates drainage of the fermented, toxic material.

BELOW GROUND

Crown Gall: Abnormal, roundish growths and swellings, or galls, usually on roots and/or trunks at or just below ground level and at graft unions, are symptoms of crown gall. Infected plants may be stunted and lack vigor. Initially, a crown gall is white or flesh-colored, soft, and spongy. Later, the gall develops an irregular, rough, corky surface and a hard or woody interior. It eventually turns brown or black in color. Plants susceptible to crown gall include cottonwood, fig, peach, pecan, and weeping willow.

Cause: Crown gall is caused by the bacterium *Agrobacterium tumefaciens*. This bacterium can infect many species of plants, and can survive several years in a wide variety of soil types. Entry and infection occur exclusively through fresh wounds. This bacterium may become systemic throughout the plant. Plants may become infected after planting from contaminated pruning tools or may already be infected when purchased. This disease rarely kills an older plant on its own; however, the galls provide entry points for other diseases.

Control: Be careful not to purchase plants that are infected with this disease. Once the bacterium is in the soil, it is difficult to destroy it. Careful pruning and other maintenance operations are important, since injuries to the trunk and/or roots during weeding, mowing, or trimming can provide entry sites for the bacterium. Clean pruning and other tools with liquid household bleach or 70% alcohol between cuts. Carefully dig up and burn (if allowed) or place in trash cans all severely infected plants. Do not replant the same type of plant in the infested spot for at least 5 years. Avoid propagating from infected plants. Plant resistant species, where available, if crown gall has been a problem in the past.

Damping-off: Damping-off is the decay of young seedlings, or of seeds in the soil before or after emergence. It is most evident in young seedlings that suddenly wilt, topple over, and die from rot at the stem base. Woody seedlings often wilt and remain upright. Seedlings are susceptible longer to damping-off in soil infested with parasitic nematodes.

Cause: Damping-off is generally caused by seed- and soil-borne fungi such as *Pythium* spp., *Rhizoctonia* spp., and *Fusarium* spp.

Control: Plant in light, well-drained, well-prepared soil. Where possible, keep soil on dry side. Avoid overcrowding, overwatering, planting too deeply, and overfertilizing. Fungicides or solarization will help control these fungi.

Nematodes: Nematodes are microscopic worm-like organisms. They have whitish, translucent, unsegmented bodies, covered by a tough cuticle. Many nematodes live in the soil, and parasitic species feed on plant roots. It is difficult to distinguish between the symptoms of nematode damage and root rot infection. You may need to have soil and plant samples examined in a laboratory to confirm a nematode infestation. Nematodes reproduce by laying eggs that are deposited either in plant tissues or in the soil. Larvae hatch from the eggs, and go through 4 stages before becoming adults. Usually nematodes produce only 1 generation per year, but some species produce more. *(See color plate, page 12.)*

Damage: Some nematodes cause small knots on roots; others cause lesions or kill the tips of feeder roots. Nematodes that do not have stylets (spears) are called saprophytes, and cannot feed on plant cells. The above ground symptoms of nematode damage may include yellowing of foliage, stunting, and a general decline of the plant.

Control: Adding compost to the soil attracts beneficial fungi that attack nematodes. Drenching the soil with fish emulsion may also help, since it repels or kills nematodes. Nematodes are easily transported on tools and shoes, and by animals and running water. Washing tools may help prevent the spread of this pest. Some pesticides are available.

Phytophthora: Phytophthora root and crown rot is responsible for the death of many ornamentals, including bougainvillea, pecan, citrus, and palm. This disease attacks the roots, crowns, and trunks of a wide variety of landscape trees and shrubs. Symptoms may be the slow decline or sudden death of the plant in dry weather. In either case, the fungus kills the root system slowly. Specific symptoms include chlorotic, sparse foliage with reduced leaf size. Eventually, dead branches may occur in the crown. Twig and trunk growth decrease dramatically during the disease progression. Initially, small roots are killed in increasing numbers, and then brown to black lesions may occur on large roots. Roots may decay or die, with areas where the root cortex has fallen away, leaving the vascular tissue exposed. Small feeder roots are sparse or totally absent. Infected plants usually die. *(See color plate, page 13.)*

Cause: Soil-borne fungi in the genus *Phytophthora* (*Phytophthora parasitica*, *P. cactorum*, *P. citrophthora*, etc.) cause this disease, which is usually associated with excessive soil moisture. The fungus spreads by mobile spores and by the movement of contaminated soil or plant material. These overwinter in soil as thick-walled resting spores or as mycelium in infected roots and plant debris. During the spring, the spores germinate and can directly penetrate into epidermal cells or small roots, or enter through wounds. Infected rootlets are killed in increasing numbers as more roots become infected. Larger roots are progressively infected, and the tree or shrub eventually dies.

Control: Phytophthora rots are most prevalent in areas with high soil moisture and low soil fertility. Planting in well-drained soils or in raised beds helps prevent this disease. Control of mildly infected trees sometimes can be achieved by applications of a balanced fertilizer. Some varieties of ornamentals are more resistant to this disease than others. The incidence of phytophthora root rot can be minimized by keeping the trees as vigorous as possible. The presence of abundant mycorrhizae on roots of vigorous trees has also been related to resistance to these diseases. Trees under stress or trees with poor mycorrhizal development are not able to stop the invasion of this disease and are killed.

Cultural controls include allowing the soil to dry between irrigations; avoiding use of susceptible plants in heavy, poorly drained soils; improving soil drainage; and growing resistant cultivars. Systemic fungicides may provide effective control of this pathogen. Several fungicides, applied as soil drenches to foliage, will protect roots from infection.

Texas Root Rot: Texas root rot causes the death of many woody plants in the Southwest, such as Arizona ash, cottonwood, elms, figs, honey locust, mulberry, pecan, pistachio, sycamore, and willows. Infected trees and shrubs suddenly wilt during the summer when temperatures are high. Dead or dying foliage remains attached to the plant. The roots of infected plants are decayed and brown. White or cream-colored fungal spore mats may appear on the soil surface in infested areas after summer rains.

Cause: A soil-borne fungus (*Phymatotrichum omnivorum*—synonymous with *Phymatotrichopsis omnivora*) causes Texas root rot. Over 2,000 species of plants are susceptible to this disease.

Control: By the time this disease is detected, it is usually too late for treatment. Diseased trees and shrubs should be cut back immediately, leaving sufficient supporting branches for normal growth. Applying soil sulfur, ammonium sulfate, and steer manure out to the drip line (and beyond) of infected trees may help control this disease. Replace dead plants with resistant species, such as palms or other monocots.

Verticillium Wilt: Verticillium wilt is a common disease of many different kinds of plants, including ornamentals. The external symptoms vary, but usually the leaves on an entire plant or on one or more limbs on one side of a plant suddenly wilt. An overall yellowing of the foliage sometimes precedes this wilting. The wilted leaves may either drop early or cling on. Some trees, such as ash, may defoliate while they are still green and before noticeable yellowing or wilting occurs. Other external symptoms are a decline in twig growth and dieback of individual twigs and branches. Woody plants that develop a limited amount of branch wilt during a growing season may show additional wilt and dieback the following year. Some plants may recover and wilt again after several years.

The internal symptom of verticillium wilt in woody plants is discoloration of the sapwood in the twigs, branches, and trunk. This symptom is visible only after the plant has shown advanced stages of foliage wilt. When infected wood is cut at a slant, the discoloration in most woody species is medium to dark brown, but in some plants the streaks may be olive green, greenish black, gray to black, yellowish brown, bluish, or purplish. *(See color plate, page 13.)*

Cause: In Arizona, the fungus *Verticillium albo-atrum* is most common, although *V. dahliae* may also be present. Infections occur through all types of wounds. The fungus is spread by the movement of infected soil; contaminated seed, vegetative cuttings, and nursery stock; contaminated pruning tools and equipment; and airborne spores and insects.

Control: Plant disease-free nursery stock in well-drained soil where verticillium wilt has not occurred in the past five years or longer. Fertilize in early spring to promote vigorous growth and to maintain high, balanced soil fertility, but avoid applying excessive nitrogen. Water thoroughly every 10 to 14 days during summer droughts. Avoid wounding the roots or the trunk when planting, cultivating, or mowing. Remove dead, wilted branches from mildly affected trees, disinfecting tools between cuts with 70% rubbing alcohol. Remove and destroy dead and severely infected plants, along with as many roots as possible. Clean any tools used to remove the infected plants. Replace infected plants with highly resistant or immune plants.

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INDEX FOR CHAPTER 4

BENEFICIAL ORGANISMS

TURF INSECTS AND RELATED PESTS

TURF WEEDS

TURF PATHOGENS

ORNAMENTAL INSECTS AND RELATED PESTS

ORNAMENTAL WEEDS

ORNAMENTAL PATHOGENS

COLOR PLATES

The color plates are grouped into 3 categories: (1) insects and related pests, (2) weeds, and (3) pathogens. Turf pests come before the ornamental pests in all categories. For example, directly following the last of the turf insects (white grubs) is the first of the ornamental insects (aphids). For pests that appear in both the turf and ornamentals sections, the pest will generally be represented by only one color plate in the turf section.

Not all beneficial organisms and pests discussed in the manual have a color plate because we were unable to find good quality slides/or prints of each one. We chose to publish the manual with only those beneficial organisms and pests represented here, rather than further delay the publishing date. We hope to update this section someday and would appreciate receiving slides/prints of any of the missing beneficial organisms and pests that you might have.

PHOTO CREDITS

All photographs have been reprinted with permission. We thank the following persons for the use of their photographs/slides:

Jack Kelly Clark, courtesy University of California Statewide IPM Project	big-eyed bug
Gary Cramer	bur clover, common chickweed, galls, henbit, london rocket, malva, prostrate spurge, red stem filaree, russian thistle, tall fescue.
Crop Science Society of America, Inc.	brown patch, dollar spot, gray snow mold, pythium blight, slime mold
Stan Heathman	dandelion
Sheila Merrigan	powdery mildew (on privet)
Oscar Minkenberg	parasitic wasp
Mike Pfieffer	annual bluegrass, crabgrass, khakiweed, mustard, nutsedge, oxalis, pigweed, puncturevine, silverleaf nightshade, white clover, wild barley, cytospora canker, fire blight, melting-out, mosaic, nematodes, phytophthora, verticillium wilt
University of Arizona Entomology Slide Library	palo verde borer
Van Waters and Rogers	ant, aphids, assassin bug, billbug, caterpillars, chinch bug, cutworm, cypress bark beetle, flatheaded borer, flea beetle, ground pearl scale, lacewing, labybug, leafcutter bee, leafhopper, minute pirate bug, sod webworm, vegetable weevil, whiteflies, white grubs, powdery mildew (on grass)

BENEFICIAL ORGANISMS

Assassin bug

Ladybug

Big-eyed bug

Minute pirate bug

Lacewing

Parasitic wasp

INSECTS AND RELATED PESTS

Ant

Cutworm

Billbug

Flea beetle

Chinch bug

Ground pearl scale

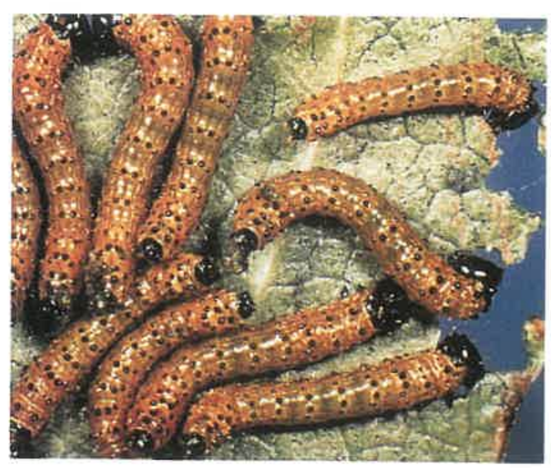

Leafhopper


White grubs


Sod webworm


Aphids


Vegetable weevil


Caterpillars

Cypress bark beetle

Leafcutter bee

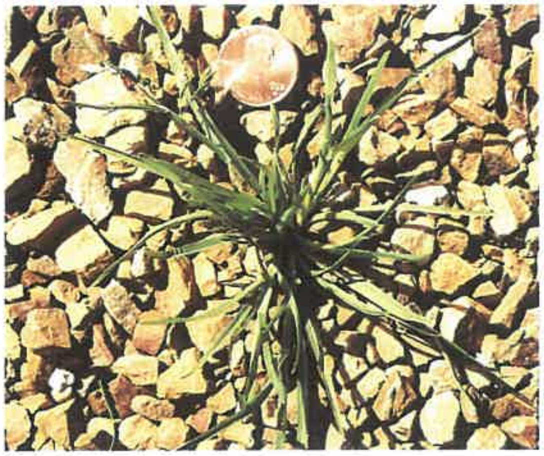
Flathead borer

Palo verde beetle

Galls

Whiteflies

WEEDS



Annual bluegrass

Common chickweed

Bermudagrass

Crabgrass

Bur clover

Dandelion


Henbit

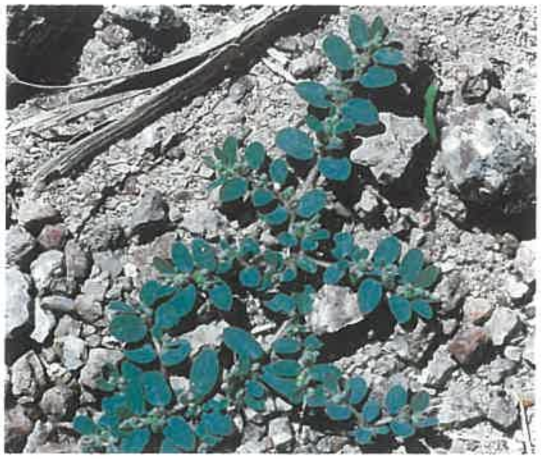

Malva


Khakiweed


Nutsedge


London rocket


Oxalis



Prostrate spurge

Russian thistle

Puncturevine

Tall fescue

Red stem filaree

White clover


Wild barley


Pigweed

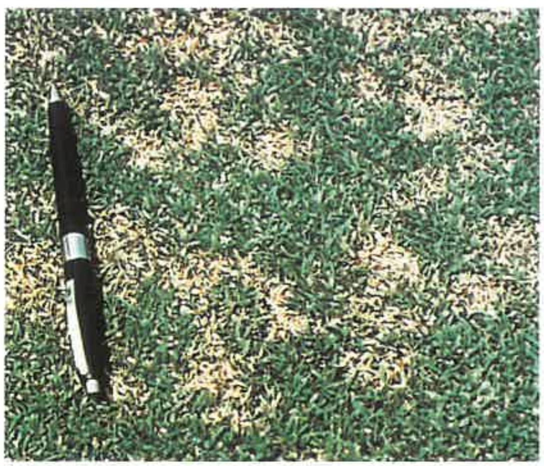

Mustard


Nightshade

PATHOGENS

Brown patch

Melting-out



Dollar spot

Powdery mildew

Gray snow mold

Pythium blight

Slime mold

Mosaic

Cytospora canker

Nematodes

Fire blight

Phytophthora

Verticillium wilt

Powdery mildew

CHAPTER 5 PESTICIDE TYPES, CLASSIFICATIONS, FORMULATIONS, AND LABELS

INTRODUCTION

A pesticide, as defined by the amended Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), is "any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any insects, rodents, nematodes, fungi, or weeds or any other form of life declared to be pests; and any substance or mixture of substances intended for use as a plant regulator, defoliant, or desiccant." A pesticide may work in four basic ways: as a systemic poison, a contact poison, a stomach poison, or a fumigant.

Insecticides can be divided into several chemical classifications, but the four most common are organochlorines, organophosphates, carbamates, and pyrethroids. Most organochlorines break down very slowly in the environment, and some are capable of being stored in the fat tissue of animals. Many of these chemicals are extremely toxic, while others are relatively nonpoisonous. Organochlorine pesticides have limited use on ornamentals or turf. Organophosphates are used to control insects and mites; some have the ability to act systemically. Examples of organophosphates used to control turf pests are chlorpyrifos and isofenphos. Carbamates are synthetic organic pesticides that are quite popular because they are highly effective, moderately priced, and generally short-lived in the environment. Examples of carbamates are oxamyl, used for insect control on ornamentals, and carbaryl, used to control turf insects. Most pyrethroids affect the function of the central nervous system, stimulating nerve cells to produce repetitive discharges, and eventually causing paralysis. Examples of pyrethroids used to control pests on ornamentals are permethrin and fluvalinate.

In the past, herbicides were generally broad-spectrum contact materials; more recently, however, chemicals that kill weeds through many varied and specific modes of action have been developed. **Selective** herbicides are designed to kill only specific targeted plants, while **nonselective** herbicides kill all plants. When applied at excessive rates, however, selective herbicides may become nonselective in action. Herbicides have contact or systemic modes of action. **Contact** herbicides kill the plant parts to which the chemical is applied. **Systemic** herbicides, which are absorbed by the roots and/or the above-ground parts of the plant are translocated throughout the plant system.

Herbicides are also classified by the timing of their application with regard to weed life cycles. **Preemergence** herbicides prevent or retard the growth of germinated weed seeds. **Postemergence** herbicides are used to control actively growing weeds. Most postemergence herbicides remain active in the soil for a very short time, so they are reasonably safe for the environment; repeated applications, however, may be necessary to control weeds, since these chemicals are not persistent. These three types of classifications—selective/nonselective, contact/systemic, and preemergence/postemergence—may appear in any combination. For example, glyphosate is a *nonselective, systemic, postemergence* turf herbicide, oryzalin is a *selective, preemergence* turf herbicide, MCPP combined with MSMA and/or 2,4-D produces a *selective, postemergence* turf herbicide, dignate is a *nonselective, postemergence* herbicide, and sethoxydim is a *selective, systemic, postemergence* turf and ornamental herbicide.

Fungicides and bactericides can be used to control most turf and ornamental plant pathogens. Sometimes, however, it may take two or three chemical applications before the pathogen is controlled. Some fungicides and bactericides can be applied as a preventive measure before any disease symptoms show. Fungicides and bactericides can also be applied after disease symptoms have appeared to retard or stop the disease. Organic fungicides are generally more selective and less harmful to the environment than inorganic fungicides and bactericides. Benomyl is a systemic fungicide that is classified as a carbamate chemical. Chloroneb is an example of an organochlorine with contact action. Dyrene and maneb are both foliar fungicides; dyrene, however, is an organochlorine and maneb a carbamate.

Read the pesticide label to fully understand the pesticides you use or plan on using. The pesticide label refers to the printed information attached to the pesticide container or retail package. The pesticide label is a legal document. It contains instructions on using the pesticide effectively and safely. The label lists the uses for the product that are approved by the Environmental Protection Agency (EPA). Always take the few minutes it takes to read the label carefully before using any pesticide—DO NOT RELY ON YOUR MEMORY.

FORMULATIONS

A single active ingredient of a pesticide may be sold in several different formulations. When applicators have the opportunity to select from several formations, they should choose the formulation that will best meet the requirements for a particular job. Consider the following nine factors:

(1) effectiveness against pest;
(2) habits of pest;
(3) plant, animal, or surface to be protected;
(4) application equipment available and best suited for the job;
(5) danger of drift or runoff;
(6) possible injury to the protected surface;
(7) safety of the public (clients, children, pets, etc.);
(8) safety of the applicator and helpers;
(9) safety of the environment.

LIQUID FORMULATIONS

Aerosols (A)

Aerosols are fine particles, either liquid or solid, that are dispersed in a gas. Aerosols come in two types of formulation: ready-to-use and smoke or fog generators. Ready-to-use aerosols are usually packaged in small, self-contained units with an inert gas under pressure. Pesticide is released in fine droplets when a valve is pressed. Although easily stored, these aerosols can be used only in certain situations, have a potential risk of inhalation injury, and are difficult to confine to a target site or pest. Ready-to-use aerosols work well in greenhouses, small areas inside buildings, or in confined outdoor spaces.

Aerosol formulations for smoke or fog generators are not under pressure. They are used in machines that break the liquid formulation into a fine mist or fog. These formulations can easily fill an entire space with pesticides and are used primarily for insect control in greenhouses or warehouses, and for mosquito and fly control outdoors. However, they are relatively expensive and can be used only in certain situations. Fog or smoke aerosols are difficult to confine to a specific site or pest, and have a high risk of inhalation injury to the applicator and the public.

Emulsifiable Concentrates (EC or E)

Emulsifiable concentrate formulations contain the active ingredient, one or more petroleum solvents, and an emulsifier that allows the formulation to be mixed with water. These formulations are very versatile and are used to control pests in turf and ornamentals, agriculture, forestry, structures, and food processing industries, as well as on livestock and in public health. They are adaptable to many different kinds of application equipment, and work well on turf and ornamentals as well as on greenhouse plants, since they leave little visible residue. However, caution is advised when using these formulations—especially when mixing—since they have a high concentration of active ingredient, and are easily absorbed through the skin of humans and animals. Some ECs can damage foliage, especially when temperatures are high. Petroleum-based materials may cause phytotoxicity in some sensitive ornamentals.

Flowables (F or L)

Flowable formulations contain finely ground particles and inert ingredients suspended in a liquid. All this is mixed with water at the time of application. Flowables are often less toxic than ECs and are often used for the same type of pest control operations as ECs. They would not, however, be as good a choice as ECs for ornamentals in commercial greenhouses, since flowables leave a visible residue.

Fumigants

Fumigants are pesticides that form poisonous gases when applied. These formulations are often used in greenhouses and inside buildings to sterilize soil and to control pests that cannot be reached by other pesticide formulations. The applicator should take special precautions when using fumigants. Label guidelines for protective equipment, including a respirator, should be carefully followed. Be sure no gas escapes from the targeted site, since this formulation is highly toxic to a wide range of organisms, including humans.

Invert Emulsions

Invert emulsion formulations contain a water-soluble pesticide dispersed in an oil carrier, which results in a much thicker material than the emulsifiable concentrates described earlier. Due to their increased thickness, these formulations form large droplets that do not drift easily. Invert emulsions are commonly used in weed control along rights-of-way, where drift could cause problems.

Solutions (S)

Solutions are formulations comprised of active ingredients and additives that are readily dissolved in water. When these formulations are mixed with water, a dilute solution is formed that will not separate or settle. Few pesticides are available as solutions.

Low Concentration Solutions (S)

Low concentration solutions contain small amounts of active ingredients that are generally mixed with petroleum solvents. They are ready to use and do not need to be further diluted. These formulations are easy to use, and are unlikely to harm nontarget organisms. Low concentration solutions are a good choice to use if the area sprayed is accessible to the public, such as city parks and street ornamentals. Some of these formulations, especially prepared to be used indoors, may have no unpleasant odors and may not stain fabric. Petroleum-based carriers, however, may injure the foliage of sensitive plants.

Ultra-low-volume Concentrate Solutions (ULV)

ULVs may be almost 100% active ingredient. They are to be used as is, or only slightly diluted. These must be applied with highly specialized spray equipment and are used outdoors, including on some ornamentals.

DRY FORMULATIONS

Baits (B)

Baits are active ingredients often mixed with an attractant such as food. These may be used indoors or out, to control a variety of pests. Baits do not target a specific pest, and may kill nontarget organisms. Children and pets are often attracted to this type of pesticide, so care should be taken when placing baits. Use only tamperproof bait stations. Be aware that the public may express concern if dead or dying baited birds or animals are seen in a public area.

Dusts (D)

Most dust formulations are ready to use and contain a low percentage of active ingredients, plus a fine, inert carrier. Since dusts are used dry, they can easily drift into nontarget areas and may harm nontarget organisms. They are often used in hard-to-reach indoor areas or in areas that require only spot-treatments, and are effective where moisture from a liquid spray may cause damage to the plants. Dusts leave a residue, however, and thus may have limited application on ornamentals and in commercial greenhouses.

Granules (G)

Granule formulations are similar to dusts, but the active ingredient is mixed with an absorptive coarse material such as clay, corncobs, or walnut shells. The particle size is much larger than that of dusts, and the amount of active ingredient is relatively low. Granules are applied primarily to soil to control pests at ground level or lower. Granule formulations do not stick to foliage, so will not control pests that remain on foliage throughout their lives. Granules are often used on turf, ornamentals, and rights-of-way. To reduce labor costs, granular pesticides are often applied in combination with fertilizers on turf. Drift is usually not a problem with this formulation, and it is a preferred formulation where drift is a potential problem. Granules are sometimes attractive to birds, bees, and other nontarget organisms. Care should be taken, such as limiting application to times when plants are not flowering and therefore bees not foraging, to minimize the impact on these organisms.

Microencapsulation

Microencapsulated formulations are particles of pesticides (either liquid or dry) surrounded by a plastic coating. These plastic-coated particles are mixed with water and applied as a spray. Once applied, the capsules slowly degrade, releasing the pesticide. This encapsulation process can prolong the effectiveness of the pesticide by providing a timed release of active ingredient. This formulation is good when a slow, long-term release of pesticide is needed. The slow release feature also reduces applicator exposure to the active ingredient. Unfortunately, bees may pick up capsules and carry them back to the hive, where the released pesticide may poison an entire hive. Apply this formulation only when bees are not present in the area.

Pellets (P or PS)

Pellets are very similar to granules, except that pellets are formed to a specific shape and weight.

Soluble Powders (SP)

Soluble powder formulations look like wettable powders; however, soluble powders readily dissolve and form a true solution when mixed with water. Few pesticides are available in this formulation because few active ingredients are soluble in water.

Water-dispersible Granules (Dry Flowables)

Water-dispersible granules are similar to wettable powder formulations, except the active ingredient is prepared as granule-sized particles. These granules must be mixed with water before application.

Wettable Powders (WP)

Wettable powders are formulations consisting of the pesticide combined with a finely ground dry carrier, such as mineral clay, or other ingredients that help suspend the powder in water. Wettable powders resemble dusts but usually contain a higher concentration of active ingredient than dusts, and are intended to be mixed with water prior to application. Use formulations with the highest percentage of active ingredients if visible residues are a concern, because carriers and other inert ingredients are the most common source of unsightly residues. Wettable powders are among the safest formulations to use when treating tender foliage or when plant phytotoxicity is a problem, because the carriers are inert materials. Equipment used to apply wettable powders must be capable of good agitation, or nozzles will clog. Wettable powders also cause excessive wear on some types of sprayer pumps.

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SAMPLE TEST

QUESTIONS

Use each of the following terms only once in answering the following four questions: organochlorines, pyrethroids, carbamates, organophosphates.

1. Most ____________ breakdown very slowly in the environment and some are capable of being stored in the fat tissue of animals.

2. Some ____________ have the ability to act systemically.

3. ______________ are synthetic organic pesticides that are quite popular because they are highly effective, moderately priced, and generally short-lived in the environment.

4. Most _____________ affect the function of the central nervous system.

Use each of the following terms only once in answering the following four questions: contact, nonselective, systemic, selective.

5. ____________ herbicides are designed to kill only specific targeted plants.

6. ____________ herbicides kill all plants.

7. ____________ herbicides kill the plant parts to which the chemical is applied.

8. ____________ herbicides, which are absorbed by the roots and/or the above-ground parts of the plant, are translocated throughout the plant system.

Answer the next two questions using the appropriate terms from the following list: dusts, emulsifiable concentrates, low concentration solutions, fumigants.

9. __________________ work well on outdoor turf and ornamentals, since they leave little visible residue.

10. Because ____________________ are easy to use and unlikely to harm nontarget organisms, they are a good choice to use if the area treated is accessible to the public.

ANSWERS

1. organochlorines 2. organophosphates 3. carbamates 4. pyrethroids 5. selective 6. nonselective 7. contact 8. systemic 9. emulsifiable concentrates 10. low concentration solutions

CHAPTER 6 APPLICATION EQUIPMENT AND APPLICATION TECHNOLOGY

INTRODUCTION

How effective a pesticide is at controlling a particular pest problem often depends on proper application of the pesticide. The equipment used to apply pesticides varies with the type of vegetation being treated, the pest to be controlled, and the formulation used. This chapter discusses the many different kinds of application equipment used by turf and ornamental pesticide applicators, as well as application technology—when and how to use that equipment.

APPLICATION EQUIPMENT

Take the time to choose your application equipment wisely. If you select the right equipment, you will not only be assured of satisfactory results, but will also be able to use the same equipment for several types of pest problems. Even an applicator who specializes in one specific type of pest control will need to give careful consideration to equipment. The primary function of the equipment is to provide a continuous and consistent amount of pesticide to the target area.

Choose your equipment according to the following factors:

Time: How quickly do you have to apply a specific pesticide to achieve an acceptable level of control? Will the equipment be of sufficient size and capacity to treat the required area in a timely fashion?

Suitability: Will ground equipment be restricted by the type of vegetation or ground conditions? Will the equipment damage the plants, or spread the pest or disease? Can the equipment be cleaned easily after use?

Frequency: How many applications will be needed in a season or year?

Treated and Surrounding Areas: What is called for—spot-treatment of small areas, or a broadcast treatment of a large area? What type of buffer zone does this equipment require? Will the application cause damage to the surrounding environment? Should you consider other methods of control that would reduce or eliminate the need for pesticide treatment?

Costs and Inputs: Which method is most economical? Can the equipment be used for other applications? Can changes in cultural practices reduce the need for treatment?

Drift: Have you considered potential drift problems? Are there highly sensitive areas, such as a house, school yard, or pond, near by? Will equipment be restricted by current weather conditions?

TYPES OF EQUIPMENT USED

The types of equipment used to treat ornamentals, such as shrubs and small trees, are usually manually operated sprayers or low-pressure power sprayers with a single-nozzle spray gun attached. To treat tall trees, high-pressure, high-volume hydraulic or air-carrier sprayers are often used. The equipment used to apply pesticides to turf, such as lawns or golf courses, varies greatly. For spot-treatments a spray bottle may be adequate, while large, continuous turf areas may be best treated by aerial application. Usually, however, manually operated sprayers, powered boom sprayers, hand-held boom sprayers, or granular spreaders are used.

DESCRIPTION AND APPLICATION TECHNOLOGY OF EQUIPMENT

Different types of equipment offer certain advantages and disadvantages, which you need to evaluate in your choice.

AERIAL EQUIPMENT

Fixed-wing aircraft. About 7,500 aircraft are used each year in the United States for aerial application—mostly for agricultural purposes. Aircraft, however, may also be used by applicators to treat rights-of-way or large areas of turf in parks or golf courses.

Advantages: Aerial application is fast and convenient, especially when quick action is required. Aerial methods also allow treatment when the target area is too wet for operation of ground equipment.

Disadvantages: Fixed-wing aircraft cannot generally treat small areas, and are difficult to operate in urban areas due to hazards such as power lines and/or tall trees and the potential of nontarget exposure. Application costs generally are higher with aircraft than with ground equipment (although the speed and timeliness may offset the cost differential).

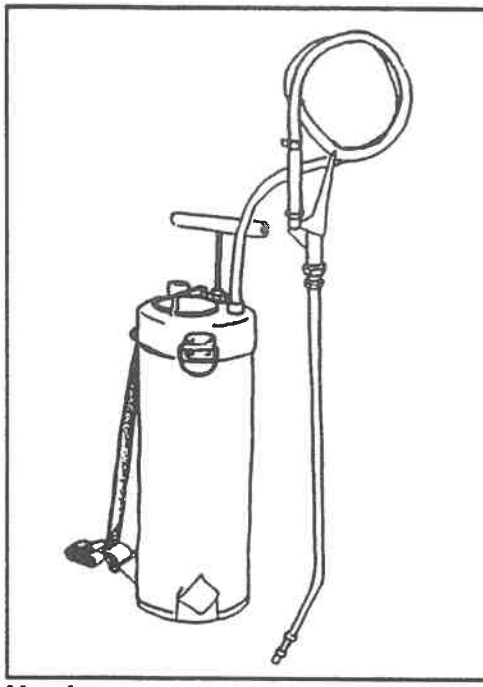
Helicopters have shown a substantial increase in use in recent years, but total flight time is quite small compared to other aircraft. Helicopters, like fixed-wing aircraft, have limited use in turf and ornamentals. They can only be used when large areas of turf need to be treated.

Advantages: Helicopters can be flown at slower speeds and can make faster turns than fixed-wing aircraft. As a result, there is potentially less danger of drift with helicopters than with fixed-wing aircraft, but still substantially more than with ground equipment. Helicopters may provide more uniform coverage than fixed-wing aircraft.

Disadvantages: Helicopters are more complex and require more maintenance than other aircraft; this increases the application cost.

GROUND EQUIPMENT

Liquid Formulations



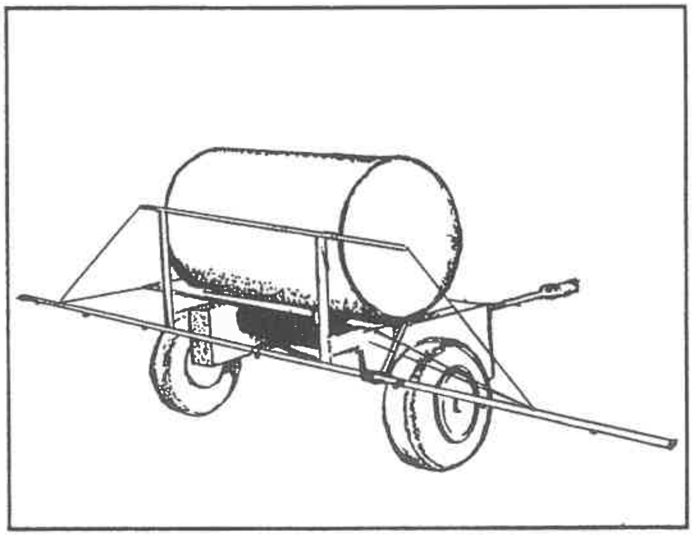
Hand sprayer

Hand sprayers are compressed-air and backpack sprayers designed for spot-treatment or use in small areas, or around trees where larger sprayers are unable to maneuver. These small sprayers are capable of delivering 1 to 3 gallons of pesticide per minute at pressures up to 30 pounds per square inch (psi). Single-nozzle hand guns are usually attached to the canister, but spray booms may also be used. Most compressed-air hand sprayers do not have pressure gauges or pressure controls. Most have a hand-operated hydraulic pump that allows the pressure in the tank to drop as the material is sprayed from the tank. There are backpack units available that have a compact gasoline engine to drive the pump. When spraying, with hand sprayers, either hold the spray extension at a steady, constant height and spray while walking back and forth; or swing the extension back and forth at a uniform speed in a sweeping overlapping motion. Maintain a uniform walking speed.

Advantages: These sprayers are inexpensive and simple to use and clean. They can be used in areas where space is restricted, and require little storage space.

Disadvantages: These sprayers are not practical for large jobs. Since these sprayers have a small tank capacity, they may require frequent refilling.

Low-pressure boom sprayers are usually mounted on tractors, trucks, or trailers, and can be driven over large turf areas for broadcast or band pesticide applications. Low-pressure sprayers generally use relatively low volumes (10 to 40 gallons per acre) of dilute spray, applied at 20 to 60 pounds of pressure. Hand guns may be attached for treatment of individual plants and areas with limited pest infestations. Low-pressure sprayers generally have a tank capacity of 100 gallons or more.



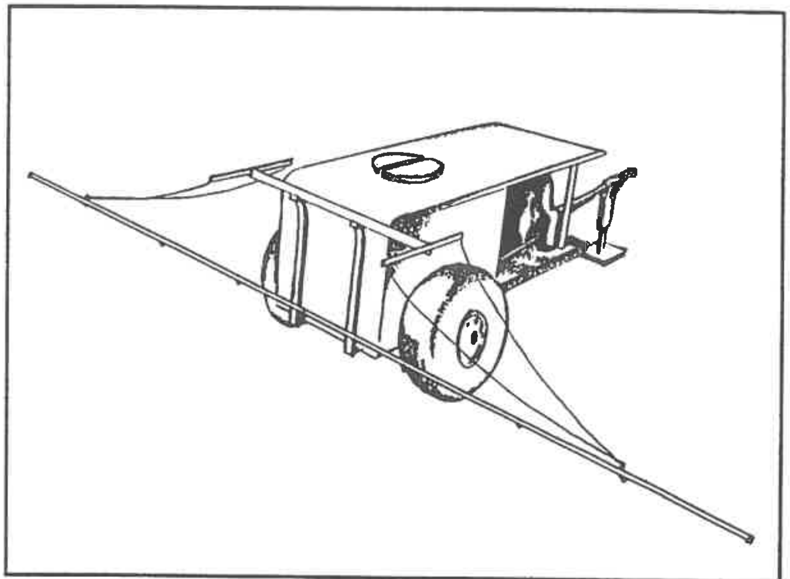
Low-pressure boom sprayer

Advantages: Low-pressure sprayers are relatively inexpensive and lightweight. They can be adapted to many uses and cover large areas quickly. Since they are usually low-volume sprayers, one tank load will cover a large area. There is less danger of drift with a low-pressure boom sprayer than with aerial equipment.

Disadvantages: They cannot adequately cover or penetrate dense foliage because of the low-pressure and gallonage rate. Since most rely on bypass systems and return-flow agitations, wettable powder formulations often settle out; this problem can usually be overcome with mechanical agitators.

High-pressure sprayers (often called hydraulic sprayers), operate with dilute sprays, but at regulated pressures up to several hundred psi. The pesticide is usually distributed through a hand-held gun or a multiple-nozzle spray boom.

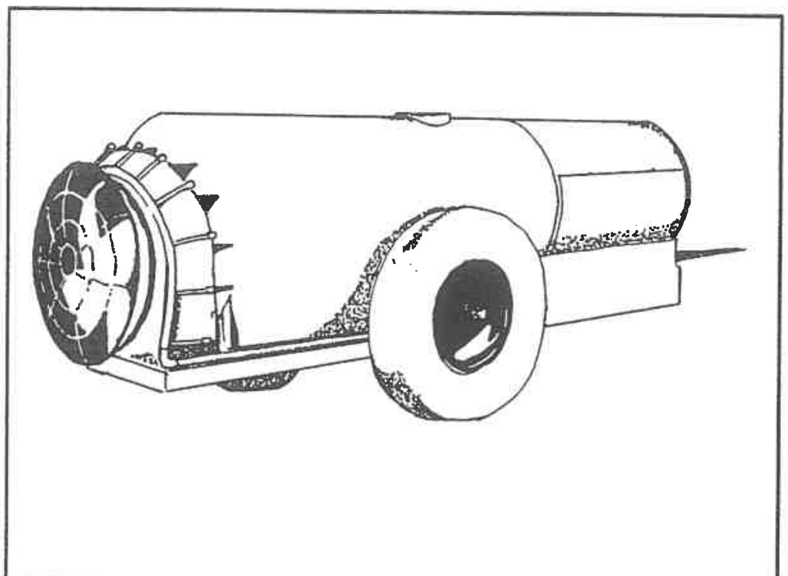
The force required to carry the spray droplets from nozzle to foliage comes from pressure created by the pump. High-pressure sprayers are used for spraying shade trees, ornamentals, and other vegetation when dense foliage requires good penetration.


High-pressure sprayer

Advantages: High-pressure sprayers are used for many different pest control jobs because they can penetrate heavy vegetation and can reach the tops of tall shade trees. Since they are sturdily built, they are relatively long-lasting and dependable.

Disadvantages: High-pressure sprayers are usually heavy and expensive and require large amounts of water and frequent filling. High pressure means fine spray droplets which increase drift problems.

Air-carrier sprayers are primarily used for foliar spraying in orchards or on shade trees. The effectiveness of the chemical used with this type of sprayer is dependent on the spray coverage obtained. In many areas hydraulic sprayers are still being used for tree spraying. But for spraying large numbers of trees, most applicators are now choosing to use air-carrier sprayers, which


Air-carrier sprayer

replace the large quantities of water needed by hydraulic sprayers with air; thus, the name, air-carrier. These sprayers were designed to increase the efficiency and effectiveness of coverage by carrying the pesticide and water mixture under pressure to the target site. Air-carrier sprayers make use of radial fans to create a current of high-speed air. This turbulent air passes over spray nozzles, which pick up spray droplets and transport them into the trees as the sprayer moves between the trees. The blast of air aids in breaking up larger drops and transporting the droplets to provide thorough coverage. Research has shown that, to obtain uniform coverage, it is necessary to direct a larger proportion of the spray material towards the top of the tree. Although there is disagreement over what the proportions should be, it is suggested that 2/3 of the liquid output be in the upper half of the tree, and the remaining 1/3 be in the lower half.

Advantages: A concentrated spray can be used since both air and water transport the spray. Air-carrier sprayers use only a small amount of water to cover large areas; very little operating time is lost in refilling, making them potentially less tiring to operate than hydraulic sprayers.

Disadvantages: Air-carrier sprayers can be used only in calm weather. The air blast causes significant drift, and windy conditions interfere with the normal pattern of the sprayer. Larger models cannot be used to treat small areas. It is difficult to determine how much spray to apply and to apply the spray uniformly.

Aerosol generators or foggers break certain pesticide formulations into very small droplets or aerosols, so fine that a single droplet cannot be seen. When large numbers of droplets are formed, however, they appear as a fog or smoke. Foggers are usually used to fill an area, such as a greenhouse or open recreational area, with a pesticide fog to control insects and other pests. Aerosol generators or foggers are not suited for herbicide use.

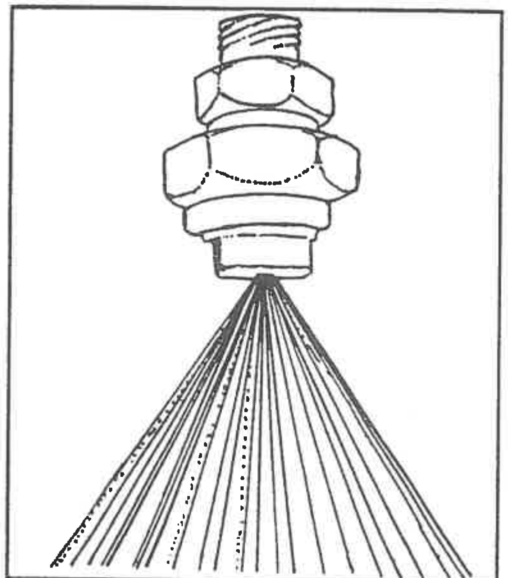
Advantages: Droplets produced by foggers are so fine that they do not stick to surfaces within the area. Foggers usually apply fairly safe formulations that can be used in populated areas for mosquito or other insect control, without the problem of unsightly residues. The droplets float in the area and penetrate into tiny cracks and crevices or through heavy vegetation to control pests in hard-to-reach places.

Disadvantages: Little, if any, residual control is possible since the droplets produced by foggers do not stick. As soon as the aerosol dissipates from an area, pests can move in. Foggers must be used under the correct weather conditions; for example, rising air currents could carry the fog out of the treated area, without any contact and with no control. Drift onto nontarget areas is also a problem.

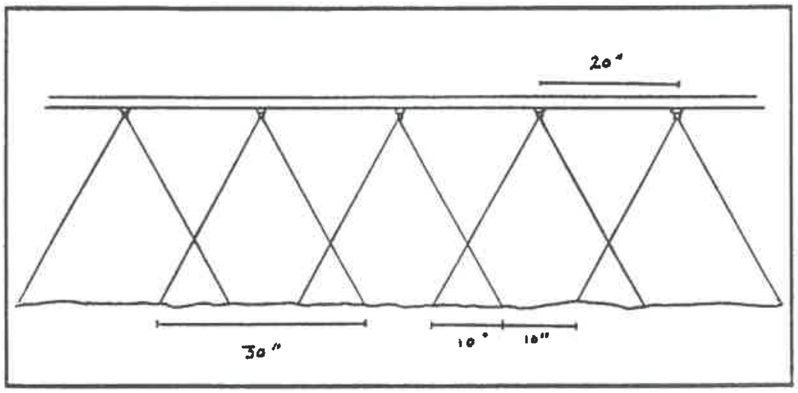
Nozzles

One piece of equipment used on sprayers that is vital for proper application is the spray nozzle. Selection of the correct nozzle type and size is important for proper application of pesticide to ornamentals and turf. The nozzle determines the amount of spray applied to a particular area, the uniformity of the applied spray, the coverage obtained on the sprayed surface, and the amount of drift. Drift problems can be minimized by selecting nozzles that give the largest drop size while providing adequate coverage at the intended application rate and pressure. Although nozzles have been developed for practically every kind of spray application, only a few types are commonly used for applying pesticides to ornamental plants and turf.

Regular flat-fan nozzles are used for most broadcast spraying of herbicides and for certain insecticides when foliar penetration and coverage are not required. When applying herbicides with flat-fan nozzles, keep the operating pressure between 15 and 30 psi. At these pressures, flat-fan nozzles produce medium to coarse drops that are not as susceptible to drift as the finer drops produced at pressures of 40 psi and higher. Because the outer edges of the spray pattern have tapered or reduced volumes, adjacent patterns along a boom must overlap in order to obtain uniform coverage. For maximum uniformity, this overlap should be about 40% to 50% of the nozzle spacing.

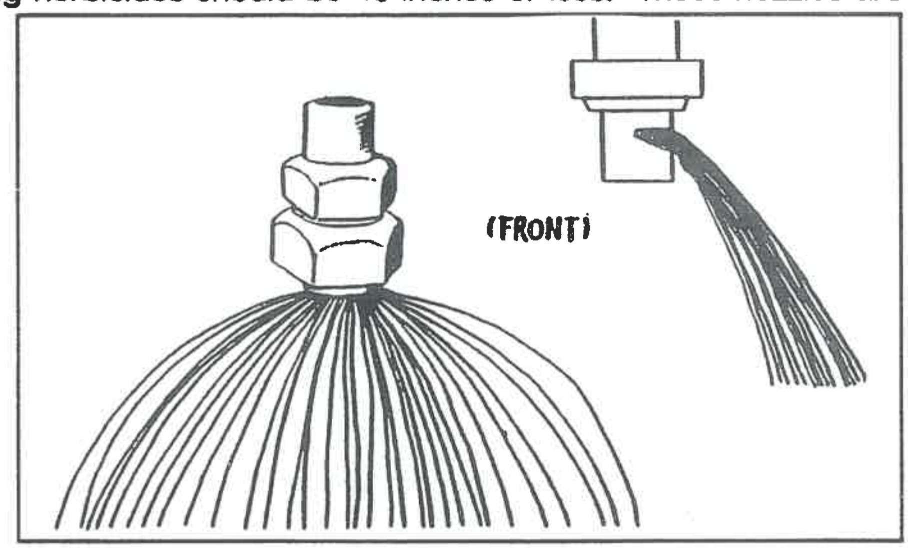


Regular flat-fan nozzle

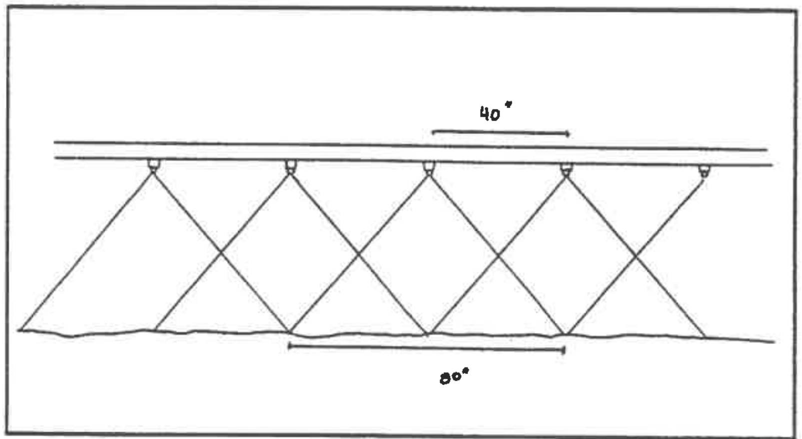


50% overlap

Flooding flat-fan nozzles produce a wide-angle, flat-fan pattern, and are used to apply herbicides and mixtures of herbicides and liquid fertilizers. The nozzle spacing for applying herbicides should be 40 inches or less. These nozzles are most effective in reducing drift when they are operated within a pressure range of 8 to 25 psi. Pressure changes affect the width of spray pattern to a greater extent with the flooding flat-fan nozzle than with the regular flat-fan nozzle. In addition, the distribution pattern is usually not as uniform as that of the regular flat-fan nozzle. The best distribution is achieved when the nozzle is mounted at a height and angle to obtain at least double coverage or 100% overlap.

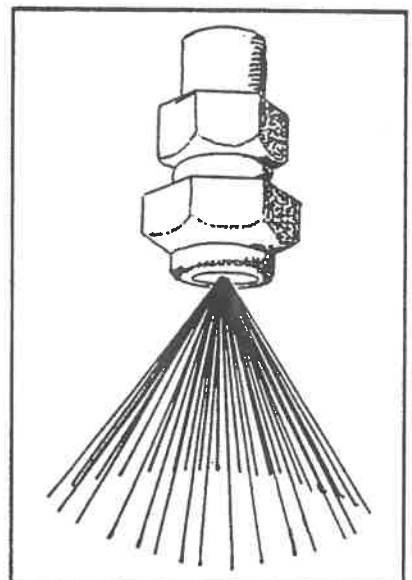


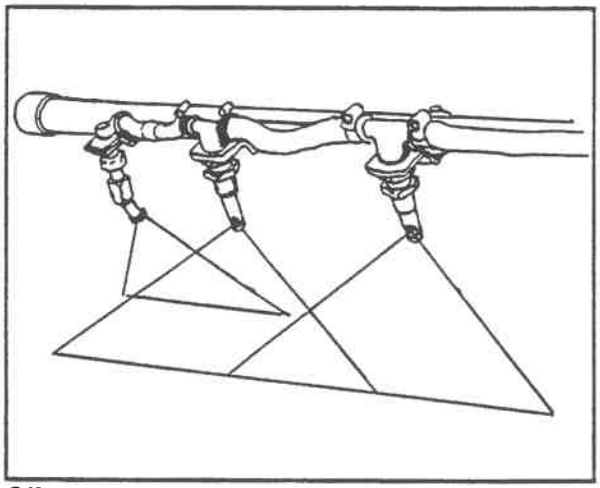
Flooding flat-fan nozzle



100% overlap

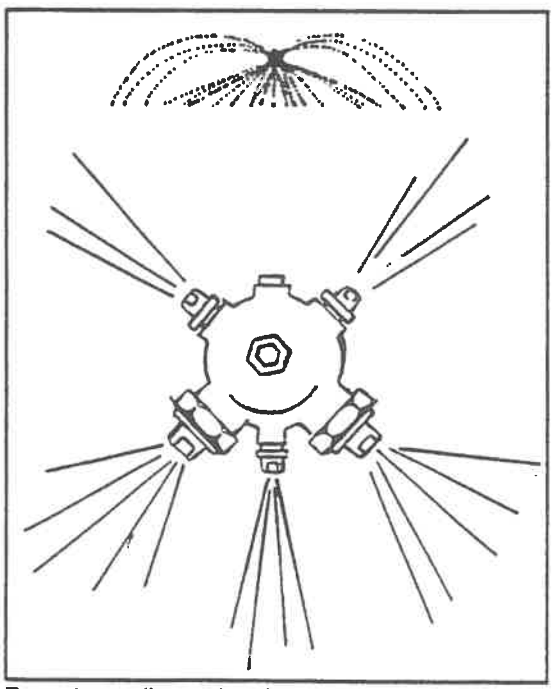
Hollow-cone nozzles (disc and core type) are used primarily when plant foliage penetration is essential for effective insect and disease control, and when drift is not a major concern. At pressures of 40 to 80 psi, hollow-cone nozzles produce small drops that penetrate plant canopies and cover the underside of leaves more effectively than other nozzles. If penetration is not required, the pressure should be limited to 40 psi or less.


Hollow-cone nozzle



Off-center nozzle

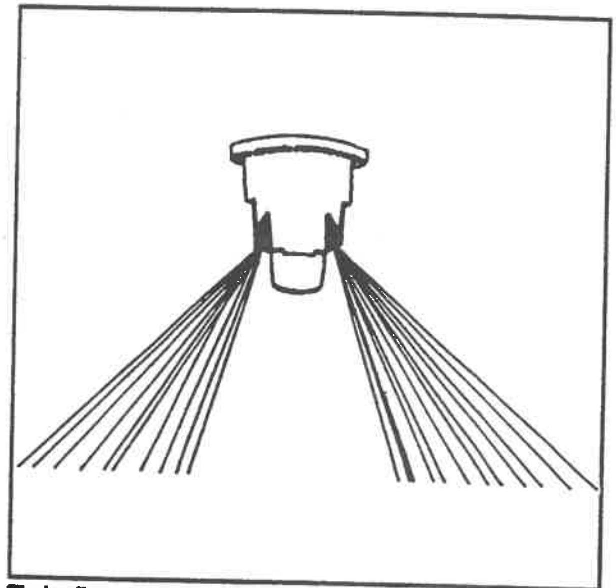
Off-center nozzles. Off-center, flat-fan nozzles are used when extended coverage is needed at the end of a boom. These nozzles produce an off-center spray pattern extending in one direction from the nozzle tip. The coverage is relatively uniform when the nozzles are mounted at the proper height and operated within a pressure range of 15 to 40 psi.



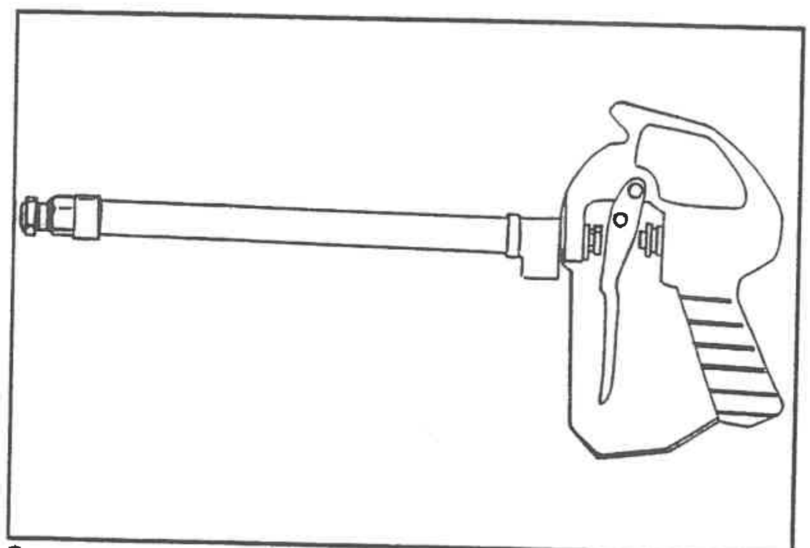
Broadcast (boomless) nozzle

Broadcast (boomless) nozzles are used to spray swaths up to 30 feet or more. The spray is more susceptible to drift than that from nozzles mounted on a spray boom, and the distribution across the swath is not as uniform as with other nozzle types. Broadcast nozzles produce small droplets immediately under the nozzle, but extremely large droplets are deposited at the outer edge of the swath. Broadcast nozzles are used for boomless sprayers to extend the effective width, on the end of the boom, or when thorough coverage of the surface is not necessary. They are not recommended for lawns, but are suggested for spraying fairway perimeters, fencerows, and roadsides, where trees and other obstructions make using a boom undesirable.

Twin flat spray nozzles are used when two angles of spray are needed for better penetration of dense foliage. Droplets, smaller than those from single flat spray tips, are produced that provide more thorough coverage and more uniform spray distribution along a boom than hollow-cone nozzles. There is a high probability of drift since small droplets are produced.


Twin flat spray nozzle

Spray guns for spraying ornamental plants and turf areas range from a low flow rate with a wide cone spray pattern to a high flow rate with a straight stream spray pattern. Spray guns are not normally recommended for spraying turf areas such as lawns or golf course greens. It is very difficult to obtain constant, uniform coverage of turf areas with a spray gun. A hand or walking boom with conventional nozzles should be used if it is not possible to use a conventional sprayer with a boom. If a spray gun must be used because of rough or very irregularly shaped areas, the operator must be aware of the difficulty in obtaining a uniform spray in the correct amount over the area.


Spray gun

Metered spray guns are available that deliver a precise amount of spray. A precise volume, generally ranging from 1 to about 16 milliliters, is released with the pull of the trigger. Once the trigger is released, the gun will then measure out the set amount again and be ready for the next trigger pull. This spray gun is ideal for delivering a small, set amount of spray to a number of plants.

Nozzle material. Nozzle tips are available in a wide variety of materials, including hardened stainless steel, stainless steel, nylon, ceramic, and brass. Hardened stainless steel and ceramic are the most wear-resistant materials, but also the most expensive. Stainless steel and ceramic tips have excellent wear resistance when used with either corrosive or abrasive substances. Although nylon and other synthetic plastics are resistant to corrosion and abrasion, they are subject to swelling when exposed to some solvents. Brass tips are the most common, but they wear out rapidly when used to apply abrasive substances such as wettable powders, and are corroded by some liquid fertilizers. Brass tips are probably the most economical for limited use, but other types should be considered for more extensive use. Nozzles should be checked regularly for pattern distribution and clogging, and should be changed annually or sooner if spray equipment is used often or with abrasive materials.

Spray nozzles and caps are available that are color-coded. The color-coding helps ensure that the same size nozzle tips are used across the boom. Be certain that the type and size of the nozzle you select is appropriate for the type of material being applied (i.e., do not use a herbicide nozzle when spraying an insecticide, or a nozzle made for applying a systemic when applying a contact pesticide).

Dry Formulations

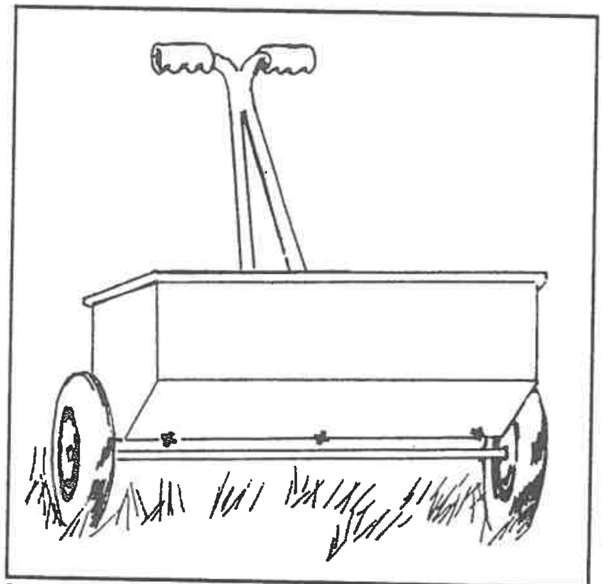
Dusters blow fine particles of pesticide onto the target surface. Simply constructed, dusters are used mostly for individual spot-treatments or for small areas of plants.

Advantages: Dusters are lightweight, relatively cheap, and can be quickly set up for use. They do not require water.

Disadvantages: Dusts are highly visible, which limits their use on turf and ornamentals if aesthetics are important. Dusts are difficult to control and can easily drift. Dusters are therefore undesirable for certain vegetation types or large outdoor areas, and are not suited for herbicide use.

Granular Spreaders are often used to apply pesticides to turf. Proper selection, care, calibration, and use of these spreaders is important to achieve good results and minimize costs. There are two types of granular spreaders: (1) drop or gravity spreader and (2) rotary or centrifugal spreader.

Drop (gravity) spreaders are designed to apply coarse, uniformly sized, dry particles to soil, water and, in some cases, foliage. Drop spreaders are generally more precise than rotary spreaders, and deliver a better pattern.



Drop (gravity) spreader

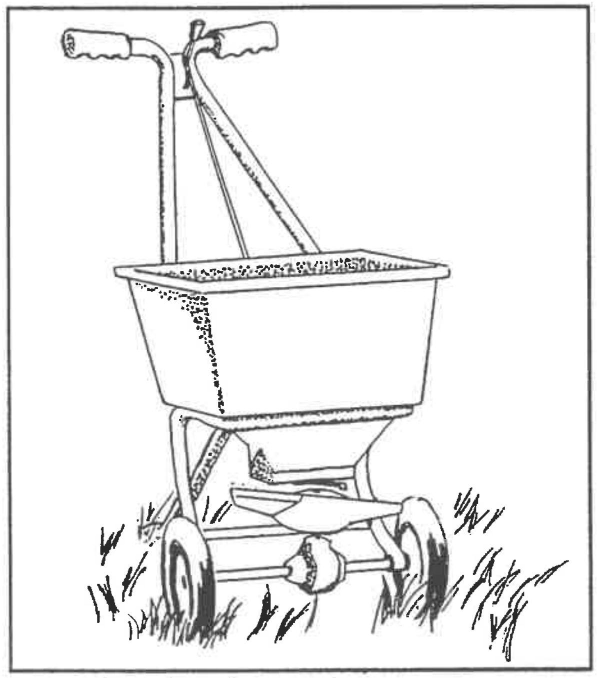
Advantages: Drop spreaders, in general, are light and relatively simple; no water is needed. Because granular formulations are uniform in size, they flow easily and are relatively heavy. Since the granules drop straight down, there is minimal chemical drift and good control, with little chance of applying pesticide to nontarget area. Some drop spreaders have a means of shutting off one side of the spreader which is desirable if edging a driveway or sidewalk.

Disadvantages: Some drop spreaders will not handle large granules. Since the edge of a drop spreader pattern is sharp, any steering error will cause strips to be missed or doubled. Uniform coverage can be difficult to achieve. The amount of material flowing from the spreader does not change proportionately with changes in speed. A constant ground speed is necessary to maintain a uniform application rate. The applicator will also need other machinery for most foliar applications.

Rotary (centrifugal) spreaders, cover a wide swath and so cover an area faster than drop spreaders. Steering errors are also less critical.

Advantages: Rotary spreaders can cover areas quickly, and compared to drop spreaders, are usually easier to push and not as easily knocked out of calibration. When made of plastic or fiberglass they are resistant to corrosion.

Disadvantages: Rotary spreaders are more sensitive than drop spreaders to ground speed, physical characteristics of the granules, and environmental factors. A change in ground speed will change the distribution pattern by throwing the granules farther at a faster speed, or not as far at a slower speed. Heavier granules will not travel as far as lighter granules. The shape of the granule may also affect distribution pattern. Environmental conditions such as wind, temperature, and humidity may also affect the distribution pattern. Drift may be a problem with fine particles when wind is present. Generally, rotary spreaders are less precise in uniformity and distribution than the drop spreader. Other equipment is usually needed for foliar applications.



Rotary (centrifugal) spreader

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SAMPLE TEST

QUESTIONS

1. How effective a pesticide is at controlling a particular pest problem often depends on proper application of the pesticide. True or False?

2. The primary function of application equipment is to provide a continuous and consistent amount of pesticide to the target. True or False?

For questions 3 to 8 match up the terms on the right with the correct answer on the left.

3. Cannot adequately cover or penetrate dense foliage because of low pressure and gallonage rate. _____

4. Inexpensive and simple to use and clean—can be used in areas where space is restricted. _____

5. Can penetrate heavy vegetation and can reach the tops of tall shade trees. _____

6. Can only be used in calm weather—the air blast causes significant drift, and windy conditions interfere with the normal pattern of the sprayer. _____

7. Apply coarse, dry particles in a precise pattern with little chance of drift. _____

8. Apply coarse, dry particles quickly, but with the possibility of drift. _____

A. Hand sprayers.

B: Rotary (centrifugal) spreaders.

C: Drop (gravity) spreaders.

D: High-pressure sprayers

E: Air-carrier sprayers

F: Low-pressure boom sprayers.

9. ______________ nozzles are used primarily when penetration is essential for effective insect and disease control, and when drift is not a major concern.

10. ______________ nozzles are used when two angles of spray are needed for better penetration of dense foliage.

ANSWERS

1. true 2. true 3. low-pressure boom sprayers (F) 4. hand sprayers (A) 5. high-pressure sprayers (D) 6. air-carrier sprayers (E) 7. drop (gravity) spreaders (C) 8. rotary (centrifugal) spreaders (B) 9. hollow-cone 10. twin flat spray

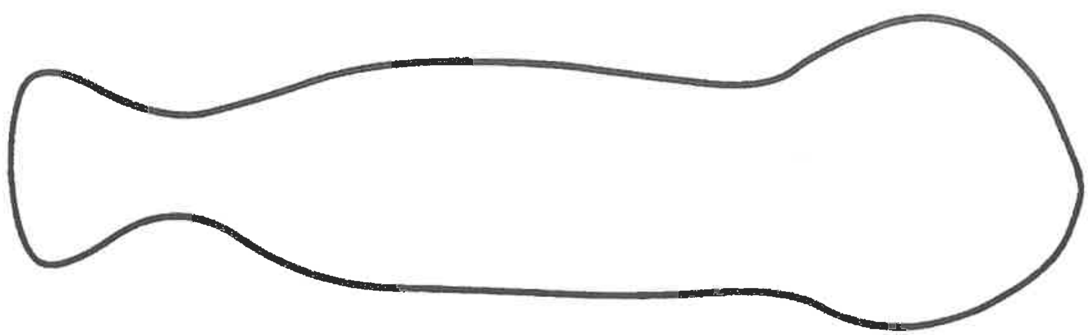
CHAPTER 7 EQUIPMENT CALIBRATION[1]

INTRODUCTION

For pesticide applicators, calibration refers to the act of setting up your equipment to deliver the correct amount of pesticide on a specified area. Equipment that is not calibrated correctly is one of the most common reasons a correctly chosen pesticide fails to produce the desired results. Pesticide applied incorrectly may result in damage to the target plant(s), lack of control of the pest, increased costs, and damage to nontarget organisms and the environment.

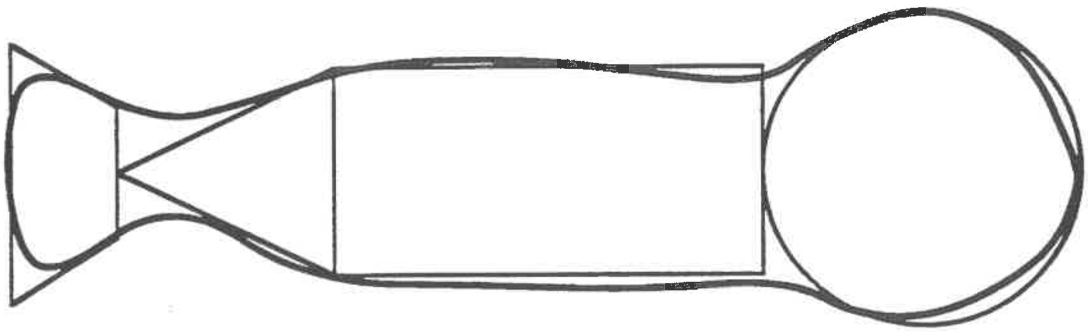
AREA MEASUREMENT

In order to apply a pesticide at the proper rate, the area to be treated must be accurately determined before calibrating your equipment. When treating ornamentals, area measurements may not be a problem, since many ornamentals are treated on a plant-by-plant basis. However, area measurements are important for treating large areas of turf. Determining the area of a homeowner's lawn may not be difficult if it is roughly rectangular, but determining the area of a golf course green or city park may be more difficult due to irregularly shaped areas of turf. One solution is to make the turf fit into geometric figures, find the area of each figure, and then add all the areas together. For example, this irregularly shaped area of turf



[1]Much of this section has been taken directly from *The Calibration of Commercial Pesticide Application Equipment for Ornamentals and Turfgrass* by Loren E. Bode and Stephen L. Pearson. This manual was published by the Agricultural Engineering Department, University of Illinois, Urbana. Manual M444-4.

can be reduced to several geometric figures.

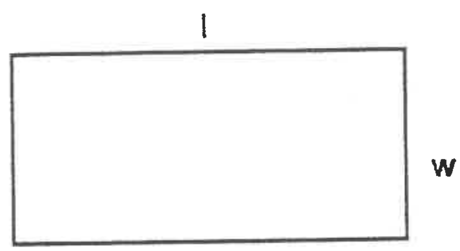


The area of each geometric figure is then calculated and the areas of all the geometric figures are added together. Formulas for calculating the area of a rectangle, trapezoid, circle, and triangle are as follows:

Rectangle The area of a rectangle is found by multiplying the length by the width.

$$Area = l \times w$$

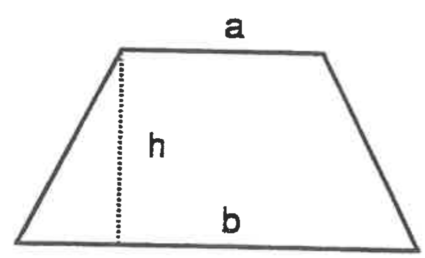
l = length
w = width



Trapezoid — The area of a trapezoid is found by multiplying the average length of the parallel sides by the height.

$$Area = \left[\frac{a + b}{2}\right] \times h$$

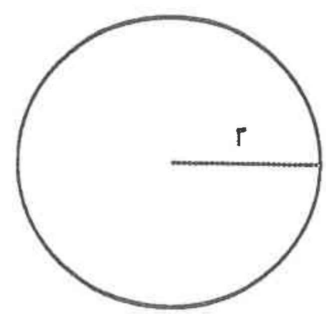
a = length of the top side
b = length of the bottom side
h = height



Circle — The area of a circle is the radius (one-half the diameter) squared and then multiplied by π (3.14).

$$Area = \pi r^2$$

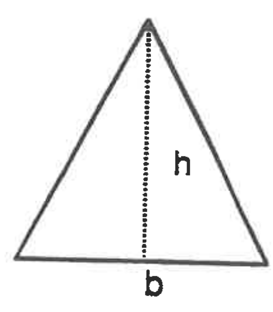
π = 3.14
r = radius (1/2 the diameter)



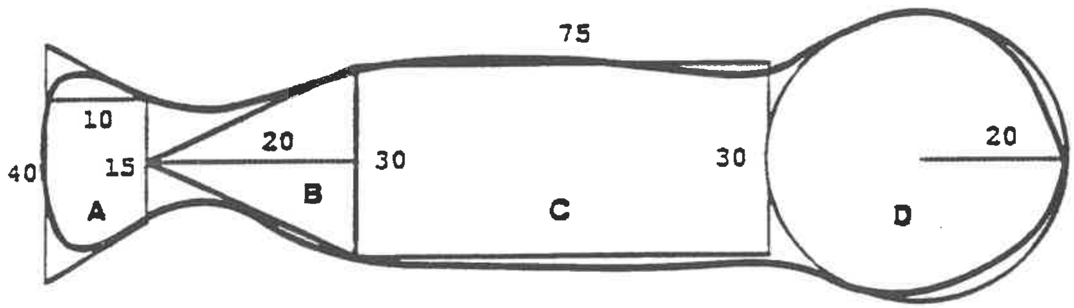
Triangle — The area of a triangle is the base multiplied by the height divided by two.

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

b = base
h = height



Therefore, for this figure with these given lengths, the area is 4081.



Trapezoid (A):

$$Area = \frac{15 + 40}{2} x\ 10 \qquad Area = 275$$

Triangle (B):

$$Area = \frac{30\ x\ 20}{2} \qquad Area = 300$$

Rectangle (C):

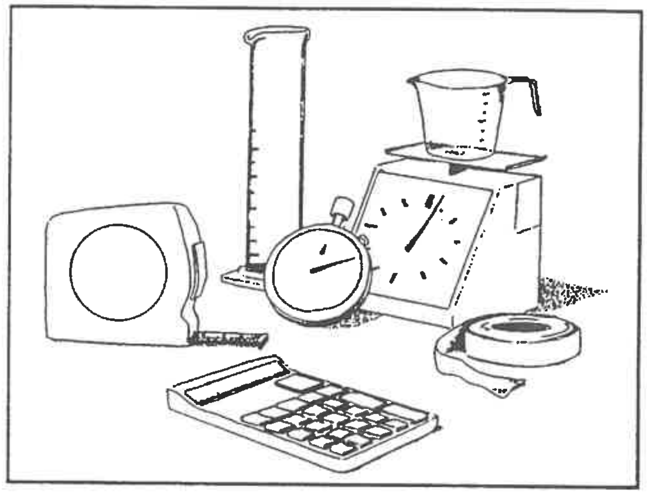
$$Area = 75\ x\ 30 \qquad Area = 2250$$

Circle (D):

$$Area = 3.14\ x\ 20^2 \qquad Area = 1256$$

(A) (B) (C) (D)
Total Area = 275 + 300 + 2250 + 1256 = 4081

CALIBRATION



The first step in calibrating equipment is to determine the amount of pesticide needed to adequately cover the target area. Determine the appropriate rate of application and mix the correct amount of pesticide and water (if using a liquid formulation), or measure out the amount of dry formulation needed to complete the job. Factors to consider when calibrating your equipment are: ground speed, sprayer pressure, nozzle size (liquid) or hole size (granular), and wear and tear on the equipment. As parts wear out, the equipment becomes misaligned. Generally, equipment is not calibrated often enough. Recalibrate your equipment: (1) any time you change pesticides or location; (2) if the equipment has not been used for a long time; (3) if the equipment has been used regularly and may be experiencing wear and tear; and (4) anytime you change parts, such as nozzles or hoses.

Calibration of four types of equipment will be discussed in this section: hand sprayers, power sprayers, air-carrier sprayers, and granular spreaders.

HAND SPRAYERS

Hand sprayers are often used to treat ornamentals or small areas of turf. The directions on many ornamental pesticide product labels say to "spray until foliage is wet" or perhaps "spray until runoff." Unfortunately, these directions are subject to each applicator's interpretation of what "wet" or "runoff" is. As discussed in chapter 6, there are spray guns available that can be set to deliver a measured amount of pesticide. However, the setting for the amount of spray to be delivered is still determined by the applicator.

For spraying small areas of turf, calibrate your sprayer for a small area, such as 1,000 square feet. It is important that a uniform walking speed be maintained during calibration and application. The amount of spray solution applied per 1,000 square feet can be determined as follows:

1) Measure and mark an area of 1,000 square feet. Use water to practice spraying the area. To obtain uniform coverage, spray the area twice, with the second application at right angles to the first. Move the sprayer extension back and forth in swaths, or in a sweeping overlapping motion. Be sure to maintain a constant nozzle height and a constant speed when moving the extension.

2) Measure out a reasonable amount of water for your sprayer. Place this water in the tank and apply to the measured area, walking at a comfortable pace and, if appropriate, pumping to maintain a constant tank pressure. Measure the amount of water remaining in the tank. The difference between the amount of water in the tank before and after application is the amount used. For example: If 3 gallons of water were initially placed in the tank and 0.5 gallon remain after application, the application rate is 2.5 gallons per 1,000 square feet.

POWER SPRAYERS

Spray pressures range from nearly 0 to over 500 psi, and application rates can vary from less than one ounce per 1000 square feet to over 100 gallons per acre. All power sprayers have several basic components: pump, tank, agitation system, flow-control assembly, and distribution system.

Three variables affect the amount of spray mixture that is applied per acre or per 1,000 sq. ft.: nozzle flow rate, ground speed of the sprayer, and effective sprayed width per nozzle. To calibrate and operate your sprayer properly, you must know how each of these variables affects sprayer output.

Nozzle Flow Rate. The flow rate through a nozzle varies with the size of the tip and the nozzle pressure. Installing a tip with a larger opening or increasing the pressure will increase the flow rate. Doubling the pressure will not double the flow rate. To double the flow rate you must increase the pressure four times. Pressure cannot be used to make major changes in application rate, but it can be used to correct minor changes.

Ground Speed. The spray application rate varies inversely with the ground speed. Doubling the ground speed of the sprayer reduces the gallons of spray applied per acre (GPA) by one-half.

Sprayed Width Per Nozzle. The spray application rate also varies inversely with the effective sprayed width per nozzle. Doubling the effective sprayed width per nozzle decreases the gallons of spray applied per acre (GPA) by one-half.

One method to determine the gallons of spray applied **per acre** (GPA) is:

$$GPA = \frac{GPM \; x \; 5,940}{MPH \; x \; W}$$

GPM = output per nozzle in gallons per minute
MPH = ground speed in miles per hour
W = effective sprayed width per nozzle in inches
5,940 = a constant to convert gallons per minute, miles per hour, and inches to gallons per acre

To determine the gallons of spray applied **per 1,000 sq. ft.**:

$$Gal./1,000 \; sq. \; ft. = \frac{GPM \; x \; 136}{MPH \; x \; W}$$

GPM = output per nozzle in gallons per minute
MPH = ground speed in miles per hour
W = effective sprayed width per nozzle in inches
136 = a constant to convert gallons per minute, miles per hour, and inches to gallons per 1,000 sq. ft.

Equipment Calibration

Check the calibration every few days, if sprayer is used daily, or when changing pesticides. Once you have learned the following calibration method, you can check application rates quickly and easily.

1) Select the spray application rate you want to use, gallons per acre (GPA) or gallons per 1,000 sq. ft. Pesticide labels recommend ranges for various types of equipment. The spray application rate is the number of gallons of carrier (water, fertilizer, etc.) and pesticide applied per treated acre or 1,000 sq. ft. If the spray application rate is given in GPA only, you may convert this to gallons per 1,000 sq. ft. using the following equation:

$$Gal./1,000 \; sq. \; ft. = \frac{gal./acre \; x \; 1,000 \; sq. \; ft.}{43,560 \; sq. \; ft.}$$

2) Select or measure an appropriate ground speed in miles per hour (MPH), according to existing terrain conditions. Do not rely upon a speedometer as an accurate measure of speed. Slippage and variation in tire sizes can result in speedometer error of 30% or more. Measure ground speed with the following equation:

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

(1 MPH = 88 feet in 60 seconds)

3) Determine the effective sprayed width per nozzle (W) in inches. For broadcast spraying, W = nozzle spacing. Nozzle spacing is often 20 inches, but may vary from 8 inches to 30 inches or more. To obtain uniform coverage, you must consider the 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.

4) Determine the flow rate required from each nozzle in gallons per minute (GPM) by using a nozzle catalog, tables, or one of the following equations:

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

GPM	=	gallons per minute of output form 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.

$$GPM = \frac{\text{gal./1,000 sq. ft.} \times MPH \times W}{136}$$

GPM	=	gallons per minute of output form each nozzle
Gal./1,000 sq. ft.	=	gallons per acre desired from step 1
MPH	=	miles per hour from step 2
W	=	inches sprayed per nozzle from step 3
136	=	a constant to convert gallons per minute, miles per hour, and inches to gallons per 1,000 sq. ft.

5) Select a nozzle that will give the flow rate determined in step 4 when the nozzle is operated within the recommended pressure range.

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

$$OPM = GPM \times 128$$

(1 gallon = 128 ounces).

> Example: The required nozzle flow rate = 0.56 GPM. What is the required OPM? OPM = 0.56 x 128 = 71.7 OPM.

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 falls within 5% 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 then recalibrate. It is important for spray nozzles to be operated within the recommended pressure range.

Replace nozzles that have an obviously different fan angle or a nonuniform appearance in spray pattern. Worn or partially plugged nozzles produce nonuniform patterns. Many nozzles are now color-coded by size. The color-coding makes it easy to determine, at a glance, if all the nozzles are the same size. Misalignment of nozzle tips is a common cause of uneven coverage. The boom must be level at all times to maintain uniform coverage. Skips, and uneven coverage, will result 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. Change the nozzles regularly—at least once per year.

8) Determine the amount of pesticide needed for the area to be sprayed and for each tankful. It is very important to **mix only the amount of pesticide you need** to complete the job. Leftover pesticide is very difficult to dispose of. Do not apply excess pesticides to the application site, as it is a violation of both federal and state law to apply more pesticide than the label allows. It is also illegal to just dump excess pesticides. Be sure to comply with federal and state laws regarding disposal of pesticides. To determine the amount of pesticide needed for the area to be sprayed and for each tankful:

A) Read the label for pesticide rate.

Example: 1 oz./1,000 sq. ft.

B) Determine the job size (the area to be treated). Refer to the area measurement section.

Example: 2,000 sq. ft.

C) Multiply: Rate x job size = amount of pesticide.

Example: 1 oz. of pesticide is required to treat 1,000 sq. ft. If 2,000 sq. ft. need to be treated, how many ounces of pesticide are required?

$$\frac{1\ oz.}{1{,}000\ sq.\ ft.} \times 2{,}000\ sq.\ ft. = 2\ oz.\ of\ pesticide$$

D) Determine total volume of tank mix (pesticide + water = total volume). The amount of water to use is generally given on the label.

Example: The label may say use 1 oz. pesticide/1,000 sq. ft. in 10 gallons of water. If you need to treat 5,000 sq. ft., 50 gallons of water and 5 oz. of pesticide would be needed.

E) Determine what volume your tank can hold. Is it large enough to hold the total volume, or only part of the total volume? If it can hold only part of the total volume, determine what fraction of the total volume it can hold, and then divide the water and the pesticide by that same fraction.

Example: A 5,000 sq. ft. area needs to be treated and you have determined you will need 50 gallons of water and 5 oz. of pesticide to treat that area. Your tank has only a 25-gallon capacity (1/2 the capacity needed), therefore, you will need to cut the volume of water and pesticide in half, and to mix one tankful at a time.

$$50 \text{ gal. of water} \times \frac{1}{2} = 25 \text{ gal. of water}$$

$$5 \text{ oz. of pesticide} \times \frac{1}{2} = 2.5 \text{ oz. of pesticide}$$

F). Add the pesticide to a partially filled tank of carrier (water, fertilizer, etc.), then add the rest of the carrier with continuous agitation to the desired level.

9) Operate the sprayer at the speed you measured and at the pressure you determined in step 7. You will be spraying at the application rate 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.

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

3) AIR-CARRIER SPRAYERS[2]

Before calibrating your air-carrier sprayer, you must first determine the travel speed in miles per hour. Load your sprayer with clear water and make a test run on the target area to determine the ground speed at which you plan to spray. Speed can be calculated by measuring the time it takes to travel any measured distance. The following formula can be used to determine travel speed:

$$Speed\ (MPH) = \frac{distance\ (feet) \times 60}{time\ (seconds) \times 88}$$

[2]The information presented in this section has been taken directly from *The Calibration of Air-carrier Sprayers* by Stephen L. Pearson and Loren E. Bode. Published by the Agricultural Engineering Department, University of Illinois, Urbana. Manual M444-7.

To calibrate your air-carrier sprayer:

1) Calculate the total gallons per minute (GPM) required per side:

$$GPM\ (per\ side) = \frac{GPA \times MPH \times W}{1{,}000}$$

GPM	=	gallons per minute (per side)
GPA	=	gallons per acre
MPH	=	miles per hour traveled
W	=	spacing between rows of trees in feet.

2) Divide the total gallons per minute per side into proportional parts.

3) Select the correct nozzle type, size, and operating pressure. Air-blast sprayers normally use disc-core-type cone spray tips. A spraying pressure range must be selected for the type of spraying being done, and the range selected should take into consideration the limits of the spraying equipment.

4) Install the disc-core nozzles into proper outlets. Inspect all nozzles and outlets for foreign material, and determine whether the sprayer is operating correctly or not. Your sprayer tank should have a sight gauge with graduated markings.

5) Measure the total GPM from all the nozzles selected in step 4. Fill the sprayer tank with water to a graduated mark on the sight gauge. It should be at least half full. Prime the sprayer system and check all the nozzles to make sure none are clogged or partially clogged. Record the exact amount of water in the spray tank. Bring the sprayer up to the desired pressure and turn the nozzles on. Use a stopwatch to record the amount of time the sprayer is running. The sprayer should be operated for at least 3 minutes.

> Example: The spray tank was filled to the 200-gallon level. It was predetermined that the nozzles selected would give a total gallons-per-minute output of 8. The sprayer was operated for 5 minutes at 150 psi on the gauge. After the 5 minutes, the sight gauge was read and found to be at a level of 170 gallons.
>
> Solution: The actual output was 200 gal. (start) - 170 gal. (stop) = 30 gal. per 5 min. or 6 GPM. The calculated output, however, was 8 GPM. When the difference between actual output amount and the calculated

output is small, adjustments can be made by changing the pressure. When the difference is large, change the nozzle sizes.

Repeat these calibration procedures whenever changes are made in the speed, gallons per acre, or nozzle spacing. Periodically, check the output from the nozzles during the spraying season. Remember, the effectiveness of the spray material is directly dependent on your skill as an operator.

GRANULAR SPREADERS

Because of the large number of variables affecting delivery rate, it is strongly recommended that all granular 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 many factors can contribute to significant rate variations. A label setting should be used only as the initial setting for verification trials by the operator prior to large-scale use.

It is suggested that calibration 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 when 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 put a weighed amount of product in the spreader, make an application to a measured area, preferably at least 1,000 square feet for a drop spreader and at least 5,000 sq. ft. for a rotary, and then weigh the product remaining in the spreader to determine the rate actually delivered.

If you prefer not to apply the pesticide to an area during a verification trial, a similar procedure can be followed in which a plastic tarp is placed on the ground. An application is made on top of the tarp. The granules are then collected from the tarp and weighed. No pesticide remains on the area. To calculate the rate of application, first determine the area of the tarp treated (length x width = area in sq. ft. of a rectangle). Divide the amount of pesticide applied (in pounds) by the area of the tarp (in square feet) and multiply by 1,000 to get an answer in lbs./1,000 sq. ft., or by 43,560 for an answer in lbs./acre. Make adjustments either to the walking rate or the spreader to coincide with the label rate.

With rotary spreaders, it is necessary to check and correct the distribution pattern. Again, the product label may give a recommended setting and width, but the applicator should verify the setting and width before treating a large amount of turf. 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 direction of travel. Boxes 1 to 2 inches high, with an area of about 1 square foot, spaced on 1 foot centers are good for commercial, push-types rotaries. The row of boxes should cover 1-1/2 to 2 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 3 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. A simpler procedure, however, is to pour the material from 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 1/2 the average rate at the center. For example, if the center 3 to 4 bottles have material 2 inches deep, and the bottles from the 6-foot positions (6 feet left of the spreader centerline and 6 feet right of the spreader center-line) have material 1 inch deep, the effective swath width is 12 feet.

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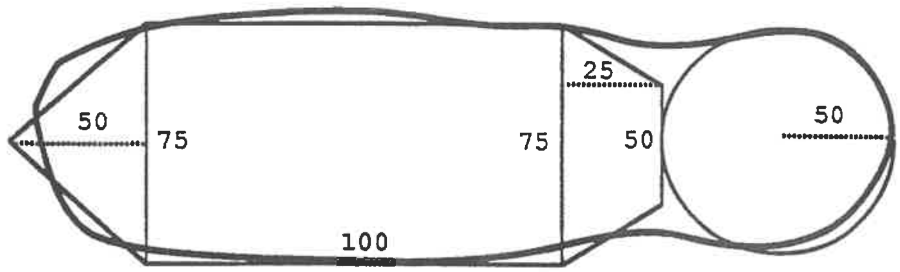
SAMPLE TEST

QUESTIONS

1. Calculate the area of the following:



2. When calibrating equipment, the first step is to determine the amount of pesticide needed to adequately cover the target area. True or False?

3. Recalibrate your equipment
   a. anytime you change pesticides or location
   b. if the equipment has not been used for a long time
   c. if the equipment has been used regularly and may be experiencing wear and tear
   d. anytime you change parts, such as nozzles or hoses
   e. anytime you change direction

   A. a only.
   B. a, d, and e.
   C. a, b, c, and d.
   D. all of the above

4. When using power sprayers, three variables affect the amount of spray mixture that is applied per acre or per 1,000 sq. ft. They are ________________, ________________, and ________________.

5. Because of the large number of variables affecting delivery rate, it is strongly recommended that all granular spreaders be calibrated for proper delivery rate with the specific __________ and __________ to be used.

ANSWERS

1. 18,787.5 2. true 3. C 4. nozzle flow rate, ground speed, sprayed width per nozzle
5. operator, product

CHAPTER 8 INDOOR PEST CONTROL[1]

INTRODUCTION

Living plants are commonly used in indoor settings, primarily for aesthetic purposes. Businesses such as restaurants, shopping malls, and office buildings use plants to make the indoor environment more pleasing for customers and employees. Indoor plants are susceptible to attack by many kinds of pests. In addition, many indoor plants are often under great stress due to such conditions as suboptimal light, water, and temperature. Many plants are struggling to stay alive, and experience little growth.

Often these plants are subjected to mistreatment, such as having coffee, soda pop or cleaning liquids poured on them, or cigarettes crushed out on them. Under these stressful conditions plants are more susceptible to pest attack, and less capable of recovering from the effects of a pest attack. Treatment methods are often very constraining. Pest control on ornamental interiorscapes in public areas is a highly sensitive issue. Since the public has access to these plantings, pest control measures must be safe for all ages of humans and for the plants themselves. One way of making pest control safer in these public areas is to limit pesticide applications and/or use beneficials (natural enemies of the target pests). Use of beneficials, while generally considered safer than use of pesticides, may also be

[1]Much of the information in this chapter has been taken directly from *Interior Landscape Pest Control* by M.L. Albrecht and D.K. Kuhlman, 1991. This publication is the 3C subcategory training manual for the state of Kansas.

viewed negatively by the public, since these beneficials themselves may be perceived as pests in a public indoor area.

A complicating factor for pest management in the interiorscape is that most of the plants used have at one time passed through a greenhouse in which pesticides were used extensively. Consequently, some interiorscape plants may be infested with pests that are potentially resistant to pesticides. Therefore, pest management in interiorscapes may be more labor-intensive, because the selection of pesticides is limited to those labeled for interiorscape use and effective for pesticide-resistant pests.

An applicator must be aware of these added constraints when working in interiorscapes. Additional effort may be needed to care for these indoor plants without adverse effects to the public.

PLANT MANAGEMENT

When managing indoor plants and the pests associated with them, factors affecting the foliage of the plant and factors affecting the roots of the plant can be placed into separate categories. Concern for foliage and roots is necessary to ensure healthy indoor plants.

FOLIAGE

Light

Although more severe pest problems occur under the high-light, long-day conditions associated with greenhouses or outdoor areas where the plants are grown, pests do quite well in the lower light conditions indoors—especially on stressed plants.

Most plants easily acclimate to varying light conditions, provided these conditions do not vary widely from day to day. Proper acclimatization will help ensure successful pest control. It may be necessary to move the plants, over a period of several months, from a high-light situation to a low-light situation. Another option is to purchase acclimatized plants. Although some plants are said not to need this acclimatizing process, it is a good general principle to follow.

Improper acclimatization may produce symptoms that are easily confused with a pest attack. For example, *Ficus benjamina* will promptly yellow and drop its leaves if it is moved abruptly from a high-light to low-light situation.

Temperature

Most plants used indoors are tropical plants, generally not found in areas where cool nights are common. While cooler nights are generally desirable, for tropical plants nighttime temperatures should not be below 50° to 55° F.

Temperature fluctuations can damage foliage plants. The heat or air-conditioning is turned off on weekends in many commercial interiorscapes, making the environment either colder or warmer over the weekend than on weekdays. Other temperature-varying situations to be aware of are hot or cold drafts from doors, windows, or heating ducts.

Relative Humidity

While low humidity is a common problem in many interiorscapes during the winter, it can be a problem at other times of the year, too. Low humidity produces problems with the maintenance of indoor plants. Air-conditioning, in the summer, will also reduce interior relative humidity, which also adversely affects plants. Low humidity is especially harmful to plants exposed to direct sunlight for a few hours during the day. The incoming sunlight raises the leaf temperature, requiring rapid transpiration to cool the leaf. If the growing medium is kept slightly dry, which is common in interiorscapes, the plant leaves will dry out and scorch or turn yellow. Spider mites may then become a problem.

Temperature and humidity affect some pests directly. Spider mites, for example, survive best in warm, dry conditions where dust accumulates. There is evidence that drought-stressed plants are more favorable for spider mite development. Powdery mildews flourish when foliage is subjected to daily temperature fluctuations. Thus, anything that can be done to stabilize the foliage environment and to manage plant stress will help keep many pest and disease problems from becoming too severe.

ROOTS

The root system environment of a specific plant is key to its health management. Most root-rotting fungi are more active on damaged roots. In fact, many of the root pathogens are termed "secondary" or "weakly pathogenic" because they cannot infect a truly stress-free (healthy) system.

Two factors affect the root system environment: physical makeup and nutrition. Parameters of a good physical root environment have not been established.

However, many plants do well in soil with a pH of 5.5 to 6.5. Other plants have different requirements, so you need to know what pH is required by your plants. Other generalities for a good root environment include using a soil (or growing medium) that contains amendments providing a high degree of aeration (about 20% air-filled pore space) and a water-holding capacity of about 40% of its weight, (10 pounds of soil with 4 pounds (4 pints) of water added equals 40% moisture content). These parameters are measured relatively easily, and most people working in interiorscapes have adopted routine measurement procedures.

In order for interior plants to remain healthy, a small amount of growth is necessary. Under low-light conditions, growth may be induced by fertilizers. When fertilizing, use a well-balanced fertilizer that contains trace elements. For best results, make most fertilizer applications during the summer, when light levels are at their maximum. To counter low-light situations use low-light fertilizers, which have high amounts of potassium. These high-potassium fertilizers compensate for lack of light and keep plants healthy by encouraging a small amount of growth.

Leach irrigations, which remove salts, should be carried out frequently, if not at every watering. Unless irrigation water is drenched completely through the growing medium in the container or bed, there is a high probability that salts will build up to toxic levels. While salt damage generally shows up on foliage first, it can also occur on roots. Salt-damaged roots are especially susceptible to root rot infections, especially with medium that is allowed to dry excessively between waterings. The medium may be difficult to rewet and water will channel down a portion of the soil-root mass, failing to wet it thoroughly and uniformly. To help solve this channeling problem, use a small amount of light soap or wetting agent when watering.

It is important that anyone working in interiorscape situations realize that it is possible to acclimatize plants so that they will tolerate being grown with less frequent irrigations. This can be handled like the light-acclimatization procedures mentioned previously. Some plants seem to be naturally adapted to dry situations, and these plants are popular in interiorscapes. Excessively dry plants may lead to spider mite population increases, or soluble-salt damage to the roots.

Water that drains in the saucer under a plant should be removed after each irrigation. Use a siphon system to remove water from the bottom of containers and beds that do not provide drainage. Potting medium that compacts and settles excessively over time will eventually become prone to overwatering

Table 1. A general diagnostic guide for indoor plants.[2]

Symptom		Possible Causes
Brown or scorched leaf tips.	1.	Poor root health from overwatering, excessive soil dryness (especially between watering), excessive fertilizer, or other soluble salts in the growing medium.
	2.	Specific nutrient toxicities (such as fluoride, copper, or boron).
	3.	Low humidity.
	4.	Pesticide or mechanical injury.
Leaf spots, blotches, blemishes, blisters, or scabby spots.	1.	Intense light (sunburn) associated with a recent move of the plant or excessive medium dryness and wilting.
	2.	Chilling injury (below 50° F).
	3.	Chemical spray injury.
	4.	Overwatering.
	5.	Fungal or bacterial infections (rare unless plants have recently come from a field or greenhouse).
Foliage yellow-green: older leaves.	1.	Insufficient fertilizer, especially nitrogen.
	2.	Poor root health due to pot-bound growth, compacted soil, or poor drainage.
	3.	Insufficient light.
Foliage yellow-green: newer leaves.	1.	Soil pH (acidity) imbalance.
	2.	Trace element imbalance.

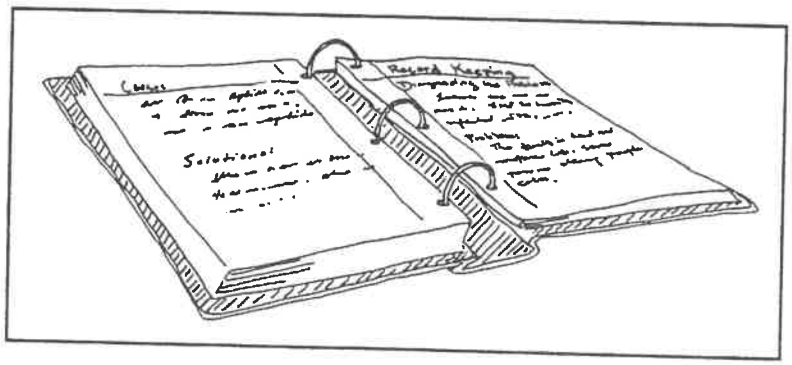
[2]Table 1 is taken directly from the Kansas State University Cooperative Extension Service publication *Interior Landscape Pest Control* by M.L. Albrecht and D.K. Kuhlman, 1991.

Foliage yellow-green: general.	1.	Too much light.
	2.	Insufficient fertilization.
	3.	High temperatures, especially when associated with dryness.
	4.	Insect infestation or root rot disease.
Leaf drop.	1.	Poor root health from overwatering, excessive dryness, excessive fertilizer, or other soluble salts in the medium, compacted medium, or pot-bound roots.
	2.	Sudden change in light, temperature, or relative humidity.
	3.	Root rot disease.
Wilting or drooping of foliage.	1.	Poor root health from overwatering, excessive dryness, excessive fertilizer, or other soluble salts in the medium, compacted medium, or a poorly drained container.
	2.	A toxic chemical (e.g., alcoholic beverage, cleaning solutions) poured into medium.
Roots brown in color, soft or rotted; roots with tissue that can easily be "slipped off," leaving behind the string-like center tissues; roots massed at top or bottom of pot. Associated with one or more of the symptoms noted above.	1.	Poor root health from overwatering, excessive dryness, excessive fertilizer or other soluble salt in the medium, compacted medium, or a poorly drained container.
	2.	A toxic chemical poured into medium.
	3.	Over- or underwatering.
	4.	Root rot disease.
Yellowed leaves with tiny speckling; leaves later bronzed and drying; webbing noted near growing points.	1.	Spider mite infestation.

Leaves covered with a sticky substance; mold growing on leaves; tiny brown or white objects seen on leaves or in crotches of branches; leaf drop or branch dieback; leaf or growing-point distortion.	1.	Scale or mealybug infestation.

3. PLANNING SOLUTIONS

Once you have perceived there is a problem and have determined the cause of the problem, you must plan a solution. You may decide to take steps to prevent, cure, or control the problem, or you may decide the problem is not severe and take no action.



If you decide from past experience that the environment in your interiorscape is providing an ideal situation for a certain pest attack, you may choose to take preventive action, such as changing that environment, applying pesticides that will protect the plants from the inevitable pest attack, or changing the type of plant. It is not uncommon for plant managers to remove plants from an interiorscape and replace them with other plants.

An integrated pest management (IPM) program utilizes all available control measures to reduce a pest population to one you can live with. Often pesticides must be applied in order to cure the plant of its problem or to control the pest. Some mechanical or cultural practices, such as changing the physical environment, or disposing of litter or other material that may harbor pests, may be employed to control the pest. Changes in watering or fertilization regimes may increase plant vigor and help cure the plant of its ailment. Some managers rotate their smaller, potted plants through a greenhouse to allow the plants to return to good health.

You might decide to take no action after you determine the pest is not a serious threat, or when the curative action could possibly cause more problems than the current one. Sometimes a pest may be causing extensive damage, but there are no practical methods of control during this particular stage of the pest's development. No action might be best until the pest is in a vulnerable stage.

The final step in planning a solution is to monitor the plant and determine how it is responding to treatment (or lack of treatment). If the plant is not responding as expected, you may need to change your action strategies; or perhaps you misdiagnosed the problem and you need to change your perception of the problem and redetermine the cause of the problem.

COMMON DISEASES

Infectious diseases are caused by pathogens that grow within plant tissue, causing disruptions of normal physiological functions. Once an infectious disease sets in, the process is continuous until the pathogen is removed or suppressed, environmental conditions no longer favor the pathogen's development, or the host dies. Pathogens can, and often do, spread to nearby plants. It is often difficult to identify pathogens due to their small size. However, the many foliar leaf spots and blights that occur on plants outdoors or in greenhouses are not usually a problem in interiorscapes because of the lack of damp air and splashing water.

FUNGI

Fungi cause more plant diseases than any other type of infectious agent. Fungi obtain all their food from living and/or dead plant and animal material. Many fungi grow as fine, threadlike filaments (hyphae). These hyphae can penetrate plant surfaces even when there is no natural opening or damaged surfaces. Fungi usually grow in circular lesions that may overlap, giving a blotchy appearance, and often in concentric rings that look like bull's-eyes.

Most fungi produce a multitude of spores that function like plant seeds. Spores may be dispersed by wind, water, pruning or other tools, insects, and other animals (including humans), or they remain dormant in the soil for an extended time period. Each spore can start a new infection. Usually, individual hyphae and spores can only be seen with the aid of a microscope. Some fungi, however, develop into masses of hyphae (mycelia) or aggregations of spores, which may be visible to the naked eye.

Examples of fungal diseases include leaf spots and root rots. Leaf spots usually appear first on the lower leaves, often as dark brown, pinhead-sized spots that sometimes have a yellow halo. Spots may enlarge to cover an entire leaf. Wet conditions are usually necessary for infection. Root rots associated with the fungi *Phytophthora* and *Pythium*, cause roots to become soft, mushy, collapsed, or hollow. Eventually, the roots die. Low soil temperature, low light intensity, poor air circulation, and overcrowded plants are conditions conducive to the establishment of these fungi. Fungal diseases are often difficult to control once they are established.

BACTERIA

Bacteria obtain their food from plants. Bacteria grow by cell division, and lack a physical form that allows them to firmly anchor themselves to plant surfaces. Bacteria usually require some type of opening, either natural or due to damage, in the plant surface to enter a host.

Much smaller than fungi, and visible only through a microscope, bacteria often appear as oily, greasy, or water-soaked spots on leaves. One common sign of many bacterial diseases is the oozing of a viscous, slimy mass from infected tissues. The two types of bacterial disease are systemic and localized.

Systemic bacterial disease. 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. The bacteria are spread by splashing water, and by contaminated hands and pruning tools.

Chemical sprays may not be effective if the pathogens occur throughout the plant, including deep within its tissues. Picking off or incomplete pruning of blighted or rotted areas on plants may result in contamination of hands or pruning tools. The organisms are most active under warm, damp conditions on soft tissues in heavily fertilized plants.

Systemic bacterial diseases can sometimes be controlled in interiorscapes through a combination of sparse watering and low fertilization. The cooler temperatures of many interioscapes may keep bacteria from proliferating and causing much leaf yellowing and wilting. Splashing water must be avoided when trying to control bacterial diseases.

Localized bacterial diseases. Species of *Pseudomonas* and *Xanthomonas* bacteria cause leaf spots or leaf blights on many interiorscape plants. These diseases are characterized by dark green, water-soaked spots that may turn tan, dark brown, or black with a yellow border. The spots can enlarge until the entire leaf blade is involved. Sometimes these lesions spread into the petioles and stems, and may look virtually identical to the systemic bacterial diseases mentioned previously.

Control of localized bacterial diseases generally involves prompt removal of infected plant parts. Fixed-copper sprays plus zinc can be used, but an unsightly residue remains on the leaves. At the present time, there are no fixed-copper sprays registered for use on indoor plants, unless the plants are taken outdoors for treatment.

VIRUSES

Viruses are systemic pathogens that live and multiply only within living cells of the host. Viruses cannot penetrate an intact host, and must be introduced into plants through an opening caused by injury, pruning, or grafting. They may also be spread by sucking insects such as aphids or leafhoppers. Viruses are generally too small to be seen even by a light microscope and so are usually identified by characteristic symptoms that they cause in plants. Symptoms are diverse, depending on the virus, and include a yellowish or light green, ringed pattern on foliage, vein banding, mosaic, flecking, yellow blotching, growth abnormalities, and stunting of plants.

There are no means of treating viral diseases on plants used in interiorscapes. If the plant is badly infected, it will need to be replaced. Spread of viruses from one plant to another is not likely to occur in the interiorscape unless plants are contaminated when handled. Most viruses are specific to only a few types of plants, so it is unlikely a virus will spread from one plant type to another.

NEMATODES

Nematodes are microscopic roundworms that may attack any part of a plant host, depending on the species of nematode involved. Nematodes possess stylets (hollow, sharp tubes), which they insert into plant cells for feeding. Eggs are most frequently laid in plant tissue.

Good sanitation is the primary means of controlling these pathogens. Pasteurizing the growing medium prior to planting will kill adults as well as eggs of root nematodes. Fumigants are as effective as steam for this purpose.

However, be aware that fumigants are not registered for interior use. Fumigation of growing medium can only occur prior to bringing the medium into the interiorscape. Most nematode problems are encountered when soil is a growing medium component. If planting beds have medium in contact with native soil, the native soil needs to be examined for nematode contamination and possible treatment. Be sure your plants are free of nematodes before placing them in the interiorscape. Some pesticides may help control nematodes. A product is available that acts as a biological control agent. It is a chitin-protein material from crustacean skeletons. It stimulates the growth of normal soil microorganism (e.g., fungi, bacteria) that produce chitinase and destroy nematodes and their eggs.

MITES AND INSECTS

Most pest problems on interiorscape plants originate because the plants were not grown in an indoor environment. Once introduced to the interiorscape, many insects and mites will thrive, and spread to other plants. The key to controlling insects and mites is to remedy the situation before "permanent" installation of the plants. There is much greater flexibility in control procedures (chemicals, application methods, etc.) in a greenhouse or even an acclimatization room than in the interiorscape.

Early detection and diagnosis of the problem cannot be overemphasized. This is the key to controlling nearly all pests before significant plant injury or control expenses occur. Pesticides and/or natural enemies will control most insects and mites, if correct procedures are followed.

MITES

Several mite species attack plants indoors, often causing severe injury.

Two-spotted spider mites. The most common mite is the two-spotted spider mite. Spider mites have a wide host range, and very few plants are immune to attack. Adult spider mites are about 1/50 inch long and are usually found on lower leaf surfaces. Feeding injury on many plant species involves light-colored, speckled or mottled areas on leaves. Webbing is also produced. Severe spider mite infestations cause leaves to dry and fall from the plant. At 75° F, about two weeks are required for mites to develop from egg to adult.

Broad mites and cyclamen mites. Other mites, including the broad mite and cyclamen mite, can also cause problems. Because these mites are about 1/100 inch long, infestations are recognized by plant injury symptoms, rather than by seeing the mites. Most feeding injury occurs on young foliage, where injury is characterized by thickened and brittle foliage, with leaf margins cupped downward and stunted. Many of these symptoms are characteristic of injury by pesticides, so infestations can go unnoticed for long periods of time. Since these mites are attracted to dusty conditions, removing dust from the plants with soapy water (which will also remove the mites) will help discourage their presence.

INSECTS

Many insects cause injury to plants indoors.

Mealybugs. Mealybugs are very common and are difficult to control. There are several species of mealybugs found on plants indoors, including some that feed on plant roots. One of the most common species is the citrus mealybug, *Planococcus citri*. All foliar-feeding mealybug species have sucking mouthparts that remove plant fluids. A sticky honeydew is excreted, which coats foliage below the infested area, attracts ants, and promotes black sooty mold growth. Damage results in stunted plant growth or death of the plant. Each female may produce several hundred eggs. The egg-to-adult cycle is 6 to 8 weeks. Moving infested plant material into the interiorscape is virtually the only way mealybugs become established.

Scale insects. Several species of scale insects infest plants indoors, arriving on previously infested plants. One of the most common species is the soft brown scale. Scales are sap-sucking insects, which, like mealybugs, excrete honeydew. Females produce up to 1,000 eggs underneath their protective shell or "scale." The eggs hatch into tiny crawlers, which spread about the plant. After dispersing, crawlers settle and feed in one location for the remainder of their lives. The length of the life cycle varies with each species, ranging from 1 to 8 or more generations per year. Scale damage reduces plant vigor. The honeydew attracts ants and promotes the growth of a black, sooty mold.

Aphids. Aphids also have piercing-sucking mouthparts and produce honeydew. They are soft-bodied, somewhat pear-shaped insects. Indoors all aphids are female, reproduce year round, and multiply rapidly. Each mature female may produce up to 50 daughters that, in turn, will begin reproducing in 7 to 10 days. Aphid infestations often are evident by the white cast skins that are shed by the aphids when molting. Aphids reduce plant vigor and distort leaves. The honeydew attracts ants and promotes the growth of a black, sooty mold.

White flies. White flies have piercing-sucking mouthparts with which they suck juices from the plants. They excrete large quantities of honeydew. White flies, especially the greenhouse white fly, *Trialeurodes vaporariorum*, are common pests of many ornamental plants. Indoors, white flies are most likely to be found on poinsettia, fuchsia, chrysanthemum, or other flowering plants brought into the location for color. All white fly life stages develop on undersides of leaves, but the adult is usually found on the upper leaves. The egg-to-adult cycle takes 21 to 36 or more days, depending on temperature.

Thrips. Thrips cause problems indoors on both foliage and flowers. Thrips are small, slender insects less than 1/8 inch long. Thrips feed by rasping plant tissues with their mouthparts and consuming plant fluids. Heavily infested areas on leaves appear silvery gray, with lighter infestations showing up as small whitish-colored areas.

Black dots of excrement also are present. Eggs are laid on or in plant tissues. The egg-to-adult cycle takes 18 to 21 days. Some species of thrips leave the plant and transform to the adult in the growing medium. Thrips are difficult to control indoors. Few insecticides are registered for use on plants indoors that provide effective control, unless the plants are moved to a greenhouse or outdoors prior to treatment.

Fungus gnats. Fungus gnats are small, dark gray or black flies that resemble midges or mosquitoes. Presence of fungus gnats may indicate an overly wet situation. The flies often get trapped in the moisture on leaf surfaces, which detracts from the plant's appearance. Decreased aesthetic value is the greatest damage done by adult fungus gnats; however, the larvae also damage plants by feeding on decaying or healthy organic matter (including roots) and fungi. Fungus gnats have increased in importance recently because of the prevalence of soilless mixes in the plant industry. Some of these growing media, especially those that contain peat moss, apparently are excellent for survival of the insects.

Shore flies. Shore flies resemble fruit flies, except they are black. The larvae feed on green algae, which often grows in wet areas and nutrient-rich locations.

BIOLOGICAL CONTROLS FOR MITES AND INSECTS

Many interiorscape situations offer opportunities for using alternative pest management procedures. Biological controls involve using parasites, predators, or pathogens to suppress pests. Usually, these biological control agents need to be introduced into the area to become established and some may need reintroduction on a relatively frequent basis. A number of predators and parasites are available. Among the most widely available are

> *Phytoseiulus persimilis*, a mite predator of two-spotted spider mites that normally develops twice as fast as its prey, and so is able to reduce a population of spider mites rapidly (4 to 6 weeks) for a biological control agent;
>
> *Cryptolaemum montrouzieri*, a ladybug beetle predator of mealybugs;
>
> *Leptomastix dactylopii*, a tiny, parasitic wasp whose developinf larva prey on immature and adult citrus mealybugs;
>
> *Encarsia formosa*, a small, parasitic wasp that has been used for many years to control white flies;
>
> *Chrysopa carnea*, a green lacewing that feeds on soft-bodied insects, especially aphids.

CHEMICAL CONTROL

CHOOSING CHEMICALS

Before applying pesticides, identify the pest you are trying to control and determine which pesticide is effective in controlling that pest. Also determine if the pesticide can be used on the target plant(s). Always choose the least toxic substance that can effectively control the pest, and never apply higher concentrations of pesticide than instructed on the label. Applying higher concentrations is illegal and may be harmful to you, the plants, and anyone else in the area. Always read the label before mixing a pesticide, again before applying the pesticide, and once again after application for cleaning and storage instructions. Be certain the chosen pesticide is labeled for use in interiorscapes. If the label does not specifically state that the pesticide may be used indoors or for interiorscapes, use a different pesticide. Be aware that many of the pesticides registered for use in greenhouses are not allowed for use in indoor public areas.

TIMING AND COVERAGE

You can use the best and most expensive pesticides in the world, but if they are not applied thoroughly and at the proper time and rate, poor results can be expected. For optimum performance, a pesticide must be applied at the proper rate and uniformly on the upper and lower surfaces of the plant foliage. Pesticide should be applied during the life stage that the pest is most susceptible to the pesticide. Applications must be repeated as frequently as necessary to keep a pest or pathogen population at a low level.

Another aspect of timing, especially critical for applicators spraying in an interiorscape, is consideration of public exposure to the pesticide. To keep public exposure to a minimum, apply pesticides after normal work hours, or when a minimum of other people are around, or when the treatment area can be partitioned off or otherwise isolated from people. Always use the least toxic material for treating interiorscapes accessible to the public.

PESTICIDE FORMULATIONS AND COMPATIBILITIES

Pesticides are often available in several different formulations, each of which has advantages and disadvantages.

Granules (G) may be applied to the soil surface or buried beneath it, to control soil pests or contain a systemic pesticide that is taken up by plants.

Wettable powders (WP) give uniform, long-lasting residues which may be unsightly on leaves of plants used indoors. Wettable powders generally are less likely to injure plants than emulsifiable concentrates.

Emulsifiable concentrates (EC) are liquid products made by dissolving the active ingredient in organic solvents. Emulsifiable concentrates often cause plant injury because of these solvents. Do not use EC formulations on ferns.

Flowables (F) are essentially suspensions of insoluble pesticide that generally give more even coverage than WP formulations and cause less phytotoxicity than ECs.

If you desire to mix two or more pesticides for a single spray application, you must check on possible compatibility problems. In general, when using a wettable powder, mix only other wettable powders with it. Even this may not be safe. Because of excess solvent, never use more than one EC in any mixture. Be sure to check all labels for restrictions and warnings.

Before using any pesticide or combination of pesticides on a plant for the first time, it is best to treat a few plants and wait three to four days for any phytotoxic effects to appear.

USING SPRAY ADJUVANTS

An adjuvant is a material added to a substance that increases the effectiveness of that substance. Many kinds of adjuvants are used with pesticides. Some adjuvants, called stickers or spreaders, increase the adherence of material to leaf surfaces. Other adjuvants, often called activators, increase the systemic uptake of the chemical. Still other adjuvants reduce drift, serve as antifoaming agents, wet the leaf well so that pesticides spread over leaf surfaces, and serve various other functions.

The most commonly used adjuvants are sticker/spreaders, which have two functions. First, they wet the leaf, creating a good barrier of pesticide over the leaf and other plant surfaces. Second, they make the pesticide stick to the surface and resist weathering. Fungicides generally work as preventives on leaf surfaces. Thus, spreading and sticking enhance the activity of the fungicide.

If used incorrectly, adjuvants can change the chemistry of a pesticide mixture to such a degree that they can contribute to plant damage, and in a high concentration, can burn plant material directly. You may wish to check a new spray additive on a small number of plants before spraying a large number of plants. Indoor plants may be more sensitive to adjuvants than landscape plants outdoors. In order to minimize the chances of damaging the plant, use only the amount needed to wet the foliage sufficiently.

Some manufactured pesticide formulations already contain sufficient sticker/spreader. The formulations most likely to contain these adjuvants are emulsifiable or liquid products. Therefore, added adjuvants are more commonly used only with wettable powder pesticides. Often, the pesticide label information will provide adjuvant suggestions. Be careful not to add too much adjuvant. Most of the pesticide phytotoxicity problems on ornamentals result from excessive use of spray adjuvants.

PESTICIDE SAFETY

The decision to use pesticides in an interiorscape should be carefully thought out. Generally, there is a greater risk of danger to the applicator when applying pesticides indoors than outdoors. There is a potential danger to the public. Be sure there are no harmful residues on the plants or in the air, before allowing the public into an area that has been treated with pesticides. Be especially cautious if children will be present in the area.

There is also a risk of damage to furnishings of the indoor site. Some pesticide ingredients used to dissolve pesticides may cause permanent damage to indoor furnishings. Staining, blistering, or other damage may occur on wood products and paints, and fabrics may be stained. Consider covering all surfaces which may be contacted by the pesticide. If possible, plants should be moved from areas where contamination or damage may occur, to an area where such risks are minimized. Pesticide application in restaurants, bakeries, or other food handling areas must be done with extreme care so that food or utensils are not contaminated. Be sure all food handling areas are thoroughly cleaned following pesticide application.

Be sure to read the pesticide label carefully, and to follow any precautionary statements. The most important consideration is the safety of humans of all ages who may frequent the area being treated. Store pesticides in original containers away from heat and moisture, and in a locked area to protect anyone not certified to handle pesticides. Dispose of unwanted pesticides and empty containers properly.

LEGAL REQUIREMENTS

As with pesticides used outdoors or in greenhouses, the law requires that a material safety data sheet (MSDS) for each pesticide used be available to all persons that work with or around pesticides. The MSDS provides information about the pesticide, handling and storage instructions, emergency medical treatment information, personal protective clothing requirements for applying the pesticide, as well as other important information.

Just as there are right-to-know laws that ensure your right to be fully informed about the pesticides you are handling, there are laws which also ensure this right to your clients, or to other people in the vicinity where you will be applying pesticides. Never apply pesticides without first informing these people. The Associated Landscape Contractors of America suggests following these nine steps when informing a client about applying pesticides:

1. Be calm and professional, to avoid alarming the client.
2. Be sensitive to the client's natural worries about pesticide use.
3. Let the client know precisely what you need to do to rid the plants of pests.
4. Anticipate that the client will have many questions, and be prepared to answer them as simply and directly as you can.
5. Let the client know that you understand and share his/her concerns.
6. Assure the client that the pesticide is registered for interior use.
7. State that you are using the least hazardous product on the market to get the job done.
8. Remind the client that treatment for disease and insects is included in the client's service contract.
9. Minimize the client's anxiety by emphasizing you will treat the plants in a separate location (if possible) and/or after normal working hours.

It is very important that you communicate with your client and/or personnel who work near the plants being treated.

REFERENCES AND ADDITIONAL INFORMATION

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Cutten, Geoff. 1988. *Indoor Plant Maintenance*. Hazardous Contaminants Coordination Branch, Ministry of the Environment, Ontario. 46 pp.

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SAMPLE TEST

QUESTIONS

1. One way of making pest control safer in indoor public areas is to limit pesticide applications and/or use beneficials. True or False?

2. People working in interiorscapes must be able to quickly identify the causes of plant problems. Diagnosis consists of three general steps: ________________, ________________, and ________________.

Use the following terms to answer questions 3 to 6. Use each of the terms only once: virus, nematodes, bacteria, fungi.

3. Most ____________ produce a multitude of spores that function like plant seeds.

4. ____________ often appear as oily, greasy, or water-soaked spots on leaves.

5. ____________ are systemic pathogens that live and multiply only within living cells of a host.

6. ____________ are microscopic roundworms.

7. Most pest problems on interiorscape plants originate because the plants were not grown in an indoor environment. True or False?

8. A pesticide label must specifically state that the pesticide may be used indoors or for interiorscapes. True or False?

9. Generally, there is no greater risk of danger to the applicator when applying pesticides indoors than outdoors. True or False?

10. There is a potential danger to the public when applying pesticides indoors. True or False?

ANSWERS

1. true 2. perceiving problems, determining causes, planning solutions 3. fungi
4. bacteria 5. viruses 6. nematodes 7. true 8. true 9. false 10. true

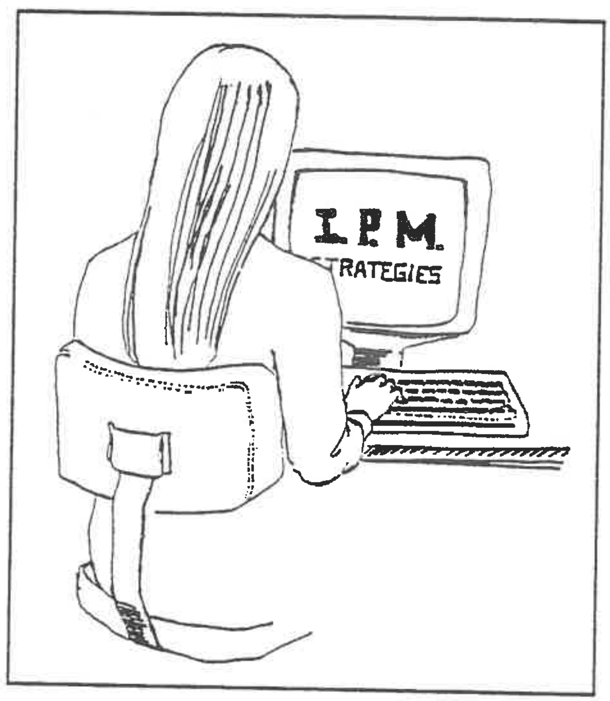
CHAPTER 9 PEST CONTROL IN GREENHOUSES

THE GREENHOUSE ENVIRONMENT

Greenhouses are closed systems in which intensive cultivation takes place. The greenhouse environment can be characterized as warm, humid, and with limited air movement. Temperature variations are slight, and relative humidity is generally 60% to 90%. Crop growth is generally rapid and lush. This protected environment not only provides favorable conditions for plants, but unfortunately, also for pests.

Plants grown in a greenhouse usually have a high commercial value, which even small blemishes may reduce. Any pest that invades the greenhouse can quickly become a major problem. For these reasons, it is essential to have effective pest control.

INTEGRATED PEST MANAGEMENT (IPM)



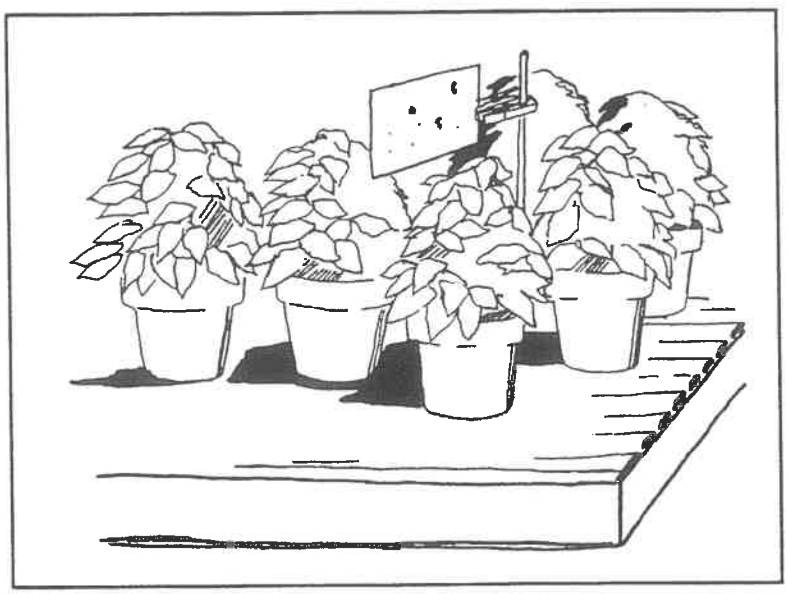
Integrated pest management (IPM) is very effective in greenhouses. IPM provides a practical, economical, and ecologically appropriate way to control pests. Chemical use, while still important, is combined with other effective control measures. Pest resistance, worker health concerns, public attitudes regarding the use of chemicals, tighter regulations, and removal of many chemicals from the market have encouraged the reduction of pesticide use.
IPM practices provide potentially less hazardous pest control methods (as opposed to strict chemical use), offering greater protection to workers, the public, and the environment.
With IPM practices, pesticide costs should decrease, since the amount of pesticide used decreases, without sacrificing plant quality. IPM programs are site-specific, to address the unique conditions of each greenhouse. An IPM program must be managed by

someone who is very familiar with greenhouse pests and the host plants; usually, the greenhouse manager has this expertise.

In order for an IPM strategy to be successful, early detection and accurate identification of pests are essential. Monitoring the pest population is necessary to follow changes in population size and life stages that may indicate the need to implement various control methods. Accurate record keeping is essential to document the effectiveness of the program, and to provide information for future pest management decisions.

PEST IDENTIFICATION AND MONITORING

Know which pests are likely to occur in your greenhouse, and be able to identify them. Highly mobile insects such as aphids, white flies, leafminers, and thrips are common pests found in greenhouses. By setting up a monitoring system, the greenhouse manager will be able to evaluate pest cycles and determine trends. An example is the use of yellow sticky cards to monitor aerial pests. These cards should be placed in strategic locations throughout the greenhouse. These traps should be checked at least once, and preferably two or more times, each week. Yellow sticky cards are effective at trapping aphids, white flies, leafminers, thrips, fungus gnats, and shore flies.



Yellow sticky cards alone, however, are not enough. Plants should also be routinely inspected for insects, fungi, and weeds. Inspectors may be people specifically trained and designated to inspect the plants, or they may be nursery workers that have been trained to identify various pests and scout for pests while doing their daily work. If inspectors find a pest-infested plant, they should flag the plant and note where pests are found, what life stage they are in, how many there are, and what treatment (if any) is used. For example, if inspectors find white flies on plants, they should record whether the flies are adults or immatures, where they are found on the plant (e.g., upper or lower side of leaves, stems), and how many there are. Record-keeping is a very important part of the monitoring program. This type of monitoring and record-keeping system allows for more limited, but also more effective, use of chemicals by treating the pest at its most susceptible life stage, and treating only those plants that are infested with the pest. Using chemicals less is more economical, more appropriate ecologically, and less likely to cause resistance problems. With specific pests, such as thrips, any indication of their presence may warrant applying pesticides.

GREENHOUSE CONDITIONS

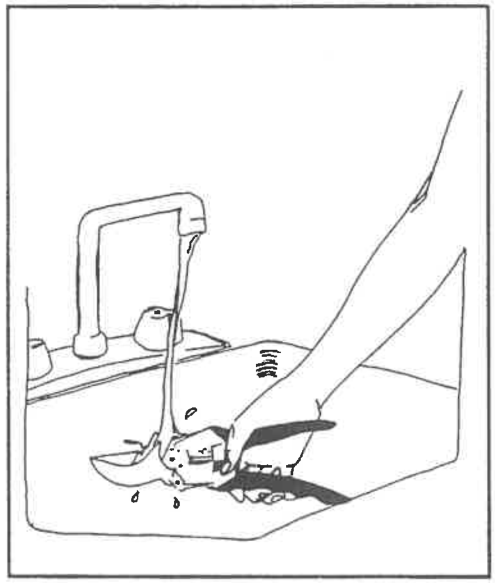
A clean and well-kept greenhouse will help minimize pests. Controlling pests outside will help reduce pest populations inside a greenhouse. To eliminate nearby pest reservoirs, remove all vegetation from around the exterior of the greenhouse, out to a distance of at least 5 feet. The inside of the greenhouse should also be free of weeds and other pests before plants are brought in.

Possible methods to reduce access of airborne insects and spores into the greenhouse include installation of double doors, an atrium, or plastic strips at the door. Screens and/or filters should be put on the ventilation system, and other openings or holes should be caulked or patched. Between plant rotations, hose down all tables, walls, and floors with a disinfectant. Raise greenhouse temperature to above 90° F for a day or two to kill lingering pests or pathogens.

CULTURAL PRACTICES

Resistant cultivars and certified seed or plants should be used when available. Before placing plants in the greenhouse, inspect them to be certain they are free of diseases and insects. If necessary, quarantine all new plants until you are certain they are not infected or infested.

Watering and feeding of the plants should be done in a manner likely to reduce pest populations. Water early in the day during cooler periods and provide air movement after watering to discourage fungal growth. Watering with misters may reduce mite populations, since mites reproduce most rapidly under dry conditions. Applying small quantities of nitrogen at regular intervals will not encourage population increases of plant juice feeders, whereas periodic heavy applications of nitrogen may.



Rinse tools and machinery with clean water and wipe them dry to prevent transporting diseases from one plant to another. To reduce the risk of infecting or infesting healthy plants, handle diseased or insect-infested plants at the end of the day, after all healthy plants have been handled. Limit the movement of workers and other personnel to certain areas in the greenhouse to help prevent pests from being transported from one area to another on hands or clothing. Discourage workers from wearing yellow clothing in the greenhouse, since white flies and other insects are attracted to the color yellow and can be carried on clothing to another area. It may be necessary to sterilize new soil, especially if it is soil just brought in from the field. Do not reuse soil, especially if pests have been a problem. A plant-free period in the greenhouse will also help alleviate pest problems.

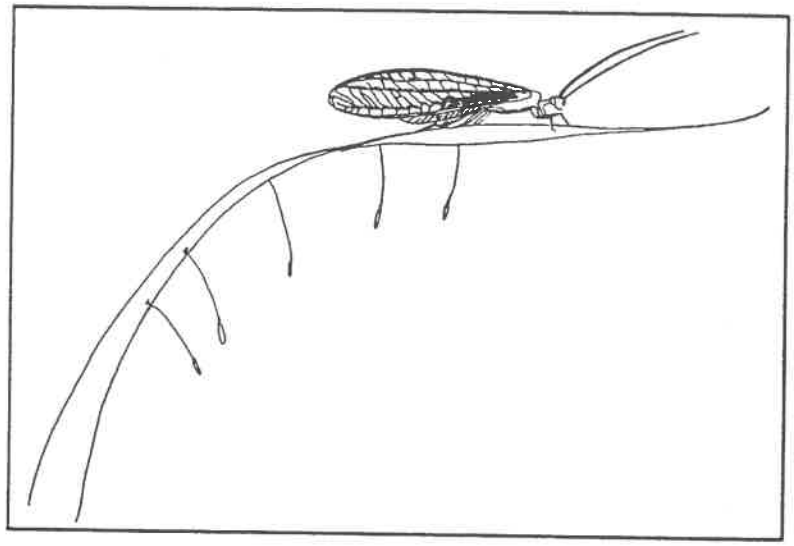
BIOLOGICAL CONTROLS[1]

Biological control is the use of natural enemies of the pest to control the pest population. Natural enemies will probably not replace chemicals, but rather should be used in conjunction with pesticides to allow for a successful IPM program.

Seldom is only one species of plant grown in a greenhouse. More likely two or more plant species are cultivated in the same greenhouse, which makes the use of natural enemies more complex. Some greenhouse managers have more success in controlling pests if they separate plant species or partition off sections of the greenhouse.

The use of natural enemies may be more favorably received in research greenhouses than in commercial greenhouses, since many people believe that the use of biological controls entail a higher risk of some pest damage to the plants. In a commercial greenhouse, any amount of aesthetic damage may have an economic impact. Many commercial greenhouses, however, have reported no increase in crop damage when natural enemies have been used as

[1]Biological controls will be used synonymously with natural enemies in this chapter.

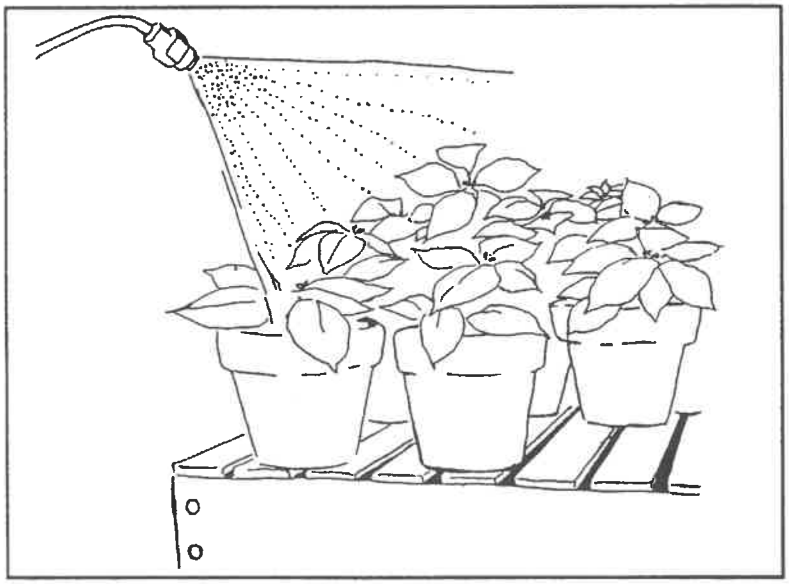


part of an IPM strategy. For example, the fungus *Cephalosporium lecanii* has been used, with limited success, for control of greenhouse white flies. Green lacewings (*Chrysopa carnea*) or tiny, parasitic wasps (*Encarsia formosa*) have also been recommended for control of greenhouse white flies.

The major difference between traditional pest control and biological control is that, when relying solely on pesticides, managers wait until pests are observed near an economic damage level before treating. With biological controls, natural enemies are introduced into the greenhouse as soon as pests are observed. Beneficial organisms are often found in greenhouses with no effort made to introduce them. The ability to recognize and encourage the presence of these natural enemies within the greenhouse is important for a successful IPM program. Your local county extension agent may be able to provide you with information on natural enemies, or put you in contact with someone who can.

PESTICIDES

Pesticides have an important role in pest control in greenhouses. However, chemicals should be used judiciously. Reduced pesticide use and increased accountability of those who apply pesticides are the current trends. Often there are many different types of plants in the greenhouse. This usually means many kinds of pests will be able to find a suitable host, making pest control more difficult. Past control strategies have been to apply a broad-spectrum pesticide to kill all the pests. This method had limited success, and increased potential damage to nontarget organisms, other nearby species of plants, and the environment. Chemicals applied under an IPM strategy are more likely to be applied to a targeted pest at a specific life stage. Be sure the pesticide you select will control the target pest and is being applied at the right time. Improper timing of pesticide application costs money and time. Also, if using natural enemies in your greenhouse, be sure that they are not injured or killed by pesticide application, as this will also increase your costs.



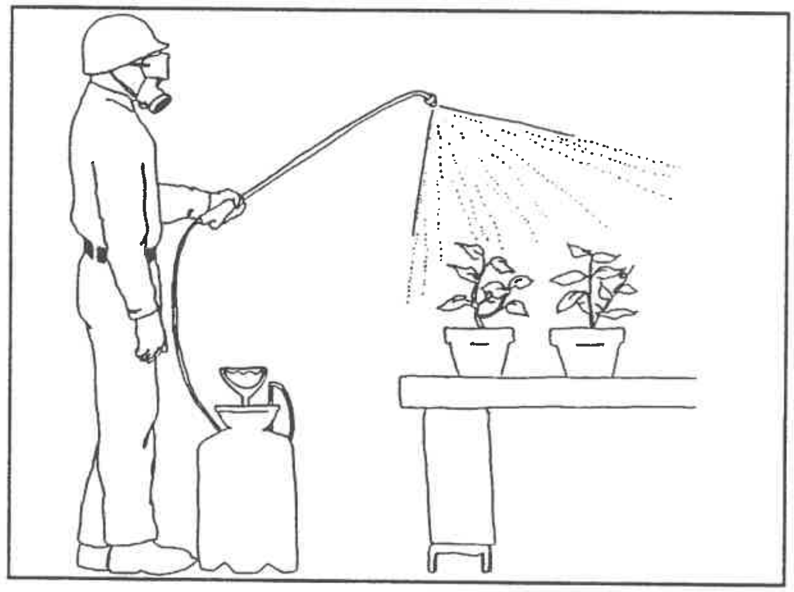
To avoid phytotoxicity, you need to be aware that chemicals may affect plants differently in the plants' various life stages. For example, some chemicals may not harm foliage, but may burn flowers. Rotating chemical classes may prevent pests from building up a resistance to any one chemical. For example, to prevent white flies from becoming resistant to an organophosphate, you may need to switch to some other chemical class, such as a carbamate or a pyrethroid. To avoid phytotoxicity, do not use foliar sprays as a drench. Good pesticide penetration is not likely on plants that are tightly packed together. Always be aware of impacts pesticides may have on nontarget species (e.g., other plants, natural enemies, workers).

CHEMICAL FORMULATION

Aerosols, which are fine particles of liquid or solid suspended in a gas, work well in confined areas such as greenhouses to control insects. Emulsifiable concentrates, which contain one or more active ingredients, one or more petroleum solvents, and an emulsifier are very versatile and work well on commercial greenhouse plants since they leave little visible residue. Be aware, however, that the petroleum solvents in emulsifiable concentrates may cause phytotoxicity. Fumigants are often used to treat greenhouse soil for nematodes, weeds, and diseases. Air fumigants are also used in confined spaces such as greenhouses; however, these fumigants are toxic to many different types and forms of organisms. Solutions, which are mixed with water before application, and low-concentration solutions, which are ready to use and require no further dilution, are also commonly used in greenhouses. Granules and dusts are also frequently used; however, dusts may leave an unsightly residue on the foliage, and granules may remain on the soil surface.

APPLICATOR AND WORKER SAFETY[2]

As a pesticide applicator, you should be properly trained not only to prevent contamination of yourself, but also of co-workers. Only applicators who have received the proper training in pesticide safety should mix and apply pesticides. Persons who may not work directly with pesticides, but could be affected by them, also have the right to know about pesticide hazards and the availability of training. Employers have a responsibility to inform all workers in the greenhouse of the dangers of pesticides, the precautions they should take, and the ways to recognize pesticide poisoning in themselves and fellow workers. Well-trained personnel will reduce the number of pesticide accidents.



Pesticide application should take place in teams of two, with no one other than the applicator and a support person in the greenhouse. It may be necessary to apply chemicals early in the morning or after working hours to be certain no unauthorized persons are in the greenhouse at the time of application. It is also important to post signs on the greenhouse door warning of current pesticide application.

Applying chemicals inside a greenhouse is different from applying them outdoors. The applicator should be aware that chemicals may react differently and may not disperse as rapidly as they do outdoors. Ultraviolet light, which helps break down many chemicals outdoors, may not be available in a

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[2]Much of the information in this section can be found in various applicator training manuals; however, one source that we found provided excellent coverage of this topic is the video (V/86-AJ) *Pesticide Safety in the Greenhouse*. Contact Visual Media, Division of Agriculture and Natural Resources, University of California, Davis, CA 95616 for more information.

greenhouse due to the ability of glass and some plastics to block certain light waves. Additionally, chemicals that readily degrade outdoors may not break down as readily indoors due to the temperature differences between greenhouses and outdoors.

Entry into the greenhouse should be restricted for a period of time after a pesticide application, to protect workers from possible contact with unsafe residues. When the pesticide label gives no specific reentry interval, some greenhouse managers allow reentry into the greenhouse only after the foliage dries or the dust settles. Be sure to allow a large enough safety margin for workers to handle the plants. If plants need to be handled sooner than the suggested reentry time, you may want to use a different pesticide.

For applicator safety, you must also make allowance for the ventilation system and direction of airflow within the greenhouse. It is safest to turn the ventilation system off while applying pesticides. Apply the pesticide by walking completely into the row and spray while backing out. If the ventilation system must remain on when a pesticide is being applied, you should start at the area closest to the exhaust fans, and while facing the fans, spray while walking sideways and backwards out of the aisle, so that the area already sprayed is downwind of you. The ventilation system will help disperse pesticide residues to the outside of the greenhouse. This presents another safety problem, though. Any plants, people, or other organisms outside the vent may be affected by the pesticide coming out the vent. If two or more greenhouses are connected to the same ventilation system, it may be necessary to remove workers from all greenhouses. Generally, the ventilation system of a multihouse greenhouse is designed to restrict air movement from one house to another; however, workers should still be removed from houses adjacent to the one where chemicals are being applied. As an applicator, you need to know that potential hazards from pesticide application do exist, and you need to be able to recognize and respond to a hazardous situation.

Most greenhouses require many workers for operation. These workers have a great deal of contact with the plants. Since many pesticides are easily absorbed through the skin, direct skin contact with plants increases risk of pesticide exposure. For this reason, it is extremely important that workers not handle recently treated plants. It is also important that workers do not work beneath recently treated hanging plants, as residue could drip or fall on the workers below. Use of highly toxic chemicals in overhead baskets should be avoided. To increase the safety of the applicator, hanging baskets should be taken down when applying pesticides. If this is not possible, the applicator should walk completely down one row and apply the pesticide to the plants while backing out of the row. Sleeves of protective clothing should be tucked into the applicator's gloves when applying pesticides overhead, to ensure that no pesticide runs under the sleeves onto bare skin.

If you, the applicator, are going to use soil fumigants, be aware that they can have acute and chronic health affects on anyone coming in contact with them. It is important, therefore, to allow all fumigant to dissipate after the tarp is removed and before handling the soil.

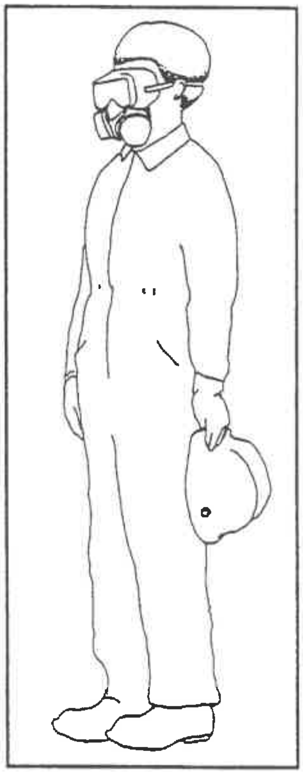
Application Equipment

Often hand-held or backpack equipment is used to apply pesticides inside a greenhouse. The applicator should be trained to inspect the equipment before use. Be sure the equipment is not damaged in any way; check for leaks in the tank and hose. When replacing hoses, make sure the new hose has the same or greater pressure rating as the replaced hose.

If pesticides are applied as chemigation, it is important that the lines are in good working order and checked periodically for leakage. Label lines clearly, so workers know which lines and connecting hoses are used for pesticide application and do not wash or drink from these. Apply only pesticides specifically labeled for chemigation application.

APPLICATOR CLOTHING

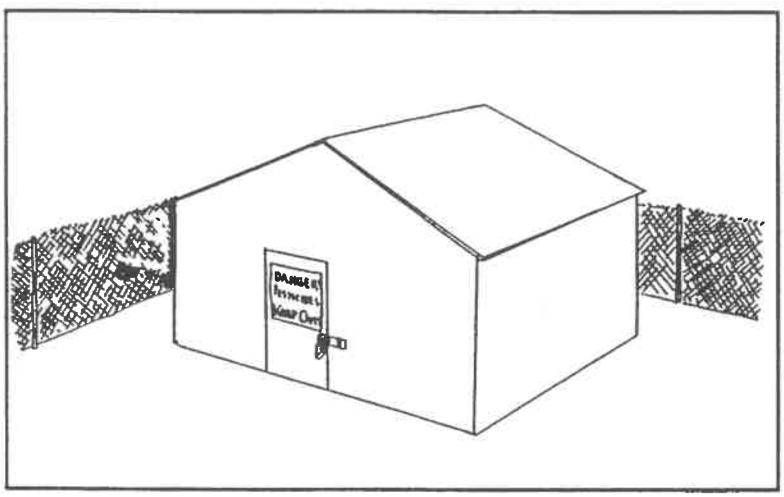
Applicators in greenhouses face some unique risks of exposure, such as working in confined spaces, working with closely spaced and/or overhead plants, and working with pesticides that may react differently in greenhouses than outdoors (e.g., sprays may dry more slowly). Therefore, applicators need to wear the protective clothing specified on the pesticide label in order to protect themselves. Pants, long-sleeved shirts, gloves, and boots may be



adequate for some pesticides. An impermeable suit with hat that protects the head and neck from drips, rubber boots, and gloves without a cloth lining are generally required. Goggles or a face shield and a self-contained respirator may also be used. Be sure the respirator fits correctly and that the filters are replaced frequently. All clothing and equipment must be washed after applying pesticides. The clothing should be stored separately from equipment and pesticides. Protective clothing may be hot and uncomfortable; however, applying pesticides without protective clothing can be dangerous to your health. Consider making applications at night or in the early morning, when temperatures are cooler.

The impermeable material used to make the protective suits or jackets is often yellow-colored. If possible, find material of a different color, since yellow attracts many insects, which may be transported on the material from the outside into the greenhouse or between different areas of the greenhouse.

STORAGE AND DISPOSAL OF PESTICIDES



Greenhouse pesticides should be stored in a cool, dry place. This area should be locked and only a limited number of persons should have access to it. Warning signs should be posted outside the storage area. Pesticides should be kept in their original packages with the label attached. If a container starts to leak, transfer the pesticide to a new container that is clearly marked and contains all necessary information. Dispose of the leaking container (or any pesticide you wish to get rid of) as specified on the pesticide label. If no disposal procedures are given, or if for some reason you are unable to follow these procedures, contact your agriculture commissioner or the regional EPA office for assistance.

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SAMPLE TEST

QUESTIONS

1. In order for an IPM strategy to be successful, early detection and accurate identification of pests are essential. True or False?

2. In greenhouses, ____________________ management is very effective. It provides a practical, economical, and ecologically appropriate way to control pests.

3. By setting up a ____________________, the greenhouse manager will be able to evaluate pest cycles and determine trends.

4. Greenhouse workers should be discouraged from wearing yellow clothing, since some insects are attracted to the color yellow and may be carried on the clothing to another areas. True or False?

5. ____________________ should be used in conjunction with pesticides to allow for a successful IPM program.

6. Pesticides do not have an important role in pest control in greenhouses. True or False?

7. In the greenhouse, pesticide application should take place in teams of two/three/five.

8. Chemicals may react differently indoors than they do outdoors. True or False?

9. The ventilation system and direction of airflow within the greenhouse are important for applicator safety. True or False.

10. In the greenhouse, it is safest to spray the pesticide in front of you as you walk forward. True or False?

ANSWERS

1. true 2. integrated pest 3. monitoring system 4. true 5. biological controls or natural enemies 6. false 7. two 8. true 9. true 10. false

CHAPTER 10 PLANT QUARANTINE[1]

The concept of quarantine as a means of pest management probably predates written history. Quarantine originally referred to a period of 40 days. An early use of the term related to the time period during which a ship, suspected of harboring an infectious disease among its crew or passengers, was required to lay offshore. Today, the term "quarantine" is generally recognized to mean a period of isolation of some people, animals, or plants to allow observation of those entities for signs or symptoms of disease or infestation. The obvious reason for quarantine is to protect healthy susceptible hosts from exposure to disease or infestation. Quarantines may be imposed by municipalities, counties, districts, states, or nations. In Arizona, turf and ornamental commodities are addressed in agricultural quarantines.

Federal interstate quarantine regulations, researched and written by the USDA, are usually enforced by a cooperative effort of state and federal inspectors. Many economically important plant and urban pests such as the red imported fire ant (IFA), the gypsy moth, and the Japanese beetle are covered by federal quarantines. When USDA regulations are in place, they take precedence over any intrastate rule or regulation a state may write which addresses the same pest.

This does not prevent an individual state from writing an intrastate rule to add controls to the pest's hosts once they have arrived within the state. Some Arizona quarantine rules regulate the movement of host material into and within the state, while others address only commodities entering the state, and a few involve control of the movement of commodities within the state. Quarantines are typically written by the receiving state to exclude pests from entrance into that state from an infested area.

Agricultural quarantines are found in all states. Some states only have "certification" requirements for incoming commodities, which are spelled out in the state's statutes. Other states, especially those in the sunbelt, have formal quarantine regulations, which are authorized by state statute, and written and enforced by the state agricultural regulatory agency.

To fully understand the concept of quarantine, regulations should be examined from several vantage points. To comprehend the entire quarantine process, including the formation and enforcement of a typical agricultural rule, we can look at the steps usually followed. The rule-making process is lengthy and

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[1]This chapter is written by Dan F. Rice, Associate Director of the Arizona Department of Agriculture.

difficult at best. In Arizona, this process, which includes several reviews and public hearings, usually takes between 9 and 12 months.

Quarantine rules are usually drafted in response to the needs of one or more components of the agricultural industry, which includes the ornamental, turf, and horticultural disciplines in addition to the food-producing disciplines of agriculture. A segment of industry may perceive a pest threat from a specific area of the country. Local members of that industry will make their concern known the Department of Agriculture. The quarantine specialist is then given the responsibility to study and perhaps to begin the development of a quarantine rule. A number of steps are routinely required to justify any rule. The process may take a few days or several months, depending upon the pest, the hosts, availability of information, and cooperation of all the people and agencies involved.

Quarantines usually address a single pest or several pests of a single commodity. The first step, then, is to identify the pest, which could be an insect, a virus, a mycoplasma-like organism (MLO), or some other plant pathogen. For example, if industry expresses concern about an insect which is suspected of causing some economic damage to plants in another part of the country, the concern is reported to the Department of Agriculture as a potential pest threat. The Department of Agriculture quarantine specialist begins the rule research by ascertaining the presence or absence of the pest in Arizona. Records in the Department's entomology division are searched. The university system is contacted for distribution information in its files. A survey may be conducted using traps or physical inspection of hosts. If trapping is required to ensure that the pest is not already a resident of the state, the survey could take a year or two to complete. If the pest is endemic to Arizona, a rule might still be written if an eradication program is put into motion. Most rules however, address pests which are not found in the state.

In order to justify a quarantine, the pest must be a threat to Arizona's agriculture or horticulture. It must exist in some other part of the nation which has hosts which are being shipped to Arizona. The quarantine specialist begins the search for the presence of the pest in those areas of the country from which known hosts are shipped to Arizona. After the appropriate agencies of infested areas are contacted and the presence of the pest is confirmed, the area to be considered infested or "under quarantine" has been identified. Cooperation between states' regulatory agencies and the agricultural community is vital in identifying the infested areas to be covered by a quarantine. A state which is infested with a significant pest such as the red imported fire ant (IFA), for instance, hopefully will assist other states to exclude that pest. Infested states often volunteer methods of treatment, special inspection programs and other helpful technology to the uninfested areas.

Data from infested areas is not necessarily applicable to Arizona's climate or topography, but it can be used to support consideration of quarantine activity. The red imported fire ant (IFA) infestation in Texas is an excellent example of support documentation for an IFA quarantine in Arizona. The USDA and the Texas Department of Agriculture have released figures relating to deaths of fish from streams and lakes, wildlife deaths, park and playground infestations, and interference with electric and electronic systems. Texas is reported to have 150 million acres of land infested with forty IFA nests per acre and 80,000 ants per colony. This type of information is reason to look carefully at an exclusion program for Arizona. The ability to inhabit urban population centers as well as agricultural areas, and the propensity to survive on such unlikely food as the joint materials of highways further support the development of a quarantine. The state of Texas has a sizable annual appropriation for IFA control, but it does not approach the total cost of the damage, eradication, and control efforts associated with this pest. One estimate for that cost is in excess of $40 million per year.

Another federally quarantined pest, the gypsy moth, is historically found only in the northern and eastern areas of the United States, but has recently been moving closer to Arizona. For the past few years, Utah has been involved in an extensive and successful eradication and control operation costing millions of dollars each year. Biological agents have been used and new techniques of application have been developed, but there is little doubt that prevention of the infestation through exclusion would have been less costly to the federal government and Utah.

Concurrent with the investigation of infested areas of the country is the research into the presence of significant host commodities in Arizona. Obviously, if there are no local hosts for the pest, a rule is unnecessary. The presence of only a limited number of scattered hosts, and the absence of significant commercial production of hosts, negates the need for any quarantine rule. If larger quantities of hosts are present, or if there is commercial production of hosts, the rule-making process proceeds.

Another important consideration which must be addressed is the biology of the pest. If the insect being considered is found to survive only in cold, wet climates, we have little concern in Arizona. Unfortunately, most plant pests seem to easily adapt to the climate of this state. If the pest requires a vector which is not found in this state, or if some stage of the life cycle of the pest will not adapt to Arizona's climate, the rule-making process stops. If it is determined that the pest will probably survive here, the rule process continues.

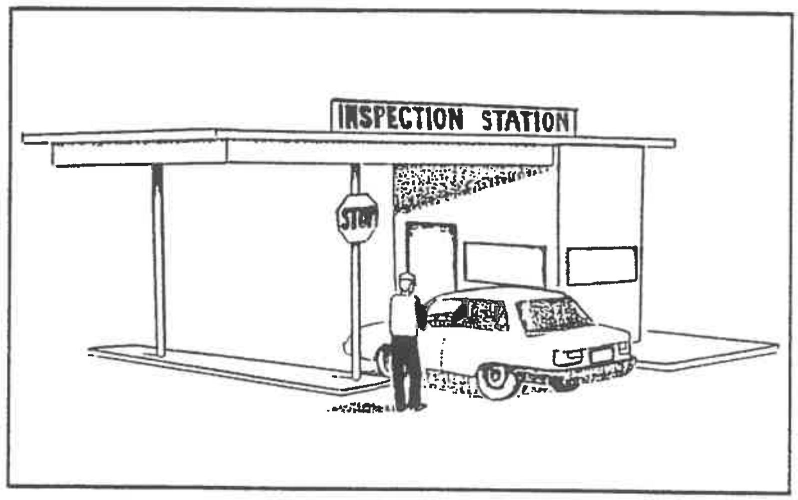
Economic impact of the pest is carefully considered. A study is made of the control of the pest in its present locality. This study includes the methods used, the cost of control, the rapidity of spread, the adaptability of the insect to new hosts, the costs of damage or loss, and the feasibility and cost of eradication. If the cost of having the pest introduced into the state is economically insignificant, a quarantine probably cannot be justified. Included in economic impact analysis is the cost of establishing the quarantine. The consumer ultimately bears the cost of quarantine rules. If a regulation requires that a commodity must be handled in some special way, such as with a chemical treatment, the cost of that treatment will eventually be borne by the consumer. In well-justified, logical quarantine rules, the cost of quarantine is less than the projected cost to the public if the pest is allowed to enter the state. For example, the ability to quickly and effectively eradicate localized, limited numbers of IFA nests in Arizona has been well documented. The cost of such eradication activities, including repeated delimiting and grid surveys, has been estimated at about $10,000 per property. This cost was considered to justify adopting an intrastate quarantine, rather than having to deal with infestations as they occurred.

The inherent cost of quarantine must be offset by the value received by the consumer. Plants which arrive in Arizona free of dangerous pests have a better chance for survival, saving replacement costs. Many pests are not host-specific and infested plants can be the source of infestation for existing clean plants in the receiving nursery, the consumer's yards or elsewhere in the neighborhood. Treatment of infestations by consumers is not always easy. Many consumers do not understand the efficacy and limitations of various chemical treatment agents. Misuse of pesticide chemicals may cause phytotoxicity of target plants or nearby plants. There are also environmental considerations related to treatment in destination nurseries or at consumers' residences. The cost of the chemicals and sometimes the cost of the plants may be minor when compared to the contemporary perception of the danger of contamination of air, water, and the environment in general.

Early in the rule-making process, input is solicited from the agricultural, horticultural, and turf industries. Questions are asked relative to the need for protection from the pest, the ability of the industries to comply with the quarantine requirements, and the perceived cost versus benefit of the rule. If the industries do not support a rule which is intended to protect them, the rule-making process is abandoned.

As the rule-making process continues, but before adoption of a rule, the regulatory agencies of the states which will be affected by the quarantine are contacted again. Their suggestions and recommendations are often incorporated into the rule. To be workable, rules must be honored by the quarantined states. A great deal of useful information relative to origin treatment or origin inspection may be provided by the state being quarantined. Agencies of infested states are usually quite familiar with the pest, and many innovative ideas regarding exclusion or control can be thus obtained. The effective date of an Arizona agricultural rule can not be predicted with much accuracy early in the process, but as it develops, an effort is made to keep the quarantined states informed of the progress.

Once all the biological elements of the quarantine are in place, the mechanism to exclude the pest is addressed. Some states, like Arizona, have border inspection offices on main highways and district inspection offices throughout the interior of the state. The inspectors staffing these offices are well trained in the use of quarantine rules, and many are educated in entomology, botany, and other biological sciences. Another important aspect of Arizona quarantine capabilities relates to the natural barriers of the state. The intense heat of the summer months and the limited number of hosts in the desert inhibit the natural migration of many pests. This adds importance to the border inspection offices and makes quarantine enforcement more practical.



Origin examination and certification is the key element to quarantine success. This involves the cooperation of origin state industry as well as the assistance of the regulatory agencies of that state. Communication between quarantine personnel of the various states is essential to establish the trust on which quarantine compliance is based. When the quarantined state's regulatory agency is familiar with the conditions of a quarantine, that agency instructs its inspectors and its industry in compliance techniques. The inspectors may establish the absence of the pest from a particular shipment, or they might monitor the chemical treatment of the shipment. Sometimes a specified area of the origin state is maintained free of the quarantined pest. In such a case, the inspector must certify that the host material did originate from the uninfested area. In any event, the certification of the origin state inspector is one key to the success of the rule.

When a shipment which contains hosts covered by an agricultural rule arrives at an Arizona border inspection office, the inspectors check the bills of lading against the inspection certificate. If the paperwork is in order, the shipment is visually inspected for the presence of pests, and if none are apparent, the shipment is allowed to proceed. In certain instances, even when certification is correct, further quarantine action is taken. This is most frequently employed when a shipment of soil-bearing nursery stock arrives from an imported fire ant (IFA) infested area. Although the federal quarantine requirements have apparently been met by the shipper, once in Arizona, the shipment is required to be held in a quarantine yard for five days' observation before the plants are released. Experience has shown that fire ants may survive chemical treatment at origin. The queen and her nest may be deep in the root ball of a plant, where they will often remain immobile during the trip from the Southeast. Once the vibration of the truck has ceased, the ants will emerge to forage. The five-day holding period has proven its effectiveness and has been one of the primary methods used to prevent fire ant infestation of Arizona. This is an example of an intrastate quarantine which has been written to supplement the federal interstate regulation.

The relationship between plant size and IFA interceptions in Arizona has not been specifically identified. Certainly, large containers or field grown balled and burlap specimen plants with large root balls containing great amounts of soil offer more protection to an ant nest than would a four-inch container plant. On the other hand, interceptions have been made in shipments of all sizes of containerized plants. One must remember that an infested load of plants is addressed as a shipment. No attempt can be made to isolate the nest(s) by individual inspection of each of several thousand containers. On occasion, the hollow wall or floor of a truck has been discovered to be the site of an IFA nest, and its workers are found foraging over many of the plants of the shipment. In such a situation, the source of the infestation may not be recognized until after the infested shipment has been addressed.

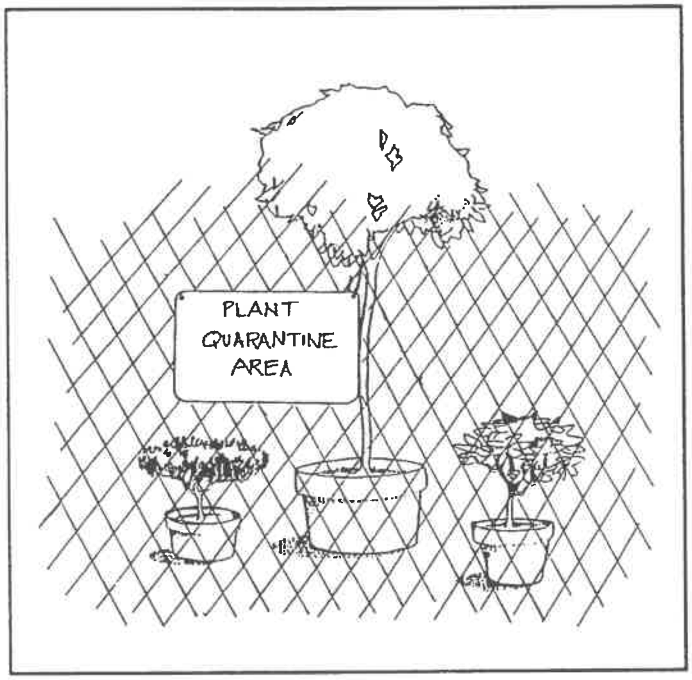
One surprising IFA infestation of a palm tree was not discovered until the tree was being physically placed into its permanent planting site. The usual surveys in the quarantine yard focused on the soil of the plants, but the IFA were nesting in tunnels in the frond remnants about five feet above the root crown. The IFA had no visible communication with the soil and were apparently thriving on a diet of honeydew from aphids, which they were appeared to be tending. The IFA nest tunnels contained all life forms of the fire ant, including multiple queens and eggs.

Arizona quarantine rules address the soils associated with nursery stock and grasses from various parts of the country. Soils with origin in the northern and eastern states can harbor pests such as the Japanese beetle. Gypsy moth egg masses have been found associated with nursery stock soil from other northern areas. Specific treatment or certifications may be required for plants in soil from areas infested with either of these two pests. Imported fire ants which are common to the southeastern states are frequently found in soil of containerized or balled and burlap plants originating from those areas.

In addition to the fire ant regulations, some states such as Arizona and California also have nematode quarantines which address soil and plants rooted in soil from several southeastern states. Shipping nurseries must be certified free of the reniform and burrowing nematodes, and additional soil and root sampling is done at the destination. Infested or infected shipments are returned to origin or destroyed when either pest is intercepted.

Grass sod, with one notable exception, is allowed entry into Arizona if certified free of the previously discussed pests. The exception is St. Augustine grass, which is commonly found in palm-tree growing parts of the world. This grass is known to be a host for the leafhopper *Myndus crudus*, which is the vector for the mycoplasma-like organism (MLO) that causes "lethal yellowing" of certain species of palm trees. Arizona's quarantine on "lethal yellowing" prohibits the shipment of susceptible species of palms from the infested areas and also prohibits the shipment of St. Augustine grass sod from areas infested with the "lethal yellowing" MLO.

The enforcement of quarantines is handled effectively through the cooperation of Arizona district offices and border offices. For example, when a truckload of nursery stock arrives at an eastern border office, it is inspected visually, the paperwork is checked, and a document containing information on the truck, driver, shipper, and receiver is sent by fax to the Arizona Department of Agriculture dispatcher in Phoenix. The dispatcher calculates the approximate time of arrival of the truck at its destination, and a district inspector is sent to meet the shipment. The shipment is unloaded and placed into a designated quarantine area under the inspector's direction. If indicated, a more complete inspection is done at this time. Soil samples may be taken if the shipment



originated in an area infected with plant pathogens, such as certain nematodes. The quarantined shipment may be watered, but may not be moved or treated with any chemical during the next five days. At the end of that time, the fire ant survey team again inspects the shipment, and if no pests are found, it is released. In cases where fire ants are found, the shipment may be returned to its origin, or by special permit in some cases, it may be chemically treated in the quarantine yard.

If a shipment of host commodities arrives at an Arizona border without proper inspection certification or proper treatment certification, the shipment is not allowed entry. If rejected, the shipment is well documented for future reference. If the shipment is found by border inspectors to be infested with a suspected dangerous pest, it will be rejected until the samples of the pest have been sent to the Phoenix laboratory for positive identification. If the pest found is a quarantine pest, the shipment is not allowed entry. It may return to origin, or in many cases, the shipper may elect the send it to a treatment facility outside Arizona, for treatment and return to Arizona. When a shipment is rejected due to infestation by a dangerous pest, the state into which it is rejected is advised.

Quarantine, as employed by the Arizona Department of Agriculture, is one of many integrated pest management (IPM) tools. It is often used in conjunction with compliance agreements or other permits with individual shipping companies or with other states' Departments of Agriculture. The success of any tool depends upon the skill and understanding of the personnel using it.

SAMPLE TEST

QUESTIONS

1. The obvious reason for quarantines is to protect healthy susceptible hosts from exposure to ________________ or ________________.

2. In Arizona, turf and ornamental commodities are addressed in ________________ quarantines.

3. Factors which are considered when setting up a quarantine include the following: presence of significant ________________ commodities in Arizona, the ________________of the pest, and the ________________ impact of the pest.

4. To prevent fire ant infestation, soil-bearing nursery stock, once it crosses the Arizona border, is required to be held for ___ days of observation before being released.

5. Quarantine, as employed by the Arizona Department of Agriculture, is one of many ________________________________ tools.

ANSWERS

1. disease, infestation 2. agricultural 3. host, biology, economic 4. 5 5. integrated pest management (IPM)

APPENDIX REVIEW OF PESTICIDE APPLICATOR CERTIFICATION CORE STUDY GUIDE[1]

INTRODUCTION

This appendix is designed to review basic principles all applicators should be aware of before continuing on to the turf and ornamental category.

PESTS

The first step in solving a pest problem is to identify the plant, animal, or disease organism that is the cause. If you do not know the exact pest, you can waste time, money, chemicals, and effort. Each pest has its own growth pattern; and specific control measures are most effective if applied when the pest is most susceptible to treatment.

ARTHROPOD PESTS

The large phylum **Arthropoda** includes insects, spiders and mites, crabs, and other invertebrates.

Insects

Insects surpass all other animals on earth today in the number of described species. Adult insects have certain distinguishing characteristics: six legs and three body regions—head, thorax, and abdomen. Most insects have one pair of antennae and two pairs of wings.

In their life cycles, insects mature by going through a series of changes, known as **metamorphosis**. (Some very primitive forms like silverfish do not undergo classic metamorphosis.) The three types of metamorphosis are gradual, incomplete, and complete.

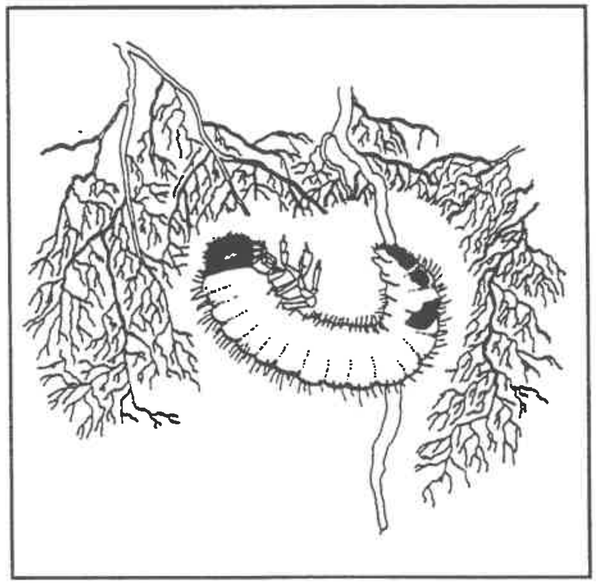
In **gradual** (or simple) **metamorphosis**, the nymph that hatches from the egg looks and acts like a miniature adult without fully developed wings. As the nymph feeds and grows, it molts (sheds its skin) several times. The period

[1]Portions of this chapter have been revised from the *Arizona Agricultural Pesticide Applicator Training Manual*, Pesticide Coordinator's Office, The University of Arizona, 1992.

between molts is called an **instar**. Grasshoppers and aphids are examples of insects that go through gradual metamorphosis.

Incomplete metamorphosis is similar to gradual metamorphosis in that there is no pupal stage. Development takes place underwater, however, and the nymphs (called **naiads**) do not resemble the adults. Examples are dragonflies and mayflies.

Complete (or complex) **metamorphosis** occurs in beetles, moths, flies, wasps, and ants, and involves several total changes in form. The larva hatches from the egg, feeds, grows, and molts several times. The mature larva then becomes a **pupa**; during this intermediate period (sometimes mistakenly called a resting stage) many major changes in form and life processes take place. At the end of pupation, the adult insect emerges.



Insects can be beneficial or harmful to humans. Helpful activities include providing honey, recycling organic matter, and feeding on pests. Insect pests may injure people and interfere with their activities. Pests that attack plants can damage them by:

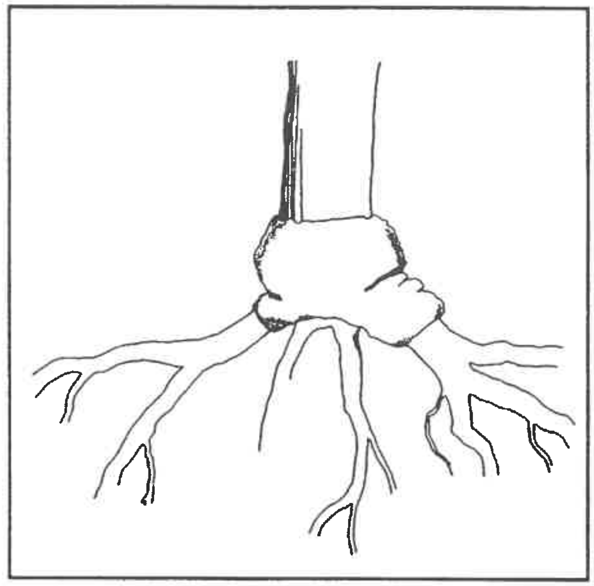
- feeding on leaves, roots, seeds
- sucking sap from leaves, stems, roots, fruits, and flowers
- tunneling or boring into branches and stems
- transmitting plant disease agents

Arachnids

Some arthropod pests are mistakenly called insects, when they are actually **arachnids**. These include scorpions, spiders, mites, crustaceans, and ticks, and have **eight legs**, **two body regions** (generally), and **no antennae**.

One type of arachnid that is very harmful to plants is the mite. Mites occur throughout the United States. These tiny creatures have four pairs of legs, and piercing-sucking mouthparts. As mites feed, they inject toxins into plant tissues, causing discoloration and distortion of the plant material. Mites thrive in hot, dry environments, especially in greenhouses.

PLANT DISEASES



Plant diseases are conditions that produce abnormal appearance, growth, or function in a plant. Plant diseases often damage or kill ornamental plants. The causes of plant disease can be grouped into two categories: abiotic and biotic.

Abiotic causes of plant disease include nutrient deficiency, too much or too little water, weather extremes, air pollution, salts, and pesticides.

Biotic causes of plant disease are living organisms **(pathogens)** that feed and live on or in plants. These may be passed from one plant to another; some can be controlled with pesticides or other techniques. Plant pathogens include the following:

Fungi, which include molds, yeasts, and mushrooms, are the largest group of plant pathogens. These simple plants lack chlorophyll and need to live on other organisms or their remains. Most fungi reproduce from spores. Powdery mildew, Dutch elm disease, chestnut blight, and melting-out of turf are fungal diseases.

Bacteria often infect plants in landscapes. These one-celled microorganisms reproduce by simple division, need an external source of organic matter for food, and enter plants through natural openings or wounds. Twig blight, leaf spot, and crown gall are bacterial diseases.

Viruses, which are too small to be seen with an ordinary microscope, cannot grow outside a living cell. They are usually transmitted by mechanical means and/or insect vectors. Viral diseases include certain types of dahlia stunt, nasturtium mosaic, and yellow stripe of narcissus.

Nematodes, such as the root knot nematode, are microscopic roundworms that weaken a plant and make it more susceptible to other diseases. Most feed on or in the roots, but some attack above-ground plant parts, causing small galls or knots.

WEEDS

By common definition, a weed is an unwanted plant, or a plant out of place. More specifically, weeds are specialized plants that are able to outcompete other plants because they adapt well to local climates and soil conditions. Most weeds produce an abundance of seeds, and many are capable of reproducing vegetatively. Weeds compete with desirable plants for nutrients, water, and sunlight. They also increase maintenance costs, harbor insect pests and plant pathogens, and reduce water flow in irrigation systems.

Identifying the weed is important in choosing the right herbicide, since growth characteristics and life cycle influence the effectiveness of control. Correct application timing is also necessary for good results; some herbicides work only when applied before weeds emerge, while others are applied to growing vegetation.

Weeds fall into two major groups—dicotyledon and monocotyledon—and different herbicides provide effective control of each type.

Dicotyledon (broadleaf) weeds can be recognized by the netlike veins in their leaves; examples are pigweed, London rocket, and little malva.

Monocotyledon (narrowleaf) weeds have parallel veins in the leaves; examples are grasses such as Johnsongrass and Bermuda grass, and yellow nutsedge.

Weeds are also classified as annual, biennial, or perennial.

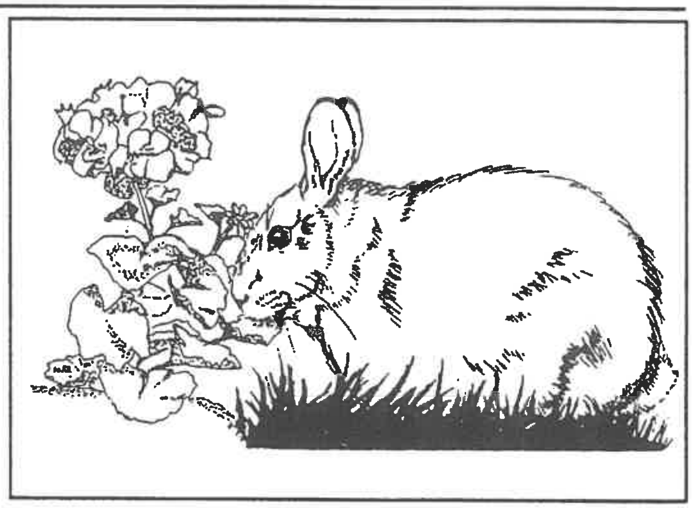
Annuals germinate from seed, grow vegetatively, flower, set seed, and die within a 12-month span. Winter annuals germinate in fall and are gone by summer. Summer annuals germinate in spring and end their life cycle by winter. Species that are summer annuals in the northern United States may be winter annuals in the southern U.S. Annuals do not usually develop deep and extensive root systems.

Biennials complete their life cycle in about 2 years. The first year they germinate and develop foliage; the second year they flower, set seed, and die.

Perennials live 2 years or more. They flower and set seed repeatedly. Many perennials are very difficult to control because, in addition to extensive true roots, they have underground structures, such as rhizomes (a modified underground stem), stolons (a modified above-ground stem), tubers, creeping roots, and taproots. These protected structures store food and produce new growth each year.

VERTEBRATES

Vertebrates, or animals with backbones, include mammals, birds, reptiles, and fish. Vertebrate pests are animals whose presence or activities conflict with human interests and well-being. The same animal can be a pest in some situations and highly desirable in others. Many of these pests (e.g., pigeons, rabbits) can transmit human pathogens.



Birds become pests when they destroy feed, eat crop seeds and fruit, endanger human and animal health, and roost near dwellings. Mammal pests can include deer and rodents such as gophers and rats. While reptiles do little real damage, they may be considered pests because so many people fear and dislike them.

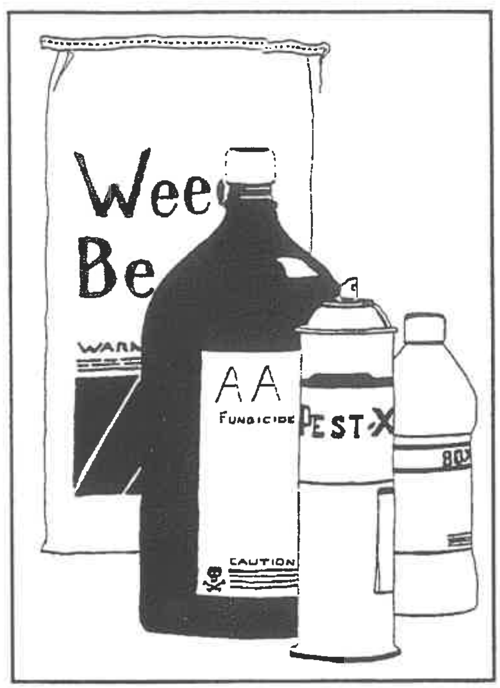
PESTICIDES

Pesticide is a broad term for any material, substance, or chemical that is used to destroy, prevent, or control pests. It also includes substances for attracting or repelling pests, regulating plant growth, or defoliating plants. Pesticides include **insecticides** for insect control, **herbicides** for weed control, **fungicides** for fungus control, **acaricides** for mite control, **rodenticides** for rodent control, and **avicides** for bird control.

TYPES OF PESTICIDES

Insecticides

Insecticides can be classified in a number of different ways. They may be divided according to their mode of action (i.e., the way in which they enter the pest), such as stomach poisons, contact poisons, systemic, or fumigants. They may also be separated into classes according to their derivation—inorganic, derived form minerals or natural chemical deposits, and organic, botanicals that were extracted from plants.



Since World War II, a wide variety of synthetic organic insecticides have been developed. These manufactured compounds, which are generally cheaper and more effective than naturally occurring compounds, now account for the major share of the pesticide market. **Synthetic organic insecticides** include chlorinated hydrocarbons, organophosphates, carbamates, and pyrethroids.

Chlorinated hydrocarbons, such as DDT and chlordane (which were once registered pesticides), were not very toxic to humans in brief exposures, but they were generally very long-lasting in the environment, and often built up in human and animal fatty tissues. Their levels are thought to have increased as they were passed up the food chain, a process known as **bioaccumulation**. Most of the registered uses of these chlorinated hydrocarbon pesticides have been canceled due to their persistence in the environment and health concerns. Some of the chlorinated hydrocarbon pesticides registered today, such as endosulfan and lindane, are not very persistent in the environment and do not accumulate in animal fat.

Organophosphates, on the other hand, can be more toxic to humans, but they usually break down rapidly, and do not remain in the environment. Common organophosphates are acephate, chlorpyrifos, diazinon, and malathion.

Carbamates are similar to organophosphates in toxicity to humans and are, as a rule, slightly more environmentally persistent than organophosphates. A carbamate in wide commercial use is carbaryl.

Pyrethroids are an important new class of insecticides. Synthetic pyrethroids emerged when it became possible to manufacture light-stable, pyrethrin-like compounds. Many synthetic pyrethroids give highly effective insect control at extremely low dosages. While not especially poisonous to mites, birds, or mammals (including humans), these pesticides can be very toxic to bees and aquatic organisms. Common synthetic pyrethroids are permethrin and fenvalerate.

Most synthetic organic insecticides affect the nervous system, but through different chemical reactions. Chlorinated hydrocarbons apparently disrupt the sodium-potassium balance, preventing normal nerve impulses. Organophosphates and carbamates inhibit the important enzyme cholinesterase, and cause rapid muscle twitching and paralysis. The mode of action for the synthetic pyrethroids also apparently involves the nervous system.

Inorganic and **botanical insecticides**, some of which have been in use for thousands of years, work in a variety of different ways. For example, arsenic inhibits certain enzymes in insects' bodies. Silica gels adsorb wax from the cuticle, until the insect dehydrates and dies. Nicotine sprays kill by attacking the nervous system.

Biological control of insects may also be accomplished through the use of predator insects, fungi, bacteria, or viruses. These types of **biological control** agents are being developed to reduce human and environmental danger. **Microbial pesticides** achieve control by introducing disease-causing microorganisms (such as bacteria or viruses) specific to a target pest. *Bacillus thuringiensis* (BT) is an example of a bacterium used as an insecticide for control of several plant-feeding insects.

Herbicides

Herbicides provide two general types of weed control: selective and nonselective. **Selective herbicides** are capable of killing only limited types of vegetation; **nonselective herbicides** kill all vegetation.

Herbicides can also be classified as pre- and postemergence. **Preemergence herbicides** are applied prior to plant emergence, and **postemergence herbicides** are applied after plant emergence. Pre- and postemergence herbicides can further be broken down as to their effect on the plant. **Contact herbicides** kill the plant parts they touch; complete coverage is essential. They are most effective against annual weeds and seedlings. **Systemic herbicides** (translocated), which are absorbed by roots or above-ground parts and moved within the plant system to all tissues, can be used to control established perennial weeds.

Petroleum oils enter the plant and disrupt movement of materials across membranes. **Phenoxy herbicides**, such as 2,4-D, resemble plant growth hormones and disrupt such functions as cell division and nucleic acid production. **Dinitroanilines**, such as trifluralin, inhibit root and shoot growth by interfering with several enzymes.

Fungicides

Present-day fungicides provide some degree of control for many plant diseases. Most are used as preventives, not as cures. Fungicides are metabolic inhibitors; they block some vital metabolic process. They may be contact, or exhibit various degrees of systemic activity. Applied when a plant is vulnerable to attack by pathogens, they inhibit fungal development and assist in bacterial control. Copper can be used as a fungicide to denature protein, as can the dithiocarbamates, such as maneb. Inorganic fungicides are rapidly giving way to synthetic organics, which last longer, are safer for crops, animals, and the environment, and can be used in lower doses. Most fungicides are low in phytotoxicity, are readily degraded by microorganisms, and do not persist in soils.

Plant Growth Regulators

Plant growth regulators (PGRs) are hormones applied to alter plant, blossom, and/or fruit growth. The six general classes of PGRs include auxins, gibberellins, cytokinins, ethylene generators, inhibitors, and growth retardants.

Auxins induce growth of shoot cells. They stimulate cuttings to root, and increase flower formation. **Gibberellins** intensify enzyme production, stimulating cell growth and division. **Cytokinins** induce cell division to prolong storage for such things as cut flowers. **Ethylene generators** regulate different phases of metabolism, growth, and development. For example, they induce uniform flowering and fruit thinning, and stimulate seed germination and sprouting. **Inhibitors** and **growth retardants**, which affect plant physiological processes, are used to prevent sprouting in root plants and to induce stem shortening. Many of the plant growth regulators used by turf and ornamental applicators are inhibitors.

Defoliants and Desiccants

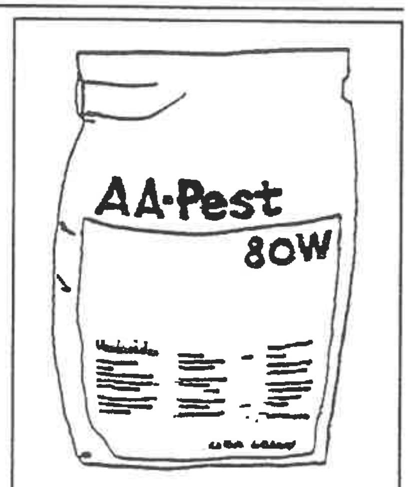
Another group of chemicals considered to be pesticides in the broad sense are defoliants and desiccants. **Defoliants** cause premature leaf drop in various ways by forming an abscission layer between the leaf and the stem. **Desiccants** speed drying of plant parts by rapidly killing leaves. Leaves remain attached, since an abscission layer usually does not have time to form. Desiccants can be applied later in the season than defoliants. A combination defoliant and desiccant is often used on golf courses for edging material around sand traps and trees.

Antitranspirants

Antitranspirants are chemicals applied directly to a plant that reduce the rate of transpiration or water loss by the plant.

PESTICIDE FORMULATIONS

Pesticides come in a variety of formulations to make them easy to apply and efficient, and to reduce danger to humans and the environment. Certain formulations are ready for immediate use, while others must be mixed with water or other diluents.



Formulations commonly used on turf and ornamentals include wettable powders, granules, emulsifiable concentrates, dry flowables, and aquasuspensions. Dusts, baits, and fumigants are occasionally used.

Dusts contain the active ingredient in finely ground carrier material, such as corn cobs or clay soils, and are applied without dilution. They often have a low percentage of active ingredient. Because of drift hazard, they are not often used for large-scale operations.

Wettable powders are designed to by mixed with water and sprayed as a liquid. They contain a fairly high percentage of active ingredient, and a wetting agent to aid suspension in water. A spreader-sticker may be added for better distribution and adhesion to plant surfaces. Advantages include a long residual effect and reduced drift; disadvantages are possible equipment wear and visible residue. Wettable powders require constant agitation.

Soluble powders are powder formulations that dissolve and form a solution in water.

Granules are large particles of active ingredient and inert carriers that are applied undiluted, either alone or with fertilizers. They are better than dusts if drift is a problem. Their principal use is as soil treatments.

Emulsifiable concentrates have the active ingredient dissolved in a petroleum-based solvent to form a concentrated liquid, which is diluted with water for application and requires agitation.

Aquasuspensions, like dry flowables, are pulverized pesticide suspended in water or a liquid solution. Whereas dry flowables need constant agitation to remain mixed, aquasuspensions do not. Only rarely do pesticide materials settle out of aquasuspensions. Aquasuspensions are potentially less hazardous to the applicator and the environment than are dusts. Dusts are easily blown anywhere, including on the applicator or in the environment.

Baits mix active ingredient with a material attractive to pests, such as apple pomace; they are commonly used to control rodent and insect pests outdoors or in buildings.

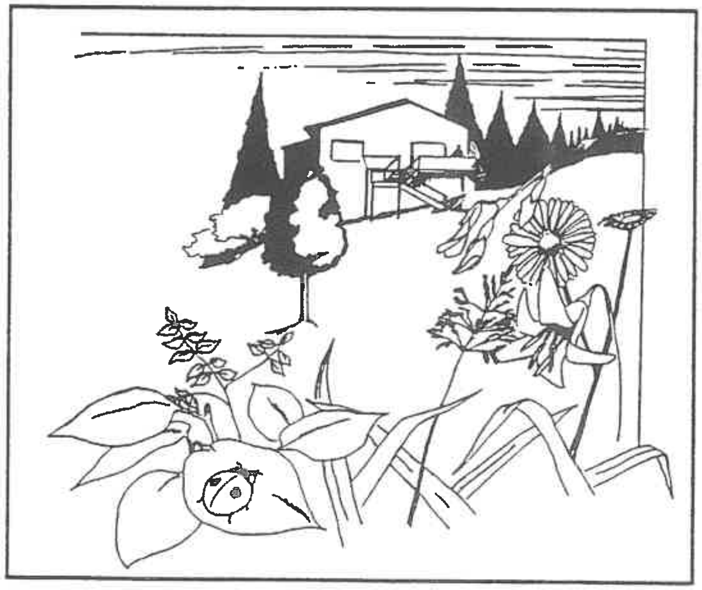
Dry Flowables suspend finely ground wettable powder formulations in liquid. Diluted with water for application and used like emulsifiable concentrates, dry flowables require constant agitation.

Fumigants may start out as a gas, liquid, or solid. When exposed to normal room temperature and pressure, fumigants all become gases.

EXTERNAL FACTORS

The activity of a pesticide may be affected by certain external conditions such as soil, climate, or pH of spray solution. The label often provides important information about applying pesticides to obtain most effective control; read and follow instructions carefully.

Soil characteristics that can limit pesticidal activity are texture, permeability, organic matter content, and structure. Coarse-textured, sandy soils provide less surface area for binding pesticides than fine-particled silts and clays, or soils with high organic matter. Texture and structure affect movement of water through soil and therefore also movement of dissolved chemicals such as pesticides. Heavy rain hinders pesticide activity by quickly leaching soluble particles away from plants or out of the root zone, or by washing off leaves.



Other factors affecting activity are humidity, temperature, and light. Herbicides give most effective control when high humidity and optimum warmth bring about rapid plant growth. While excessive heat can cause pesticides to evaporate quickly or to become phytotoxic, cold temperatures can slow down activity. Certain pesticides, such as pyrethroids, may also break down more rapidly when exposed to sunlight.

LABEL

Remember that the few minutes you spend reading the pesticide label can be extremely important. Years of costly testing and studies go into developing information on each pesticide label. Properly followed, the label can provide important information to enable the applicator to achieve effective pest control, avoid personal injury, and protect wildlife and the environment.

The word **label** refers to the printed information attached to a pesticide container or retail package. **Labeling**, a broader term, includes printed material about the pesticides, such as the product label, flyers, brochures, and other handouts, provided by manufacturers or dealers.

A label must be on the original pesticide container. The information that must appear on a label is defined by FIFRA (Federal Insecticide, Fungicide, and Rodenticide Act). Restricted-use pesticides must carry the phrase, "For sale to and use only by certified applicators or persons under their direct supervision..." Both manufacturers and distributors are responsible for ensuring that these words appear on each restricted-use product label. **All** pesticide labels must contain the instruction "Keep Out of Reach of Children."

Each label must show the following items:

1. **TRADE NAME**—manufacturer's name for a product (e.g., Sevin 4L, Roundup 2E).
2. **COMMON NAME**—generic name of active ingredient (e.g., carbaryl, glyphosate).
3. **TYPE OF FORMULATION**—how active ingredient is mixed with inert ingredients to make it ready for use (e.g., wettable powder, dust, granular).
4. **ACTIVE INGREDIENT**—the material(s) that act on the pest; chemical or common name of every active ingredient, and percent of weight, must appear. Percentage of contents composed of inert (inactive) ingredients is shown; specific inert substances are not usually listed.
5. **SIGNAL WORD**—indication of acute human toxicity category of pesticide; always accompanied by "Keep Out of the Reach of Children" and one of three signal words, Danger, Warning, Caution (see Table 1).
6. **DIRECTIONS FOR USE**—instructions on how to mix and apply a particular formulation; pest registered for; where, when, how much, and how often to apply material.
7. **FIRST AID**—what to do if someone is accidentally exposed to the pesticide.
8. **EPA REGISTRATION AND ESTABLISHMENT NUMBERS**—indication of product registration with EPA and manufacture location.

Additional information found on a pesticide label includes preharvest interval, reentry times, and storage and disposal information.

TABLE 1

Signal Word	Probable Oral Lethal Dose	Toxicity Category (Oral LD_{50} = mg/kg)
DANGER-POISON (skull & cross-bones)	Taste to a teaspoon	Category I, Highly Toxic (0 - 50 mg/kg)
WARNING	Teaspoon to tablespoon	Category II, Moderately Toxic (50 - 500 mg/kg)
CAUTION	Ounce to a pint	Category III, Low Toxicity (500 - 5000 mg/kg)

Never rely on your memory when using pesticides. Read the label often to be sure you are handling the material correctly. Always read the label at least four times:

1. **Before you buy the pesticide:** Manufacturers may use a similar trade name for new products and formulations; be sure your site is on the label and you have the application equipment needed.
2. **Before you mix and apply:** Read the label to find out how to mix the pesticide, and how much to use. Make sure you are wearing all specified protective clothing, and you know first aid procedures in case of an accident. Check application rate, timing, method, and use restrictions.
3. **Before you store the pesticide:** Never store or transport near food or feed, or where pesticides might contaminate each other. Carefully follow any special storage instructions.
4. **Before you dispose of the pesticide or the container:** To avoid health risks or contamination of the environment, be sure to follow label instructions on how to dispose of excess pesticide and/or the container.

All labels and labeling are **legal documents** and must be followed when applying pesticides. Any pesticide use that conflicts with the label carries civil and criminal penalties.

SAFETY

All pesticides are poisons that are toxic to plants, animals, and/or people, but they vary in their degree of hazard. Safe work practices will protect you and the environment from pesticide-related hazards.

Your risk of pesticide poisoning is equal to your exposure to the pesticide multiplied by the toxicity of the pesticide.

RISK = TOXICITY x EXPOSURE

A pesticide can be highly toxic but have a low hazard (risk) if exposure is kept to a minimum. The greatest exposure hazard occurs when handling pesticides during mixing and loading because the applicator is handling a concentrated pesticide formulation.

There are acute and chronic exposures to pesticides, and acute and chronic health effects from those exposures. An **acute exposure** is usually one dose (large or small) of pesticide that is sufficient to cause an immediate illness or injury. **Chronic exposure** refers to small (usually), repeated doses over a period of time that may accumulate to cause an illness or injury.

An **acute health effect** occurs soon after exposure. There is a sudden onset of symptoms. The health effect is usually of short duration (i.e. hours, days, or weeks) unless permanent damage to some physiological function occurs. A **chronic health effect** usually causes permanent damage, such as cancer, infertility or birth defects. There may be a delay from the time of exposure to the appearance of the health problem. A chronic health problem may occur as result of a single large exposure, a single small exposure, or multiple exposures.

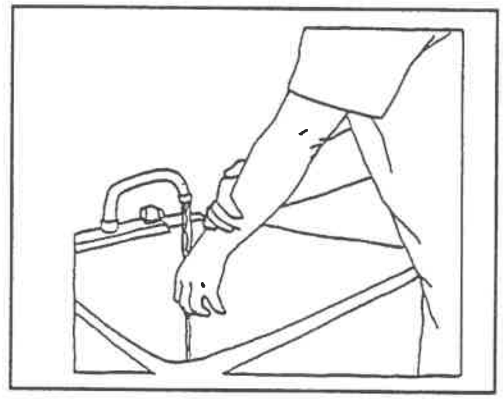
Signal words on pesticide containers generally refer only to acute health problems associated with exposure to a pesticide, and not chronic health problems.

Safe Practices

When mixing and applying pesticides, remember these important safety practices:

1. Don't allow children or unauthorized people to be where pesticides are being mixed, loaded, or applied.

2. Don't drink intoxicating beverages before handling pesticides.
3. When you finish handling pesticides, always wash thoroughly before you eat, drink, smoke, or use the toilet.
4. Read the label frequently and follow the precautions shown.
5. Pour liquid, powder, or dust slowly to avoid splash, spill, or drift.
6. When transferring concentrates from drums, use either thread tabs or drum pumps.
7. Check application equipment often for proper function and calibration.



8. Carry at least five gallons of clean water in vehicles and application equipment, to wash eyes and skin in emergencies.
9. Don't leave pesticides unattended in a field or at an operation site.
10. Plan applications carefully to avoid having to dispose of large amounts of leftover pesticides.
11. Always wear specified protective clothing, and never work alone.
12. Mix at the recommended rate and apply under proper weather conditions.

Reentry

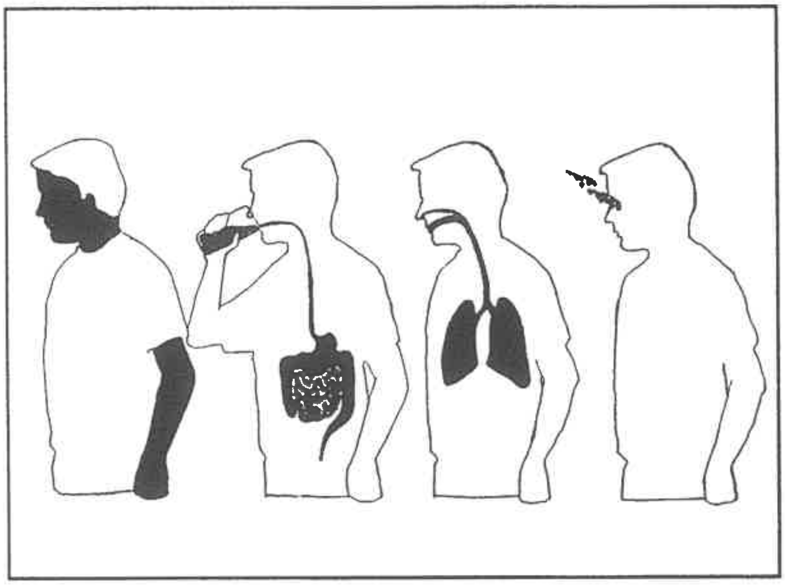
Also keep in mind that an unprotected person should not enter an area until the reentry interval has expired. The label shows the number of hours (usually 24 or 48) that must pass before the area is safe to enter without protective clothing. If you cannot find specific instructions on the label, wait at least until the pesticide is completely dry, or the dust has settled.

For more information and training on pesticide safety, contact your State Extension Program Pesticide Safety Education Coordinator.

PESTICIDE POISONING

The basic principle in avoiding pesticide poisoning is to use simple common sense. You should become familiar with this entire section on safety—you may not have time to consult a book for information in a pesticide emergency.

EXPOSURE ROUTES



The four common ways that pesticides enter the human body are through the skin, mouth, lungs, and eyes. Absorption through the skin (**dermal exposure**) during mixing, loading, or disposal is the most frequent poisoning route when working with pesticides. Common ways by which pesticide applicators can get pesticide on their skin include splashes and spills, wearing inadequate protective equipment, and wearing contaminated workclothes. Exposure to large quantities of residue can also cause poisoning. Liquid formulations are more readily absorbed by the skin than powders, dusts, or granules. **If you spill or splash a pesticide on yourself, wash immediately!**

Pesticides can be accidentally consumed or taken by mouth (**oral exposure**), especially if they have been put into unmarked containers or those which at one time held food or drink (e.g., soft drink bottles). **Always store pesticides in the original, labeled containers. Never clear a spray line or nozzle with your mouth. Don't eat or smoke while working with pesticides. Always wash hands before eating or smoking.**

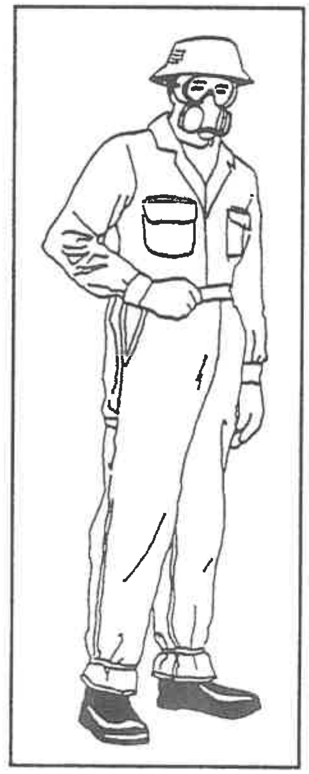
Pesticides in the lungs (**inhalation exposure**) hold the greatest poisoning danger, because they are so rapidly absorbed. **Always use protective devices called for on the label. Change respirator filters and cartridges as often as the manufacturer suggests, or more frequently if you smell or taste the pesticide while wearing the respirator. Mix pesticides out of doors or where there is plenty of fresh air. Stand upwind when mixing or loading pesticides.**

The eyes also absorb pesticides very rapidly; getting pesticides in the **eyes** can cause damage to eye tissue and serious illness. **Wear goggles or other**

protection when measuring and mixing concentrated or highly toxic pesticides. Also wear goggles when applying pesticides if the label recommend you do so.

PROTECTIVE CLOTHING

Consult the label for the kind of protective clothing needed to guard against skin contact, inhalation, and oral or eye contamination. Even though wearing the proper equipment in warm climates can be uncomfortable at times, use the protection recommended on the label.



In general, you should wear a long-sleeved shirt and trousers, or coveralls of tightly woven fabric, and impervious boots and gloves when you work with toxic chemicals. Depending on the toxicity of the pesticide, you may also need a rainsuit, head and neck covering, goggles, and a respiratory device.

Wear clean clothing each day. Change immediately if your clothes get wet with spray. Do not store or wash contaminated clothing with the family laundry. Wash separately with detergent and hot water. You must discard clothing contaminated with concentrated or highly toxic pesticides, since normal washing will not remove these.

Respirators should be worn if the label says to avoid breathing vapors or spray mists. Respirators should be checked to ensure they form an air tight seal against the face. Filter cartridges should be changed regularly and stored in a plastic bag away from pesticides to ensure a longer life span.

Goggles should be worn if the label says to avoid getting the pesticide in your eyes. Goggles should cover the front and sides of your eyes and should be cleaned after each use. Be sure the goggles you wear have been manufactured for use when using pesticides.

Gloves should be worn if the label says to avoid contact with skin. Gloves should be worn at almost all times when handling a pesticide, including during opening, mixing, loading, applying, and cleaning up. Gloves should be unlined and made of chemical-resistant rubber or other material.

Aprons or some other outer covering may be needed when mixing and loading.

Hats may be needed when making overhead applications. Hats should be made of plastic or some other impervious and easily cleanable material.

Boots should be impervious to the pesticide and should not be lined with cotton or other fabric that can absorb pesticides and hold them next to the skin. Do not tuck pant legs into boots.

All safety equipment should be chemical-resistant, unlined, cleaned after each use, and stored separately from pesticides.

When mixing and loading a pesticide, it is advisable to wear an apron or other appropriate outerwear. Read the mixing directions, measure carefully, and follow the safe practices already described, including having the wind behind you, wearing protective clothing, and keeping the container below eye level.

Many firms throughout the United States sell protective clothing and safety devices; you can find the names in the yellow pages of the telephone book. Many suppliers will ship anywhere in the United States by United Parcel Service (UPS) to accommodate applicators in outlying areas.

POISONING SYMPTOMS

Anyone who works with pesticides should be thoroughly familiar with common poisoning symptoms and basic first aid procedures. Watch for early warning signs--you can save a person's life by immediately and thoroughly removing the pesticide.

Some pesticides can cause irreversible injury. Flu or other common illnesses (even a hangover) have symptoms that can resemble pesticide poisoning, **but if any symptoms appear after contact with pesticides, contact a physician. Take a label to the physicians office. Never work alone when handling hazardous materials. Observe each other carefully for any unusual behavior when handling pesticides.**

Poisoning symptoms of organophosphates and carbamates fall into three groups:

Mild Symptoms
Fatigue
Headache
Dizziness
Blurred vision
Nausea and vomiting
Excessive sweating and salivation
Stomach cramps and diarrhea

Moderate Symptoms
Weakness
Inability to walk
Chest discomfort
Constricted eye pupil
More severe forms of mild symptoms

Severe Symptoms
Unconsciousness
Muscle twitches
Secretions from mouth and nose
Difficulty in breathing
Coma

Poisoning symptoms of pyrethroids include:

Mild Symptoms (generally from inhalation)
Stuffy, runny nose
Scratchy throat
Skin irritation

Severe Symptoms (generally from inhalation)
Nervousness
Irritability
Tremors
Coordination difficulty

FIRST AID AND EMERGENCY PROCEDURES

You need to take certain steps when someone has been exposed to or contaminated by pesticides. If you are alone with the victim, start first aid as quickly as possible. If someone else is also there, one of you can begin first aid, while the other contacts the poison center nearest you.

Speed is essential in pesticide poisoning first aid!

For Poison on the Skin

--Remove clothing.
--Cleanse skin and hair quickly and thoroughly with soap and water; don't forget fingernails.

For Poison in the Eyes

--Immediately wash eyes with a gentle stream of clean, running water for 15 minutes or more.
--Encourage victim to blink as much as possible.
--Don't use chemicals or drugs in the wash water.

For Inhaled Poison (Dusts, Vapors, Gases)

--If victim is in an enclosed area, don't enter without an air-supported respirator.
--Carry victim to fresh air immediately.
--Loosen all tight clothing.
--Give mouth-to-mouth resuscitation if breathing has stopped or is irregular.

For Swallowed Poison

--Call the Poison Control Center or a physician.
--Some pesticides should be vomited, some should not. Read the label for specific recommendations. If a pesticide is corrosive and burned the throat and stomach going down, it will burn again being vomited. Unconscious persons should not be made to vomit.
--Take the victim to the hospital as quickly as possible.

TRANSPORTATION AND STORAGE

Safe transportation and storage of pesticides are your responsibility. The safest place to carry pesticides is in the back of a truck, if you don't allow people to ride with them. Don't carry pesticides in the passenger compartment, or near food or feed. Keep paper or cardboard packages dry. Fasten all containers down to prevent breaking or spilling.

You can increase safety and shelf life by carefully storing pesticide products. Store small quantities in a locked cabinet out of reach of small children. Larger amounts require a well-lit, locked shed or room, adequately ventilated and made of fire-resistant materials. The floor should be smooth cement, with no cracks or crevices, painted with a hard sealer to simplify cleanup. The outside of the storage shed should have appropriate warning signs. Contact your local fire department for current regulations.

Stored pesticides offer fewer problems and remain effective longer when kept dry, cool, and out of direct sunlight. At high temperatures, pesticides may lose active ingredient by volatilization or decomposition; in extreme heat, glass bottles can break or explode. Certain liquids separate and become ineffective if they freeze. Excess humidity can cause dry formulations to cake.

Pesticide formulations with low concentrations of active ingredient usually lose effectiveness faster than more concentrated forms. In the process of deterioration, liquid pesticides can develop gas, making opening or handling dangerous.

Increasingly strong chemical odor in a storage area can indicate a leak, spill, or defective container closure or seal. It may indicate deterioration, since some materials smell stronger as they break down. If you investigate and find no problem, you can reduce odors by installing an exhaust fan or lowering temperature.

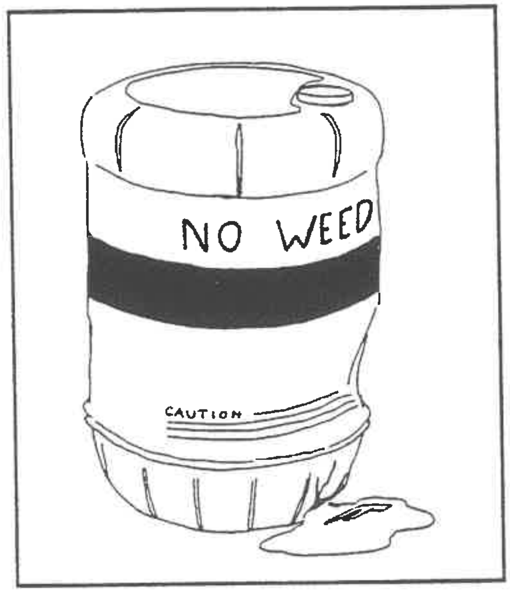
Store dry pesticides on shelves if the floor is ever damp. Separate volatile herbicides and other pesticides to prevent cross-contamination. Keep corrosive chemicals in proper containers to prevent leaks. You can extend pesticide shelf life by simple steps such as tightly closing lids and bungs.

Check containers often for leaks, breaks, or tears. Transfer contents of a damaged package to another container that once held the same pesticide or use a clearly labeled overpack. Don't tear bags or boxes to open them; have a sharp knife handy and clean it after each use. Seal opened paper containers with tape or staples.

Always date pesticides as you buy them, and maintain a current inventory. Use old materials first; don't keep pesticides over 2 years, since manufacturers do not back most products stored longer than that. Protect labels with transparent tape or lacquer.

SPILLS AND DISPOSAL

SPILLS



Even with careful handling and use, accidental pesticide spills can happen on your property or on public highways. There are legal, environmental, and health consequences if spills and disposal are not handled correctly.

For minor spills: Keep people away from spilled chemicals. Rope off and flag the area. Don't leave the scene unless someone is there to supervise. Give first aid if pesticide is spilled on someone. Dike the spill with sand or soil; soak it up with soil, sawdust, or absorbent products. Shovel contaminated material into a leakproof container, and dispose of it like excess pesticides. Don't let anyone enter the area until the spill is cleaned up.

For major spills: Keep people away, give first aid, confine the spill, then call for help. Agencies that can provide assistance may vary from state to state. Contact your local cooperative extension office for details. Generally your state's department of safety or regional EPA office should be able to provide some assistance.

The Manufacturing Chemists Association maintains a public service called CHEMTREC (Chemical Transportation Emergency Center) to provide immediate advice for those at the scene of emergencies. The telephone number is 1-800-424-3900.

DISPOSAL

To discard pesticides safely, it is important to know current disposal rules. **Triple-rinsed** and **punctured** or **broken** pesticide containers are **not** considered hazardous waste in most states, and can usually be disposed of in landfills. Check with your local landfill to see if they have any restrictions. Unrinsed pesticide containers may be considered hazardous waste. Be sure to check with local authorities for disposal regulations in your area.

Disposing of paper containers that held pesticides can be difficult. Some localities have air pollution regulations that prohibit open burning of these paper containers. Other local or state ordinances may permit limited burning of some paper containers but prohibit the burning of highly toxic pesticide containers. Read and follow label instructions when disposing of used containers. If you have questions, contact your state's environmental agency, or regional EPA office.

Disposing of unused and excess pesticides currently offers no simple solutions, but it can often be avoided by buying and mixing only enough pesticide for your needs. Contact your state's environmental agency for information on disposal.

ENVIRONMENT

Environment can be defined as the sum total of external conditions and circumstances that influence the development and existence of an individual organism or population. Careless pesticide use can contaminate the environment, cause illegal residues, produce drift, damage nontarget organisms, and pollute water through runoff.

Some pesticides are **persistent** in the environment; they break down slowly, usually in one year or more. Most pesticides are **nonpersistent**, which means that they break down in the environment in a few weeks. Persistent pesticides may concentrate in animals and eventually accumulate in the food chain. Many persistent materials (including DDT, dieldrin, aldrin, and chlordane) have had their registration for use as a pesticide canceled.

The pesticide label specifies any known environmental effects of the active ingredient. Choose the least hazardous pesticide that will control the pest and be aware of environmental conditions specific to your situation. Carefully follow directions to minimize adverse impacts.

RESIDUES

A **residue** is the amount of pesticide at any specific time left on a plant or animal by direct application, drift, contaminated soil, and other sources. EPA decides on a safe level of residue for a food crop at harvest and sets this as a **tolerance**, measured in parts per million (ppm). Applicators need to pay careful attention to rates, techniques, preharvest intervals, and other label directions, so that legal tolerances for residues will not be exceeded.

DRIFT

When pesticides **drift**, particles, droplets, or vapors move away from the target area by wind and air currents. This serious problem wastes expensive pesticide, and may result in health problems, wildlife damage, lawsuits, and injury to nontarget plants. The main factors that affect drift are weather conditions, droplet size, calibration of equipment, formulation, and type of equipment (i.e., ground-based or aircraft-mounted).

The most significant weather consideration is wind, which can blow a pesticide completely off target. The best application time to avoid wind problems is early morning or evening; be aware, however, of possible temperature inversions at these times. According to recommended practice, spraying operations are normally suspended when wind speed exceeds 5 to 7 miles per hour.

Since smaller droplets tend to drift easier and farther than large ones, use the largest nozzle size that will give adequate coverage. Reducing pressure as much as possible will also help, because higher pressures cause many small droplets. Lower boom heights may also decrease drift.

The tendency to drift also depends on the formulation. Granules are the least likely to drift; sprays are more likely; and dusts are the most likely. Adding drift control agents to liquid sprays before application may produce larger droplets and reduce the probability of drift.

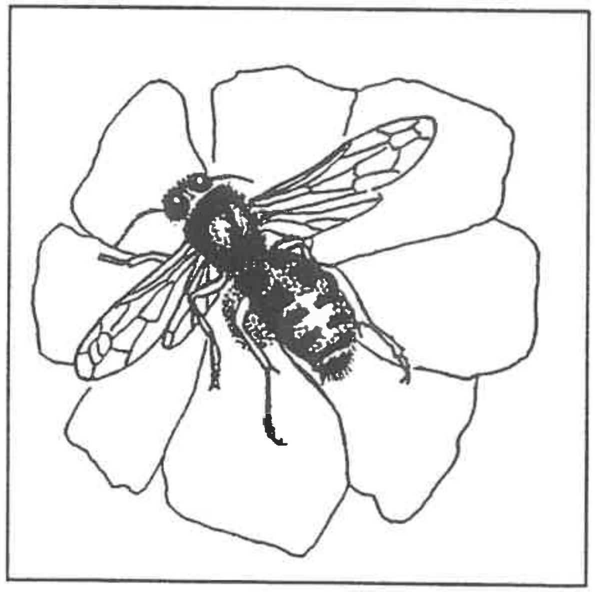
Where urban and rural areas exist side by side, drift reduction is becoming an important issue. People living in urban areas do not always understand pesticide usage. Many disagreements and lawsuits can be avoided by taking steps to minimize drift.

Applicators must observe certain restrictions when making applications of either highly toxic or odoriferous pesticides near schools, day-care or health-care facilities, or residential areas. Many states have established **buffer zones** for these areas. Contact your state's department of agriculture, department of safety, health service, or your regional EPA office for information on buffer zones.

Gross misuse of pesticides may result in a fine, prison sentence, suspension of license, or loss of certification.

NONTARGET ORGANISMS

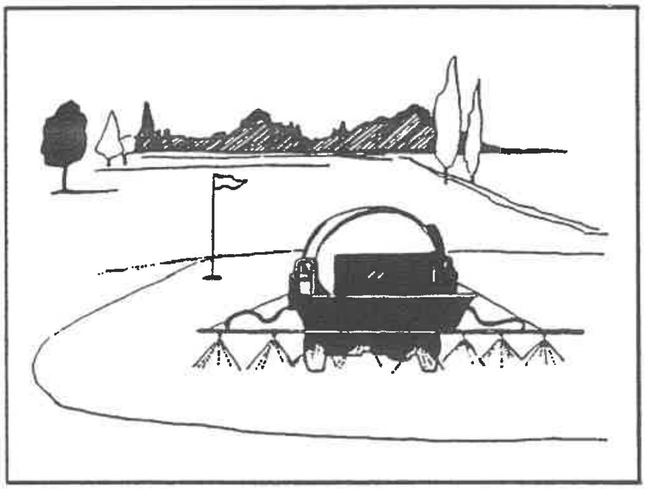
Another important environmental consideration is limiting application effects to the pest plant or animal, which is the target species. Nontarget organisms, or other plants or animals, may also be injured by the pesticide. Poisoning of nontarget organisms may occur from direct exposure to pesticides that are being applied, contact with treated surfaces, or from wind or water carrying pesticide out of the treatment area.



One adverse side effect of pesticide use can be **phytotoxicity**, the injury or death of the plant being protected or of other nearby desirable plants. Always check the label for warnings or precautionary statements about phytotoxicity.

Many beneficial species of insects or organisms may be killed during a pesticide application. Pest populations can significantly increase if predators or parasites are destroyed. Always consider whether or not these beneficial species will be harmed when choosing a pesticide.

EQUIPMENT AND CALIBRATION



The pesticide application equipment you use is important to the success of your pest control job. You must first select the right kind of application equipment. Then you must use it correctly to suit your needs, and you must take good care of it. These things are true whether you use hand-carried, tractor-drawn, self-propelled, or aircraft-mounted equipment. Equipment and calibration procedures used by turf and ornamental applicators are covered in detail in chapter 6 and 7.

LAWS AND REGULATIONS

FEDERAL

The principal federal law governing pesticide use is the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), first passed in 1947 and amended several times. This law established (among other things) the following requirements:

- All pesticide products must be registered and classified for restricted or general use.
- Applicators must be certified to buy or apply restricted-use pesticides.
- Supervisors must be certified to supervise the application or purchase of restricted-use pesticides; the supervisor must supply instructions and be readily available (but does not have to be present at application).

- Pesticides may not be used in a manner inconsistent with the label (see below for the 1978 amendment to FIFRA).

- Pesticides used only within one state are also subject to EPA authority.

FIFRA determines an applicator's competence to apply restricted-use pesticides by establishing procedures for certification. It also specifies illegal acts such as detaching, altering, defacing, or destroying a required label, using a registered pesticide in a manner inconsistent with the label, using an experimental pesticide contrary to the provisions of the permit, and improperly disposing of pesticides or their containers.

In 1978, amendments to FIFRA provided for more liberal interpretation of uses consistent with labeling. Pesticide users may now:

- use a pesticide to control a target pest not on the label, provided the site is on the label;

- use an application method not strictly prohibited on the label;

- mix pesticides with other pesticides or fertilizers, provided the label does not forbid this;

- use a pesticide at less than label rate, as long as total amount and number of applications per season do not exceed the amount shown on the label.

The Environmental Protection Agency (EPA) issues pesticide-related regulations to administer FIFRA and registers all pesticide products. One regulation EPA deals with is reentry standards. Some reentry standards apply to both workers and the applicator. EPA defines reentry time as the time immediately following application of a pesticide when unprotected workers may not enter the treated area. Among other things, the regulations state that:

- no unprotected person may be in the area when pesticides are applied;

- no pesticide application is permitted that will directly or indirectly expose any person (except the applicator) to the pesticide;

- if no reentry time is specified on the label, general standards are to be followed, namely waiting until the spray has dried or the dust settled; if the reentry time on the pesticide label is more restrictive than general standards, the more restrictive label instructions are to be followed;

- written and/or oral warning of pesticide application is to be given to workers prior to pesticide application.

Both federal and state governments may impose fines and penalties for FIFRA violations.

Hazard Communication Standard (HCS)

The Occupational Safety and Health Act (OSHA) is administered by the Occupational Safety and Health Administration of the Department of Labor. The Hazard Communication Standard (HCS) is a rule written and administered by OSHA and provides protection for employees exposed to hazardous chemicals, including pesticides. To comply with the HCS, an employer must:

- read the HCS and understand the provisions and responsibilities of an employer;

- determine what hazardous chemicals are in the workplace, and list them;

- obtain material safety data sheets (MSDS) for all hazardous chemicals;

- ensure that all containers are labeled;

- develop and implement a written communication program;

- provide employee training based upon the chemical list, MSDS, and labeling information;

- create a hazard communication file, and make it available to any employee upon request within a reasonable period of time.

STATE

The primary state regulatory agency for urban pesticide use is the Structural Pest Control Commission (SPCC). Therefore, turf and ornamental applicators fall under the auspices of the SPCC. The SPCC has the authority to regulate commercial pesticide use in structural and urban situations. SPCC licenses individuals or companies engaging in the business of structural pest control. All structural pest control applicators are considered "commercial applicators." There are no "private applicators" in structural pest control.

Other pesticide-related state agencies include: (1) the Arizona Department of Agriculture which certifies agricultural pesticide applicators, registers and ensures chemical quality of pesticides sold in-state, and approves Special Local Needs (SLN) and emergency exemption registrations; (2) the Arizona Department of Health Services (ADHS) which is responsible for monitoring and evaluating cases of pesticide poisonings; (3) Arizona Department of Environmental Quality (ADEQ) which regulates pesticide contamination of ground water or the environment and hazardous waste disposal programs; and (4) the Industrial Commission of Arizona (ICA), which has jurisdiction over employee safety and health. (For more information, see Arizona Cooperative Extension publication 9019: *Agency Profiles: Arizona State Agencies that Regulate Pesticides*.)

ARIZONA PESTICIDE LICENSE REQUIREMENTS[2]

Business License

A person who seeks to engage in the business of structural pest control or as a pest control advisor shall apply to the Commission for a business license. A business license may be held by an individual, a partnership, or a corporation. A business licensee shall furnish the following to the Commission:

- proof of financial responsibility, or at least $100,000 (deposit of money, liability insurance, surety bond, or a certified check).

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[2]For further information see The University of Arizona, Cooperative Extension Publication 890035: *Structural Pesticide Applicator Information: Licenses, Qualification, Registration, and Certification*, 1992, or contact the Structural Pest Control Commission at 1150 S. Priest, Suite 4, Tempe, AZ 85281, (602) 255-3664.

Qualification of Qualifying Party

An individual who qualifies a business to engage in the business of structural pest control is considered a qualifying party.

A person may not engage in the business of structural pest control in any classification without a qualifying party qualified in that classification. A qualifying party may only qualify one business at a time.

Registration

Each employee of a business licensee who applies pesticides shall register with the Commission before completion of 30 working days of beginning employment. Each employee who is not certified shall be trained by the business licensee. Before the employee becomes certified, the employee shall work under the direct supervision of a qualifying party or certified applicator.

Certification

Each employee who applies pesticides shall be certified by the Commission within 30 working days after registration in all categories applicable to the employee's duties.

To be certified, the structural applicator must pass, with 70%, a two-part written examination. The first part of the test covers the following "core" information.

- label/labeling comprehension
- safety
- environment
- pesticide types and formulations
- application equipment and techniques
- laws and regulations

An applicant must also pass, with 70%, an examination specific to the category in which he/she will be working, such as turf and ornamentals.

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