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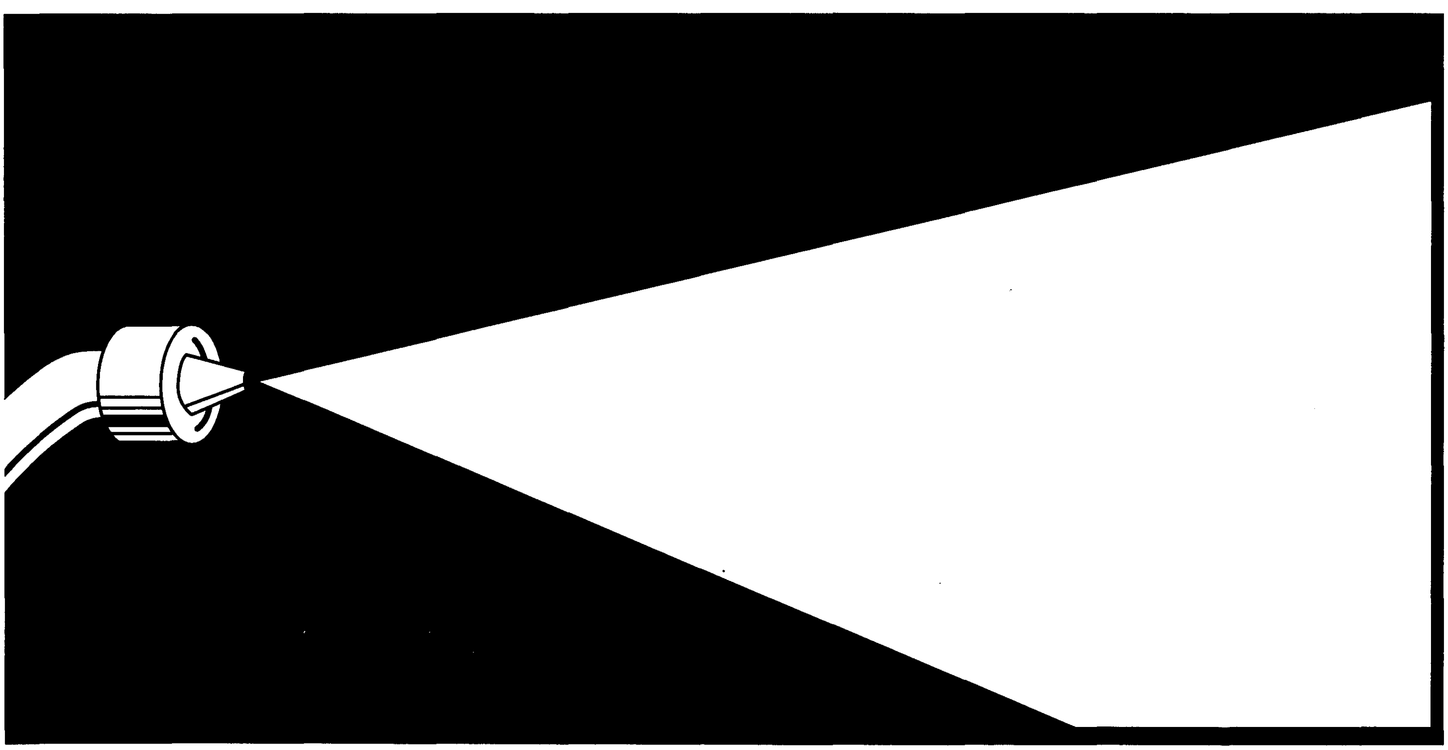
MARYLAND PESTICIDE APPLICATOR TRAINING SERIES

ORNAMENTALS & TURF MANUAL



CONTENTS

Instructions for Use of This Manual

This manual contains specific information that you will need to know about pests, pesticides, and application equipment in order to apply pesticides safely and effectively in your operations. The text is divided into one common section and three subcategory or specialty sections:

- Nursery and Landscape Ornamentals,
- Turfgrass, and
- Greenhouse Ornamentals.

Commercial Applicators

Commercial applicators must become certified in at least one category. This is the Maryland training manual for commercial applicators in Category 3, Ornamental and Turf Pest Control. You may wish to become certified in the Ornamental subcategory, or the turf subcategory, or both. To prepare for the certification examination, you should study and understand your core manual plus chapter 1 of this category manual and either chapter 2 or chapter 3, or both, depending on whether you need certification in both areas.

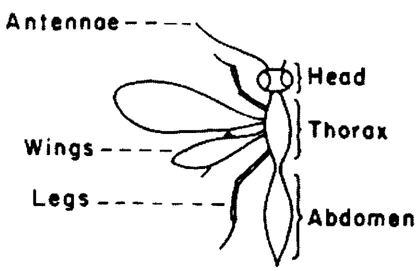
CHAPTER 1

GENERAL PRINCIPLES

In this chapter, typical life cycles and characteristics of pests will be discussed, as well as principles involved in their control by pesticides. Important pests and their control by various methods are discussed in later chapters. Consult those chapters and available extension materials for more specific information.

Insects and Mites

Insects and mites thrive in many different environments and can become pests of many plants and animals. They may cause economic injury to crops or livestock, unacceptable aesthetic damage to ornamentals and turf, or considerable annoyance to people. Some insects are capable of transmitting diseases to plants, animals, and humans.

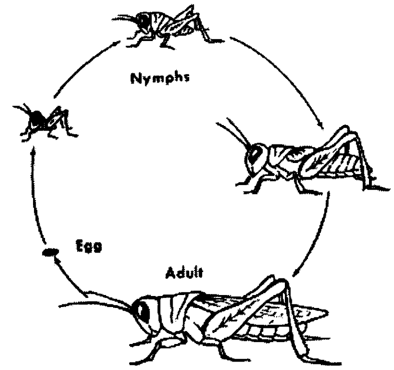


Characteristics

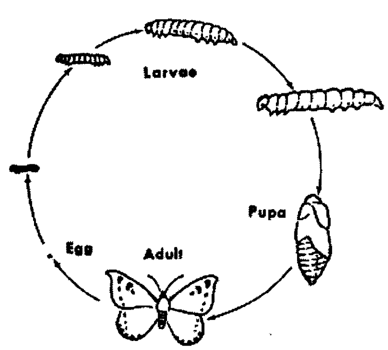
Insects and mites are distantly related and, therefore, share some similarities. They usually have jointed legs and a tough outer skin during one or more life stages. They must shed their skins several times in order to grow and become adults. Insects and mites can be distinguished by the number of body regions, legs, wings, and antennae each possesses. Adult insects usually have three body regions (head, thorax, and abdomen), three pairs of legs and one or two pairs of wings on the thorax, and one pair of antennae on the head. Scale insects are a notable exception to this body plan. Adult mites usually have one conspicuous body region, four pairs of legs, no wings, and no antennae.

Life Cycles

Metamorphosis, defined as a change in form, is a characteristic of insect and mite life cycles. Because of this change in form, immatures may not resemble adults of the same species, and may not feed in the same manner or on the same food. In order to find the weakest link in such a pest's life cycle, the pest manager should be familiar with the appearance and habits of all stages of a pest's life cycle. There are two general types of metamorphosis—gradual and complete.



Gradual metamorphosis. Newly hatched insects (nymphs) resemble the adult insect but are smaller, and the wings are not obvious. These insects change shape gradually. Each time they shed their skins they grow and enlarge their wings. Nymphs and adults usually feed on the same food source. Mite development is similar, but legs are added instead of wings.



Complete metamorphosis. Newly hatched insects do not resemble the adults. They have wormlike bodies with no external sign of wings and are called larvae. Like nymphs, larvae must also shed their skins to grow.

Each larva changes into a pupa before it can change into an adult. Wings usually are visible on the resting pupal stage, which does not feed and usually remains hidden. Adults eventually emerge from the pupal skins.

Principles of Insecticide/Miticide Use

Insecticidal control programs ideally should be aimed at the most susceptible or vulnerable stage of development of the insect pest. Generally this is the immature stage. The immatures are less mobile than the adults and therefore are confined to a given area. Only the adults reproduce—by controlling the immatures. There are fewer adults to reproduce.

Under field conditions, there are many instances where the insect pests have two or more generations per year. Hence, if the crop is a full-season crop, it will be attacked repeatedly. In these cases, it may be possible to control the second-generation adults, especially in cases where the immatures live in the soil.

Types of Insecticides/Miticides

Stomach poisons must be eaten in order to kill the pest. These materials must be applied to the insect's or mite's food source.

Contact pesticides kill pests that merely touch them. These pesticides must be applied to a place that the insect or mite will contact in its normal habits. The advantages of contact insecticides include the following:

- they are effective against both small and large chewing and sucking insects,
- they remain on the surface of the leaves and thus are susceptible to being broken down by exposure to sunlight and to washing off, and
- they generally are effective for 2 to 3 days, depending on weather.

Systemics are chemicals that are moved throughout the tissues of the plant or animal to which they are applied. When a pest feeds on the treated plant or animal, the systemic insecticide or miticide is ingested, and the pest dies. Some systemics are to be applied to the outside of the plant or animal to be protected; these will be absorbed through the skin of the animals or the outer covering of the plants. Others are formulated for direct injection into plants.

The systemic insecticides have several advantages and disadvantages when compared with the contact insecticides. Advantages of systemic insecticides are that they

- enter the tissue and are not lost through exposure to sunlight or by washing off,
- move in the tissue to a greater or lesser extent toward the growing point,
- give a day or two longer effective control, and
- are very effective against small sucking insects such as aphids and leafhoppers.

The disadvantage is that systemic insecticides generally are not effective against large chewing insects.

Broad-spectrum materials are those that control a wide variety of insects and/or mites. These materials may be desirable when more than one type of insect is causing damage. However, broad-spectrum materials are likely to kill beneficial insects as well as pests.

Factors to Consider

Residual effectiveness. Insecticides and miticides vary in how long they last as killing agents. Some break down into nontoxic byproducts almost immediately. These *short-term* chemicals are very good in situations where the pests do not return or where long-term exposure could injure nontarget plants or animals. For example, in homes where people and pets might be exposed to the chemical, short-term pesticides often are preferred for use. Other pesticides remain active killers for a fairly long time. These residual pesticides are very useful when the pests are a constant control problem and where they will not be an environmental hazard. For example, residuals often are chosen for fly control in livestock buildings or for termite control around wooden structures.

Type of foliage. Plants have characteristic foliage. The more leaves there are, the more dense the foliage becomes. The denser the foliage, the more difficult it becomes to achieve thorough and adequate coverage of the lower portions of the plants.

Leaf surface. Another factor to consider is the leaf surface. Some plants have a very waxy leaf surface, making it difficult to keep the spray material on the leaves. In these cases, additional spreader-sticker or wetting agent may be helpful. The applicator must keep in mind, however, that leaf surfaces are highly variable in ease of wetting. Hence, in some cases additional wetting agent or spreader may cause the spray to run off the leaf, which results in less spray deposit on the leaf than would have been present if no additional wetting-spreading agent had been used.

Spray coverage. There are several ways the applicator can check for thorough coverage. These include checking for the white residue of wettable powders after the application has dried on the foliage and using paper cards or other indicators placed at the site in the foliage where coverage is most difficult. Remember that coverage must be obtained where the insects live and feed, their microhabitat. Obviously, if the proper coverage is not being obtained, corrective adjustments must be made. You may need to adjust as follows:

- increase the gallonage,
- change the nozzles,
- fly higher or lower in the case of aerial application,
- use drop-nozzles,
- use more nozzles, or
- change the type of spraying equipment.

Time of application. An important factor to consider is the time of day you make the application. For maximum effectiveness, the insecticide must be at a lethal level at the time the insects are active.

Plant Diseases

Causes

The causes of plant disease may be divided into two basic groups—biotic and abiotic. Nonparasitic or *abiotic* diseases are caused by some condition unfavorable for plant growth, such as too little or too much water or fertilizer, improper light, temperature extremes, mechanical injury (such as hail and blowing sand), air pollution and other damaging chemicals. Included in the parasitic or *biotic* group are diseases caused by fungi, bacteria, nematodes, viruses, and parasitic higher plants. These parasitic organisms can be found inside or on the surface of the plant.

The severity of a disease will depend on many factors, especially the degree of susceptibility of the plant and the weather conditions that either favor or inhibit infection of the plant by the parasite. Some diseases are worse during cool, wet weather while others are most severe in hot, dry weather.

The disease organisms must be able to survive during periods when the host plant is not growing, such as over the winter. Many plant parasites form resistant resting structures, which remain in soil or plant parts. Some plant parasites survive inside insect, mite, or nematode vectors (organisms capable of transmitting diseases). Others may persist in seed or in weeds. Whatever the system, the life cycles of these parasitic organisms must be understood in order to choose an effective control practice.

Fungi. Some fungi attack plants and cause disease. Almost all crops may be damaged by some fungal diseases. In severe cases a fungus may cause crop failure. Most plant parasitic fungi are not so devastating, but still cause damage to crops and require the use of controls including fungicide treatments to produce a salable crop.

Fungi reproduce by structures called spores. Fungal spores may be dispersed by air currents, insects, or splashing water. Some fungi produce swimming spores called zoospores that swim in water. Spores are very small in size, but they may be so plentiful that they are seen as masses of fine powder. Spores may be white or brightly colored (usually orange or yellow), or they may be dark. Spores may be contained in larger fungal structures. For example, a mushroom is a reproductive fungal structure that produces many microscopic spores on the gills. Each fungus needs specific environmental conditions of moisture and temperature before it can attack the plant and cause disease.

Bacteria. A small number of kinds of bacteria cause diseases of plants. Bacteria may be spread in a variety of ways including splashing rain, water, soil movement, insects, or infected seeds and plants. Some bacterial plant pathogens can thrive on plant debris and in soil, but most require a living plant. Bacteria may enter the plant through wounds or through natural openings such as plant stomates. Bacteria can multiply rapidly inside plants where they may kill plant cells causing spots, blights and rots, or cause abnormal tumor-like growths, or block the water-conducting tissues producing wilt. Bacteria often move throughout the plant, becoming systemic.

The "yellows" diseases are caused by *Mycoplasma*, unusual bacteria that lack a rigid cell wall. For a long time these "yellows" diseases were thought to be caused by viruses because the *Mycoplasma* is difficult to see. Aster yellows is a common vegetable disease caused by a *Mycoplasma*.

Viruses. There are many viral diseases of plants. A particular virus is very specific in the type of host it infects; viruses that cause plant diseases are not known to infect animals. Once the virus is inside a host cell it takes control of the cell, and directs the cell to produce material to make more viruses. This disturbs the normal operation of the cell, producing a variety of symptoms.

Symptoms produced include mosaics, where leaf tissues show patterns of light and dark green color and distorted plant parts such as wrinkled leaves or stunted plants, ring spots, or yellowed leaf veins. Often plants can be infected with one or more types of virus and yet show no symptoms. Once the plant is infected, it cannot be cured.

Viruses may remain from season to season in perennial weeds, inside insects and nematodes, and in seed. Thus controlling insects, nematodes, and weeds should reduce the severity of many virus diseases on crops.

Nematodes. All nematodes that attack plants are small, ranging in size from 1/50 to 1/8 of an inch long. These colorless worms feed by using a rigid spear-like structure (the stylet) to pierce plant cells. The stylet and other nematode body features can be seen only with a microscope. Many different nematodes may be found associated with plants, and most are not damaging to plants. The only way to determine if nematodes are the cause of plant disease symptoms is to extract the nematodes from plant and soil, identify and count them.

A few nematodes feed on leaves and shoots causing leaf spots, blights, malformed growth, or wilts. Most plant parasitic nematodes feed on plant roots and are found in soil near plants. The plant's symptoms may be vague such as not growing well, failing to respond to fertilizer, and having poor color. Close examination of roots may reveal browned areas in roots, swelling on the roots, or a greatly reduced root system.

The damage caused to crops by nematodes is determined by the number of nematodes, weather factors, and the susceptibility of the crop to each kind of nematode. If nematode populations are low, damage will be slight.

Parasitic seed plants. A variety of higher plants have evolved as parasites of other plants. Familiar examples of parasitic plants include mistletoes on oak trees, and dodder on some vegetables and foliage plants. Parasitic plants attach to the host plant and extract nutrients from its roots or stem.

Diagnosis

A plant disease may be defined as any change from normal plant growth. These changes from normal growth are called symptoms. Symptoms caused by biotic agents usually appear slowly and gradually become worse. Biotic agents causing plant diseases are usually microscopic in size, but many produce larger structures, called *signs* by plant pathologists.

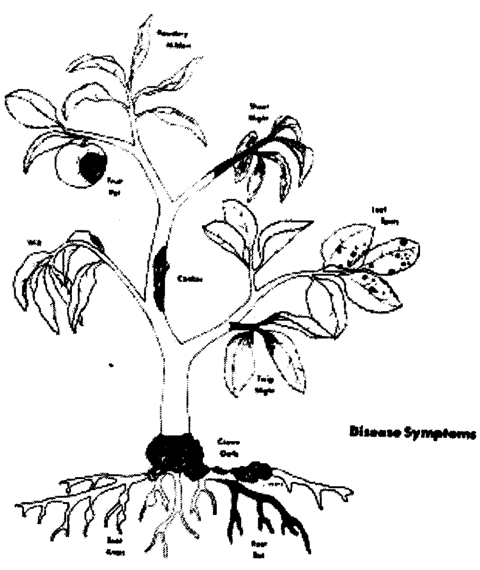
Since symptoms are the most obvious feature of plant diseases, we may group diseases together by the types of symptoms observed. Effective control methods depend on an accurate diagnosis of the cause of disease symptoms. Symptoms and signs can be useful in identifying the cause of a plant problem when combined with other information about the sick plant. Unfortunately, many different causal agents produce similar symptoms. Signs are much more useful in determining the exact cause of the disease. The following is a list of disease symptoms and signs with advice on other clues to look for to help in diagnosing the problem.

Wilt. When shoots and leaves are not getting enough water they become soft and wilt. Eventually wilted plants will begin to die from the tips and edges inward. Wilts may be caused by anything that interrupts the flow of water up from the roots: dry soil, excessive heat, root disease, physical damage to roots or stems, a girdling canker, or a vascular wilt disease. Look for evidence of damage to roots and bark. Look for discoloration in plant tissues just under the bark by cutting into the bark and peeling back a small part. A brown or olive green discoloration may indicate a bacterial or fungal vascular wilt disease.

Root rot. Plants with root rot diseases grow poorly. Foliage may be off color and smaller than normal. When most of the roots are dead, the entire plant will die. Diseased roots are usually darkened and decayed. Woody roots may become spongy. Many root rots of trees are caused by fungi that produce large fruiting structures, such as mushrooms and shelf fungi on or near the base of the tree.

Leaf spots. Most of the leaf is normal but spots or blotches appear on portions, and may cause affected leaves to yellow and drop. Leaf spots may be caused by insect or mite feeding as well as by fungi and bacteria. Many fungal leaf spots have small fungal fruiting bodies that look like little dark lumps or blobs about the size of the head of a pin, and can be seen scattered in the browned leaf tissue. Some fungal leaf spots produce a target pattern of concentric rings. The rust fungi often produce leaf spots with bright yellow or orange powdery spore masses. Bacterial leaf spots may have a water-soaked yellow margin around the spot. When very young leaves have many leaf spots, the leaf may be distorted and fail to expand properly. Spotted leaves often turn yellow and drop prematurely.

Cankers. Both woody and herbaceous plants may develop canker diseases. A canker is a sunken diseased part of a stem or branch. Often fungal cankers have fruiting bodies scattered uniformly in the dead area. Bacteria may also cause cankers. Bacterial cankers often have a sticky ooze at the edge of the canker. Damage by some insects that bore and tunnel under bark may be confused with canker diseases. Insects usually make tunnels and leave sawdust in the canker.



Galls and other excessive growths. Galls are enlarged lumps of plant tissue. Most galls caused by fungi or bacteria (such as crown gall) are somewhat disorganized looking on the surface and may produce fungal spores erupting from the surface. Insects and mites may produce galls on leaves, twigs, or stems. Most insect and mite galls have a more organized appearance. Cut into the gall and look for the insect or mites inside. Nematodes may cause galls or swellings on roots and other parts of plants.

Principles of Disease Control

Breeding crop varieties for resistance to important diseases is a common method of disease control. Most of the preliminary work is done in laboratories and test plots, and by seed increase organizations. The finished product is then sold to the grower.

Chemical control is quicker and more flexible. The chemicals used most frequently are fungicides, although a few bactericides and virucides are available.

Changing cultural practices is a practical method of disease control. Continuous culture with the same crop can result in a rapid buildup of a disease organism. Rotation with other crops slows down this buildup. The environment can favor an organism and hence result in more disease. Poor drainage and soil compaction favor certain soilborne fungi. Improving soil drainage along with aeration and improving soil structure with proper tillage and organic matter can reduce injury from soilborne fungi.

Fungicides

All fungicides work through contact with the fungus; therefore, most fungicides are applied over a large surface area to ensure direct contact of every individual. Some fungicides are systemic and are designed to be fed or injected into the plant. The systemic fungicide is then transported throughout the plant, killing the fungi. There are important differences between the two main types of fungicides that the pest manager must understand in order to choose a chemical that will be effective in any given situation.

Protectants. These sprays are applied before infection occurs. They set up a chemical barrier between the susceptible plant tissue and the germinating spores. Since new surface is exposed during constant growth, repeat application is often necessary. These fungicides are useful when a particular disease or group of diseases is likely to attack a plant under certain known conditions. This method is not economical when there is a low gross per acre except in special circumstances. The success of a protective spray program depends on the frequency of application, the ability of the compounds to resist the weathering action of sunlight, rainfall and dew, and the growth rate of the plant.

Eradicants. These sprays may be applied for a certain time after infection occurs and still destroy the pathogen and prevent damage. Eradicants often are used when protectants are not available, were not applied in time, or are too expensive. They also are useful for diseases that appear unexpectedly. Eradicant compounds should be used at the full recommended rate since lesser rates may reduce or negate effectiveness. To use these materials effectively, the grower must understand and record the progress of disease development and the concurrent weather conditions. The eradicant must be applied regardless of the weather to achieve control. Excessive delay in application of the eradicant spray may allow the pathogen to become established in its host beyond the period where the eradicant can confine and eliminate disease development.

Seed treatment is an important method of disease control with fungicides. An effective fungicide intercepts the transfer of a fungus from one crop to the next via the seed. Fungicides can be applied during seed treatment to protect the young seedling and reduce seed decay from organisms, which are in the soil. The liquid form may be a true solution, a wettable powder mixed with water, or a flowable form applied with slurry treater. The dry or dust application is a mechanical mixing; the dry fungicide is applied to the seed in the drill box or planter box. Dry methods can result in imperfect control because of incomplete coverage of the seed.

Tolerance to fungicides. Development of tolerance to fungicides has been rare under field conditions. However, recent experience with some of the new organic fungicides (especially those with systemic action) with selective action on fungi indicates fungicide tolerance can be a problem.

Although it is seldom possible to determine the source of tolerant fungal strains, the pattern of fungicide application has a marked effect on where tolerance problems will occur. High and continuous selection pressure, such as from using one fungicide or closely related fungicides year after year, tends to enhance the tolerant population. Thus, detectable populations of benomyl-tolerant fungi have been found primarily where benomyl was used regularly and exclusively for several years.

In order to reduce the emergence of fungicide tolerance in the field, specific classes of fungicides should not be used exclusively through the growing season or year after year. Rather, classes with different modes of action should be rotated.

Nematicides

To kill nematodes, nematicides must enter their bodies. Penetration may occur through skin or body openings, or by ingestion. Some nematicides reduce nematode activity by suppressing feeding and/or reproduction rather than by killing them. Nematicides may be brought into contact with nematodes by mechanical dispersal through the infested soil, watering them in, or gaseous diffusion of a nematicidal fumigant through the pore spaces of the soil.

Complete eradication of soil-borne parasitic nematodes through soil application of nematicides is impractical for field conditions. Instead, the objective of treatment is the reduction of nematode populations to a level where serious damage will be prevented. Complete eradication is possible; however, in limited volumes of soil, such as in greenhouses and seedling production.

Nematicides generally are used as a preventive measure. Likelihood of damage often can be predicted in field situations where good records of pest damage have been kept. Control procedures usually are based on preplant or time of planting application.

Soil fumigants are used to reduce infestations of soilborne nematodes, fungi, insects, and weed seeds. Most soil fumigants are injected into the soil as liquids. They then volatilize to a gas, diffusing through the soil. Immediately following application the soil must be sealed using a drag, roller, water, or polyethylene tarp to maximize the effectiveness of the treatment. Soil porosity, soil moisture, temperature, and organic content of the soil affect control results.

Contact nematicides must be applied, mixed into or carried by water into contact with the nematodes. They may be applied before or at the time of planting. When such chemicals are used, care must be taken to place the seeds into the treated portion of the soil. Label directions must be followed carefully to prevent injury to germinating seeds or seedlings. Chemically, contact nematicides are generally either organophosphates or carbamates.

Weeds

Identification

A weed is defined as a plant out of place. Weeds have been responsible for huge expenditures of money and energy. They may be problems because land use is less efficient, product quality may be reduced, crop yields may be reduced, beauty of turf and ornamental plantings may be affected, rights-of-way may be obstructed, and enjoyment of outdoor recreation may be diminished.

Weed names. The pest manager must be able to identify weeds by their common names in order to choose the correct herbicide for the job.

Life Cycles

Weeds can be grouped according to the length and timing of their cycles.

Annual weeds grow from seed, mature and produce seed for the next generation in 1 year or less. Whether they are grasses or broadleaf weeds, annuals are easiest to control when young. Herbicides, if necessary for control, should be applied early in the growing season not only to kill existing annuals, but also to prevent seed formation.

- Summer annuals are plants that result from seeds germinating in the spring. They grow, mature, produce seed, and die before winter each year.
- Winter annuals grow from seeds that germinate in the fall. They grow, mature, produce seed, and die before summer each year.

Biennials. These plants require two years to complete their life cycle. They grow from seed that germinates in the spring. Biennials develop a heavy root and a compact rosette, or cluster of leaves, the first summer, then remain dormant through the first winter. In the second winter they mature, produce seed, and die before winter.

Perennials. These plants may grow from seed, but many produce tubers, bulbs, rhizomes (below-ground stems), and stolons (above-ground stems). The above-ground portions of these plants may die back each winter, but new above-ground parts develop each spring.

- Creeping perennials produce rhizomes as well as seeds.
- Simple perennials produce seeds each year as their normal means of reproduction. In some instances, root pieces may produce new plants following mechanical injury during cultivation.
- Bulbous perennials produce seed and bulbs. They may form above-ground bulbs like wild garlic, or below-ground bulbs like wild onions.

Principles of Herbicide Use

Types of Herbicides

Selective herbicides kill some plants but cause little or no injury to others. Usually they kill either most broadleaf plants or most grasses. Some very selective herbicides kill only certain plants in a group. The degree of selectivity is affected by plant age, rate of growth, stage of the plant, and physiology.

Nonselective herbicides are toxic to all plants. They are usually used in areas where any living plants are undesirable. Some nonselective herbicides may be made selective by varying the dosage, directing the spray, or using spray additives such as wetting agents. Selective herbicides may be made nonselective by manipulating the same factors.

Soil sterilants are nonselective herbicides that kill all plants and prevent reestablishment of weeds for a relatively long period.

Contact herbicides kill the plant parts on which the herbicides are deposited. These herbicides destroy only the above-ground parts of plants. They are effective against annual weeds.

Translocated herbicides may be absorbed by leaves, stems, and/or roots. Once absorbed, they are moved throughout the plant. Root absorption and translocation occurs in the water-conducting tissues (xylem), whereas leaf or stem absorption and translocation occurs primarily in the food-conducting tissues (phloem).

Plant growth regulators increase or decrease the normal rate of growth or reproduction of a plant. Some growth regulators are used to either hasten or delay the normal harvest date. Others are used to obtain better quality and/or yield.

Defoliants and desiccants are often used to make plants easier to harvest. Defoliants cause the leaves of a plant to drop off prematurely. Desiccants draw moisture out of the plant, causing it to wither and die.

Preplant herbicides are applied before the crop is planted. These chemicals may be used in seedbeds or incorporated into soil prior to planting.

Preemergence herbicides are applied before both the crop and the weeds appear, or after the crop is up but before the weeds appear. The label directions will state "preemergence to the crop," "preemergence to weeds," or "preemergence to both crop and weeds."

Postemergence herbicides are applied after the weeds appear. These applications must be very selective, as they must control the weeds but leave the crop unharmed. Often these chemicals are applied postemergent to the crop, but preemergent to the weeds.

Methods of Application

Broadcast applications are made over an entire area of foliage or soil.

Band applications are applied in a strip along plant rows. Directed applications are aimed at the base of plants and are kept off of foliage.

Spot treatments are applications to small areas or to clumps of weeds made with hand sprayers.

Factors Affecting Herbicide Application Results

Many factors affect the movement of a herbicide to the site of action. Knowledge of these factors is helpful in obtaining more consistent responses.

Application rate. Very small amounts of herbicide can inhibit plant growth. However, sufficiently high rates must be used to compensate for the amount bound to soil or otherwise made unavailable for uptake by the plants. Rates must not be high enough to cause crop injury or excess residues.

Uniformity of distribution. Nozzles must have a uniform delivery, a uniform spray pattern, even spacing, and proper height to give uniform coverage. Uniformity of concentration and delivery rate is essential. Therefore, correct nozzles, sprayer speed, agitation, pressure, and dilution are important. Granulars present a greater problem with regard to obtaining uniformity.

Soil interception. An even, uniform surface, free of clods, manure, plant litter, and other debris will help ensure a good distribution pattern. Spray droplets cover the upper surfaces of clods, but not beneath, while granulars fall in depressions. Granular formulations again present a greater problem on uneven surfaces.

Interception by leaves. The angle formed between the leaf and stem, degree of hairiness, expansion, and the ratio of leaf area to dry weight vary. In annuals, the greatest leaf area to dry weight ratio occurs in the seedling stage. In perennials, the greatest ratio occurs later, so treatment should be delayed until considerable growth has developed. Depending on the situation, a canopy of leaves can be either a deterrent to effective control or a safeguard against injury. Wetting conditions will affect interception by changing leaf orientation and reducing leaf area.

Retention. Keeping spray droplets on the leaf is an important consideration once contact with the leaf has been made. The type of leaf surface, such as waxy coating, hairiness, or roughness will affect retention. Use of wetting agents and other materials that will lower surface tension, nonpolar formulations (esters), low spray volumes, and will increase retention. Other measures to increase spray droplet retention include use of nonpolar formulations (esters), low spray volumes, and wetting agents and other materials that will lower surface tension.

Weather conditions. Runoff can result if rain occurs during or shortly after application. For many herbicides, 1 to 2 hours without rain is enough time for penetration and absorption. Herbicides can volatilize from leaf surfaces when exposed to high temperatures.

Physical movement. Wind and water (excessive rainfall) cause runoff or movement from treated areas. Movement is toward depressions, causing increased concentrations in these areas. Some leaching into the soil is necessary for effective control. Incorporation into the soil will benefit some herbicides but distribution may be uneven or placement too deep. Band applications are lost when untreated soil is mixed in by the cultivator.

Volatility. This is a major form of loss for certain herbicides. High soil temperatures and air movement increases volatility losses. Damp or wet soil at the time of application can cause additional losses through water vapor distillation or by keeping the herbicide concentrated in the exposed surface layer as water moves to the surface. Incorporation reduces volatility losses.

Photodecomposition. Many herbicides are broken down by exposure to sunlight. Losses occur when herbicides remain on the soil surface for extended periods.

Solubility. Movement into the soil is related to solubility; therefore, salts will move more readily than wettable powders. Additional rainfall is needed to get wettable powders into the upper 1/4 to 1/2 inch of soil.

Movement in soil. Water transport provides for the greatest amount of herbicide movement in the soil. This occurs primarily when there is sufficient water to exceed field capacity. Diffusion in soil water is important only in the vicinity of roots. Diffusion in soil gases plays a part if the herbicide is quite volatile. The greatest movement is downward; however, some lateral and some upward movement occurs. Movement varies greatly in different soil types.

Degradation. Breakdown of the chemical is by chemical and biological processes. Temperature, aeration, pH, and other soil factors will affect chemical processes such as hydrolysis and oxidation. The degradation by microorganisms is one of the major means of herbicide loss from soil. Organisms may be specific for a particular herbicide and their numbers will increase when repeated applications are made. Conditions that favor growth of microorganisms will speed breakdown.

Adsorption. A great deal of variability exists in the amount of herbicide adsorbed by soil because soils differ in organic matter and inorganic soil colloids. Soil that is high in organic matter adsorbs herbicides more strongly and thereby greatly reduces the amount of chemical available and also retards movement of herbicides through the soil.

Absorption. This is the means of entry into the plant and it is favored by high humidity, high soil moisture, and conditions that favor rapid growth. The amount of root system exposed is important since amount of herbicide absorbed is generally proportional. A heavy plant population may reduce the amount absorbed by any one plant as well as concentration of herbicide in the soil.

Translocation. Herbicides tend to move to regions of high activity such as buds, young leaves, seeds, storage sites, and growing points. Excessive application rates or contact injury can reduce translocation and should be considered before combining herbicides in one application. Movement of some herbicides out through the plant roots has been demonstrated. This will reduce the amount available to the plant, and the response will be altered accordingly.

Activation and deactivation. Some herbicides are activated by an enzyme system after entering the plant, while others are deactivated by being broken down within the plant. The rate or degree of degradation is influenced by conditions affecting plant growth such as temperature, sunlight, and moisture.

Accumulation. The rates of absorption and translocation affect accumulation.

Cellular sensitivity. The ultimate response of a plant to an herbicide is at the cellular level. Susceptibility varies through the season and the year. Maturing plants develop varying degrees of tolerance. Mature or less active tissues may show little response to a dose that would have caused injury at an earlier stage of the plant.

Decontamination of Application Equipment

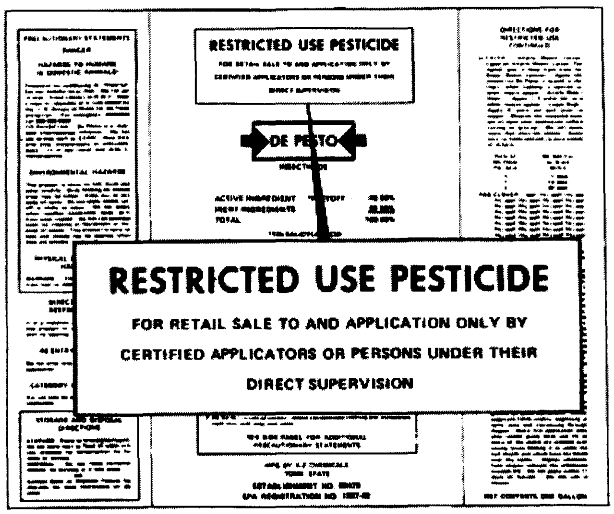
When you are using only preemergence sprays, a good rinsing with water is enough. For other spraying purposes, remove weed killers from sprayers by adding 1 gallon of household ammonia or 5 pounds of salt soda to 100 gallons of water. Allow this solution to stand in the sprayer for at least 2 hours. Drain it out through the boom and nozzles, and rinse the sprayer with water. Do not let spray solutions stay in the tank overnight. Do not allow solutions to run into streams or other water sources.

Key Pesticides

In this section you will find specific information on some of the pesticides commonly used by pesticide applicators in this category of pest control work. For more information, consult the pesticide label or your local extension office.

Restricted-Use Pesticides

Pesticides are classified for restricted use if there is reason to believe they may cause harm to people or the environment even when used according to label directions. Understanding why pesticides you use are classified for restricted use will help you avoid endangering yourself, others, or the environment. Some common reasons include acute or chronic toxicity to humans, effects on wildlife, or potential for groundwater contamination.



Cholinesterase Testing

Organophosphate and carbamate insecticides are cholinesterase inhibitors; that is, they reduce the amount of cholinesterase available for the body's use. Cholinesterase is a substance, called an enzyme, that is made by the body and is necessary for the body to work properly. When the available amount of this important enzyme is reduced below a critical level, nerve impulses to the muscles can no longer be controlled, and death may occur. Depression below the critical level may occur from a single, large exposure, such as spilling the insecticide on your clothing and not washing it off immediately, or from a series of small exposures over a long period of time, such as applying these insecticides according to label directions throughout the season. Some applicators may exhibit some of the symptoms of overexposure within 48 hours of an application, after which the symptoms may disappear until the next exposure. Symptoms include headaches, dizziness, blurred vision, sweating, nausea and vomiting, stomach cramps, diarrhea, excessive salivation (drooling), tightness of the chest, muscle twitching, and pinpoint pupils.

Applicators who work with organophosphates and carbamates should ask their physicians about having regular cholinesterase testing done. This consists of monitoring the level of cholinesterase available in the blood throughout the application season. Since the amount that is normal varies from person to person and also changes from time to time, somewhat like a blood pressure reading, it is essential to have a baseline cholinesterase level established before exposure; that is, you should have a cholinesterase test before you begin applying these insecticides each year. Your physician can then compare later cholinesterase tests taken throughout the season with your baseline value to determine whether the level of cholinesterase available has dropped significantly. If it has, you do not use any organophosphate or carbamate insecticides until the cholinesterase level has returned to your normal level.

Following label directions, wearing clean protective clothing, and showering after each application will help keep your exposure low. However, since some people have a lower baseline amount of cholinesterase available, cholinesterase monitoring throughout the season is strongly recommended for those who use organophosphates and/or carbamates frequently.

The following list includes some organophosphate and carbamate insecticides that may be used by applicators in this category. Insecticides are listed by common name followed by familiar trade names in parentheses.

Organophosphates

acephate (Orthene)
Aspon
azinphos-methyl (Guthion)
carbophenothion (Trithion)
chlorpyrifos (Dursban)
diazinon (Spectracide)
dichlorvos (DDVP, Vapona)
dicrotophos (Bidrin)
dimethoate (Cygon, De-Fend E-267)
dioxathion (Delnav)
disulfoton (Di-Syston)
ethion

ethoprop (Mocap)
fensulfothion (Dasanit)
malathion (Cythion)
methidathion (Supracide)
naled (Dibrom)
oxydemeton-methyl (MetaSystox-R)
parathion
phosmet (Imidan)
tetradifon (Tedion)
trichlorfon (Dylox, Proxol)

Carbamates

aldicarb (Temik)
bendiocarb (Turcam)
carbaryl (Sevin)
carbofuran (Furadan)
methiocarb (Mesurol)
oxamyl (Vydate)
pirimicarb (Pirimor)
propoxur (Baygon)

CHAPTER 2

NURSERY AND LANDSCAPE ORNAMENTALS

If you are a commercial applicator, you should study this chapter if you wish to become certified in the Ornamentals subcategory of Category 3.

Ornamental Plant Management

Pest control in nurseries and landscape plantings includes good cultural practices as well as chemical applications. Problems often result from causes other than pests. Be sure to consider these factors when developing a pest management program.

Factors Influencing Pest Problems

Pretransplant injury. When a recently transplanted plant fails to grow and when the cause cannot be associated with drought, excess moisture or insufficient roots, it is possible that the plant might have been injured prior to planting. It might have dehydrated while in storage or in transit, or it might have been subjected to an excessively high temperature.

Insufficient root system. Plants that have been transplanted recently may not have a large enough root system to support the crown of the plant. Therefore, it is desirable to prune the crown of trees and shrubs that have been transplanted to help reduce the amount of transpiration during the reestablishment period. When pruning trees, do not cut the central leader; rather, thin out and help shape the tree or shrub in its natural form.

Sometimes trees are dug with a root system that is completely inadequate for the size of the plant. Such plants should not be accepted for planting. Industry standards have been established to assist in determining proper root ball diameter.

Change in grade. A change in level of the soil or some type of construction work in the vicinity of plants will change the soil environment, which for some species of plants can result in their decline and eventual death. A few inches of clay fill over the roots of a beech tree or dogwood can be disastrous. Disturbing the roots of hard maples will often result in their showing early fall color and eventually the death of branches followed by death of the trees. Plants showing damage on one side may have had pipeline trenching disturb the roots on the affected side.

Soil pH. In order to make good growth, plants should be grown in soil with an optimum pH (soil reaction). Most plants grow well in a pH range of 5.5 to 7.5. However, some plants such as blueberry, holly, pin oak, and rhododendron require acid soil (pH 4.5 to 5.5). Such acid-loving plants will develop iron chlorosis when grown in alkaline soils (pH 7.5 to 8.5). Red and silver maple will exhibit manganese chlorosis in similar sites.

Malnutrition. Plants require certain elements that are essential for growth and proper development. An inadequate supply of a particular element can cause the plant to be stunted, have yellow, mottled or scorched foliage and if completely lacking can result in the death of the plant. Three of the more common deficiencies associated with ornamental plants are detailed below.

- *Nitrogen* deficiency causes yellowing of the foliage. Although the entire plant may show the symptom, it will be expressed in the oldest leaves first.
- *Potassium* deficiency produces browning along the margins of the older leaves, which will become scorched. Older foliage will drop prematurely producing a leggy appearance.
- *Iron* deficiency causes a yellowing of the tissue between the veins while the tissue adjacent to the veins remains green. Iron chlorosis is associated commonly with plants growing in soil with a pH above the optimum for that species.

Soil tests can be used to determine the levels and balance of the mineral elements in your soil. Application of the appropriate fertilizer can correct the deficiency. However, it should be recognized that similar symptoms may result from other causes and that fertilizer is not a cure for all the ills of plants.

Excess soluble salts. Too much fertilizer, especially soluble forms, can cause problems in the growth and development of plants. Plants growing in containers (pots or planter boxes) without drainage holes can become the victims of a buildup of salt within the container. Plants exposed to either of these conditions will dehydrate. The rapidity of dehydration will depend on the concentration of salt. The condition will develop slowly in containers unless fertilizer was applied, in which case the desiccation will be as rapid and injurious as when too much fertilizer is applied to plants in the garden. Always follow instructions when using fertilizer on plants, and avoid growing plants in containers without drainage holes. If too much fertilizer has been applied, it might be leached out of the root zone by applying liberal quantities of water to the soil. Soluble salt problems can be confirmed by making a conductivity test with the aid of a solu-bridge on a sample of soil.

Lack of water. All plants require some water and most plants require large quantities if they are going to grow in a normal manner. Although most plants receive adequate moisture as a result of rainfall or by artificial means, there are times when plants can dehydrate, particularly following transplanting or if they are growing in containers or in various adverse sites in a landscape (such as under a building overhang). Following transplanting, plants should be watered periodically until well established. Plants in containers and in adverse sites should be watered on a schedule to assure adequate supplies of water for their growth. Be sure to remove plastic burlap commonly used to wrap root balls of balled and burlapped plants.

Excess water. Too much water about the roots of most plants used in the landscape can result in their decline and ultimately in their death. Plant roots require some oxygen in the soil for good growth and development. Planting sites should be well drained or measures taken to artificially drain the site prior to planting. Drainage systems must be connected to free flowing drains to be effective. Often plants are placed in a shallow depression hollowed in heavy clay soil. These conditions allow little or no drainage even if rocks or gravel are placed in the bottom of a planting hole. Do not cover soil surface of planting sites with plastic if the soil is a clay or clay loam and is subjected to excess rainfall, runoff water, or irrigation.

Weather. The forces of nature can produce some dramatic forms of injury to plants. However, they also can produce injury that is more subtle and more difficult to identify as to possible cause.

- *Lightning injury*, although not too common, can be the most dramatic form of injury. Most trees struck by lightning, but not all, will have large areas of wood exposed with bark hanging in shreds. However, at times there may be no visible symptoms and the diagnosis may have to be made on circumstantial evidence, such as whether there was a recent lightning storm. Trees struck by lightning may die within a few days, live for a number of years and then die, or survive for many years. However, trees with exposed wood should be treated by an arborist.
- *Snow* that is wet and piles up on the branches of plants can damage them in the form of breakage. A more subtle form of injury can result to broadleaved evergreens (such as boxwood) that are bent to the ground as a result of snow, recover in the spring but die the following year. This delayed symptom is the result of physical damage to the bark of the branches while under stress from snow. It can be prevented by providing some means of physical support prior to the onset of winter.
- *Hail* causes physical injury to leaves and stems. In some cases, branches injured by hail may die. Damage is usually limited to the side from which the storm carrying hail approached.
- *The winter environment*, especially late winter, can cause problems to many plants, including freezing injury to buds and shoots, desiccation of evergreen foliage, and cracking of stems. Some evergreens (especially broadleaved evergreens) when exposed to the direct rays of the sun of late winter while the ground is still frozen will winterburn because of the lack of moisture or from extreme temperature changes.
- Wind can sometimes cause serious problems to plants, particularly when it carries sand that

injures the stem, commonly at the groundline. This form of injury can be prevented by maintaining a cover crop on the ground to stabilize the sand.

- High temperatures often will result in a short flowering period and if moisture is in limited supply will contribute to leaf scorch. Fire will scorch foliage and can destroy the cambium, which results in the death of plants.

Chemical injury

- *Air pollution* in industrial or large urban areas can cause damage to sensitive species. In such a situation, the problem is widespread and not limited to a single yard but will cover a larger area. Avoid planting sensitive species but, better yet, act to clean up the air. Pollutants such as ozone and sulfur dioxide have characteristic injury patterns that differ depending on the plant species.
- *Gas leaks* can cause either rapid or slow death of plants. If trees and shrubs have been growing vigorously for a number of years and then suddenly decline in vigor, even die within a matter of days, consider the possibility of gas injury to the plants if they are within 100 feet of a gas line. The gas company can check the area with a gas detection meter. However, before calling the gas company, check for girdling roots or other causes of the decline.
- *Animal urine* can be toxic to lawns and ornamental plants. Female dog urine can cause circular dead spots in the lawn and the urine of male dogs can cause unsightly brown areas on the lower portion of valuable evergreens. Cats confined to a small area can cause injury to many plants because of the excess salt problem that develops where they urinate. Various repellants are available to discourage visits by stray dogs. However, repeat applications are necessary.
- *Septic tanks.* For years, tree roots have been a problem to the proper functioning of drain fields. More recently, drain field effluent has been causing problems to trees. Borax and chemical agents used in laundry and cleaning products are leached into the soil where they injure plants growing in close proximity to the drain.
- *Spray injury.* Applying the wrong chemical or improperly applying a pesticide can cause injury to plants. The most common form of spray injury is leaf burn, particularly the margins or tip of the leaf. The propellant in aerosol sprays or the emulsifying agent can be responsible for injury to some plants. Dormant oils applied when temperatures are below freezing can also be responsible for plant injury.
- *Herbicides.* If the new growth of plants is malformed and the leaves are cupped and chlorotic (yellow or white), a herbicide may have been applied in the vicinity of the plants. Some weed and feed lawn fertilizers contain herbicides that should not be applied within the root zone of valuable trees and shrubs. Spray application of weed killers should be made only on calm days to prevent drift onto valuable plants. Nonselective herbicides should be used with caution as they may wash into areas where they could kill valuable landscape plants. Spray equipment used to apply weed killers should not be used for other purposes.
- *Road salt.* Drift from highways following the application of salts in winter can cause serious injury to sensitive plant species (such as white pine, red pine, red oak, or crab apple).

Vertebrate animals. Animals of all kinds can cause considerable damage to plants. Girdling of the stems of plants by certain rodents and rabbits is common, especially following severe winter weather. In addition, rabbits can chew the bark of young plants. Deer will eat the foliage, bark, and tender shoots of plants. Other large animals can damage trees by clawing or rubbing the bark off tree trunks, chewing the foliage, compacting the soil (when confined to a small area), and by breaking the plants.

Much of this type of injury can be prevented by fencing out animals or by applying various repellants to young plants, especially before the onset of winter.

Girdling

- *Ropes.* A decline in vigor may result from the girdling action of a wire or nylon rope encircling the stem, or to the action of girdling roots or vines. Nondeteriorating ropes used to secure the ball of soil during transplanting, and guywires that supported newly planted trees should be removed when no longer needed. At the time of planting, be sure that the roots are distributed properly in the planting site and that there are no encircling roots on plants that were produced in containers.
- *Rodents and rabbits.* Most rodent and rabbit damage occurs during winter months when animals' natural food supply is short. This form of damage can be minimized by carefully using poison bait and keeping the area clear of weeds.
- *Mechanical injury.* Many of the activities of people also can result in girdling valuable plants. Injury caused by mowers has increased considerably with the use of riding mowers. Cultivator or hoeing injury often will kill young plants. Employees should be instructed to avoid direct contact.

Delayed graft incompatibility. Although not a girdling action, this is somewhat similar in end results. The union of some grafted or budded plants fails to function and the plants die. Very often this is preceded by a massive floral display or early fall color. Inarching (grafting) can sometimes be used to repair a tree. Normally when the condition is noted, it is too late to inarch.

Diseases of Ornamental Plants

The following descriptions of some common diseases on ornamentals emphasize diagnosis and control options. For more detailed descriptions of symptoms and specific chemicals and rates, consult extension bulletins.

Diseases Caused by Fungi

Apple scab is probably the single most important disease of apples in the eastern United States, because many fungicide sprays are needed to control it. Ornamental crabapples may be defoliated by midsummer by scab.

The apple scab fungus, *Venturia inaegualis*, produces olive green, faintly velvety spots on young apple leaves. Fruit also is infected causing malformed fruit with dark scabby spots. Leaves with many spots may yellow and drop early. Microscopic fungal spores are produced on the surface of leaf and fruit spots. When it rains, these spores are splashed to other leaves to cause new infections. Infections continue whenever it rains throughout the growing season.

The fungus overwinters in fallen leaves. Early in the spring, following rainy periods, the fungus in the fallen leaves ejects microscopic spores into the air, which carries them to young apple leaves for the first infection of the growing season.

The best control for apple scab in the landscape is the use of scab-resistant apple and crabapple cultivars. The frequent application of fungicide sprays, starting when new leaves appear, and repeated throughout the season will give good control, but may be impractical in landscapes.

Petal blight is a very common disease of azaleas and rhododendrons in Maryland. The fungus *Ovulinia azalea* attacks flower petals throughout the flowering season resulting in a rapid collapse and browning of flowers. Petal blight can be prevented through the use of a fungicide spray program.

The first symptoms of petal blight are small, circular, water-soaked spots on petals; spots appear white on colored flowers, tan on white flowers; spotted petals are slimy to the touch. The spots enlarge rapidly and grow together causing collapse of the flower, which hangs limply, later drying and remaining on the plant well into summer. In mid- to late summer, small, dark, hard fungal structures 1/8 to 1/4 of an inch across, called sclerotia, are formed in blighted petals. In the spring, small mushroom-like fungal structures (apothecia) sprout from the sclerotia and discharge many spores, which are carried by wind to flowers. The fungus only attacks petals, so the damage is aesthetic; plants continue to grow and set new buds for next season. However, the spectacular flower display is the major reason why azaleas and rhododendrons are grown, so it is useful to recognize and control this disease, which if not controlled, can destroy all the flowers in large plantings in a few days.

Petal blight can be effectively controlled only with fungicide sprays. No azaleas have good resistance to petal blight.

Cedar-apple rust, quince rust, and ***hawthorn rust*** are caused by fungi in the genus *Gymnosporangium*. These rust fungi require two types of plants, a pomaceous plant (e.g., apple, hawthorn, pear) and a cedar, in which to grow. *Juniperus virginiana*, the eastern red cedar, is the most common rust-susceptible cedar in Maryland. Conspicuous symptoms are produced on both apples and cedars; fungal spores produced on one type of host plant are carried by wind to infect the other. Spores produced on apple cannot reinfect apple and vice-versa.

These rusts damage many popular ornamental plants. Colorful leaf spots, and twig and fruit malformations are produced on pomaceous plants. Peculiar round leaf galls, twig galls, cankers, and twig dieback are produced on cedar hosts. An understanding of the life cycle of these rust fungi is needed before control measures can be applied effectively.

The best control for these rusts on apples and crabapples is the use of resistant cultivars. Consult your county extension educator or nursery catalogs for available cultivars.

Fungicide sprays provide excellent control of the leaf-spotting stages of these rusts on pomaceous plants because the fungal spores that infect these plants are produced only during a short period in the spring. Fungicides are less effective in preventing the rust galls on cedars because of the long period, July through September, when cedars may be infected. Attempts to prevent infection of pomaceous plants by treating cedars are futile in most of Maryland where the eastern red cedar is common.

Cytospora canker of spruce. Blue spruce, *Picea pungens*, and other *Picea* species may be attacked by the fungus *Cytospora kunzei*, which can kill lower branches and eventually kill the entire tree. Examination of the affected branches, by cutting into the bark in areas where the pitch is oozing, will reveal that the wood beneath the bark has a red-brown, resin-soaked appearance. Close inspection finds small, blackened areas just beneath the surface bark. These black "spots" embedded in the bark are the fruiting structures (pycnidia) of the fungus *Cytospora kunzei*. In wet weather spores ooze out of these pycnidia and are washed to other branches where they can invade through wounds.

In addition to the *Cytospora* canker, infestations of insects and mites frequently are found. Dead and dying limbs are favorite breeding sites for several kinds of bark beetles that excavate galleries under the bark. Small round holes can be seen in the bark, and the bark can be chipped off easily, revealing the sawdust filled galleries. Spruce spider mite, pine needle scale, and spruce bud scale also are present often on declining spruces. Of these last three pests, usually only the spider mites cause severe damage to the tree.

Fungicide sprays are not recommended, because they are not effective as a cure for trees showing symptoms of decline. Drought is the major factor predisposing spruces to *Cytospora* canker. Any practice that reduces stress on the tree will help it resist the disease.

Discula anthracnose and lower branch dieback of flowering dogwood. This new disease of the flowering dogwood, *Cornus florida* has been causing the decline and death of dogwoods throughout the Northeast since the mid 1970s. Leaf spots appear in the spring and may progress to extensive leaf blight. The most distinctive leaf symptom that separates *Discula* from other leaf spots is the presence of small (about the size of the head of a pin) tan spots scattered uniformly on the lower surface of leaf spots. In moist weather these spots exude fungal spores that wash or splash on healthy leaves and shoots. As the tree declines, it produces many "water sprouts" from large branches and trunks. These water sprouts also are infected and blighted. The fungus grows into the main trunk, producing dark cankers. The *Discula* fungus remains from year to year in cankers. It infects foliage during cool wet weather, and is less active in hot weather.

Research has failed to provide a good control spray program. Badly diseased dogwoods with many trunk cankers should be removed. On less severely diseased trees a combination of cultural and chemical controls will help. First, all dead wood and water sprouts should be removed. A fungicide spray program starting when leaf buds break and continuing through midsummer should reduce the leaf spot stage of *Discula* anthracnose.

It appears that stressed dogwoods are more susceptible to *Discula* anthracnose. Irrigation during drought and modest fall and winter fertilizer applications will promote tree vigor and probably reduce losses to *Discula*.

Diplodia tip blight of pines. Mature two- and three-needle pines may be damaged seriously by this tip blight disease, caused by the fungus *Sphaeropsis pinea* (*Diplodia pinea*). Austrian (*Pinus nigra*) and Scots (*P. Sylvestris*) pines are most frequently seen infected in Maryland. Mugo, red, scrub, and Japanese black pines also are commonly infected. The disease is widespread and especially common on mature stressed exotic pines. Rarely is it found on seedlings and young vigorous plants unless they are growing close to infected trees.

The current season needles will brown and die in June through July, usually when they are 1/3 to 3/4 full size. The entire shoot is usually killed up to the second-year wood. Symptoms usually are more extensive on lower branches, but may be scattered throughout the crown. Resin flow is often conspicuous on infected twigs. After several seasons of infection, branches may be disfigured with clubbed tips from repeated blighting of the new growth. Branches may die as old needles drop and no new growth survives. Close examination of infected needles, twigs and cones will reveal numerous pinpoint-sized, flask-shaped black fruiting structures (pycnidia) erupting through the plant's surface. Look for these at the base of the needles under the sheath, on cone scales, and on twigs. In wet weather, dark spore tendrils are exuded from pycnidia and spread by splashing rain, insects, birds, or tools. Spores are produced from early spring through late fall, in wet weather. Spores of the fungus, *Diplodia pinea*, require at least 12 hours of 100 percent humidity to germinate and penetrate the young plant tissues. Only young needles, buds, and shoots are susceptible. Mature tissues are resistant. Thus, rainy spring weather is favorable for disease development. The fungus grows rapidly through needles and into the shoots. Blight symptoms usually are noticed by midsummer. Needles and then entire shoots turn brown. The fungus persists from year to year in infected cones, needles, and twigs on the tree and on the ground.

Control is difficult but possible through the use of sanitation, fungicides and good horticultural practices. Fungicides must be applied so that the new growth is covered throughout the susceptible period.

Dutch elm disease. Few plant diseases are as well known to the general public as Dutch elm disease. Our native American elm, *Ulmus americana*, once extensively used as a street tree throughout the Northeast and Midwest, is very susceptible. The fungus that causes Dutch elm disease (*Ceratocystis ulmi*) is carried to healthy trees by insect vectors, several elm bark beetles. In Maryland the smaller European elm bark beetle is the most important vector.

The first symptoms of wilting and yellowing of isolated branches may appear in early May and continue throughout the growing season. Internally, twigs, limbs, trunk and large roots have a chocolate brown discoloration of the vascular tissue. Wilting limbs die, and eventually the entire tree will wilt and die. The elm bark beetles are attracted to declining elms where they construct galleries under the bark and reproduce. The Dutch elm disease fungus grows in the galleries, producing many spores in sticky masses. When the beetles emerge in spring, they carry many fungal spores on their bodies. The beetles fly to healthy elms where they feed throughout the canopy on small twigs. As they feed, the fungal spores are deposited in their feeding wounds, thus infecting the tree.

An intensive program of sanitation conducted on a regional level is the most important part of a control program for Dutch elm disease. The sanitation program consists of regular scouting of cultivated and wild elms to detect diseased trees early, and prompt removal of diseased trees so they cannot serve as breeding sites for the bark beetle vector. In addition to sanitation, surveys using traps to pinpoint beetle emergence and insecticide sprays to control beetles are used often. Fungicide injections have long been a part of Dutch elm disease management programs. All wilting branches are pruned back to healthy wood, and the tree is injected with fungicide.

Plant breeding programs are continuing to select for elms resistant or tolerant to Dutch elm disease. At present none of the resistant cultivars and species duplicates the form of the American elm. Because of Dutch elm disease, the American elm will never be as prominent among urban tree plantings as in the past. However, if communities are willing to support a comprehensive management program, this elm can continue to be a valuable urban tree.

Lophodermium needle cast of pines. Scots and red pine are very susceptible to *Lophodermium* needle cast disease, which can kill red pine seedlings and cause dramatic browning of foliage on Scots pines of all ages, making them unsalable as Christmas trees. Trees weakened by early death of many needles are prone to other diseases and pests.

In March through April brown spots with yellow margins are seen on needles, which then turn entirely brown in May through June. In July through October small, black, football-shaped fungal fruiting bodies (acervuli) are formed in dead needles. In rainy weather, spores are ejected from these fruiting bodies and carried by wind to infect the current season needles. The disease is worse in wet summers.

Cultural practices can reduce significantly damage from *Lophodermium*. Whenever possible, select resistant pine cultivars. Do not plant young pines near older trees of the same species. Irrigate nursery seedlings in the morning so they will have time to dry and avoid the prolonged periods of moisture that favor *Lophodermium* infection. Once the disease is established in a planting, fungicide sprays may be needed. The fungicide must be applied once every 2 to 3 weeks during the major infection period from late July through October.

Juniper blights. Maryland junipers may be damaged by two different tip- and twig-blighting diseases.

- *Phomopsis blight.* The fungus *Phomopsis juniperovora* causes a blighting of new juniper growth in the spring. *Phomopsis* overwinters in blighted twigs and bark on or near plants. Small, black fungal fruiting structures (pycnidia) are produced in early spring. During wet spring weather many microscopic spores are extruded from pycnidia and washed or splashed onto the susceptible young, succulent growth and wounded twigs. Older, unwounded shoots are not attacked.

The blighted twigs first turn pale green. Usually the twig is killed back to the previous season wood; by early summer, blighted tips are brown. Sunken, dark cankers are formed at the junction of live wood and dead wood. Black pinpoint-sized pycnidia are produced throughout blighted tips.

- *Kabatina blight.* The fungus *Kabatina juniperi* attacks juniper twigs during warm summer weather. The fungus requires a small wound to invade the plant. Insect feeding and abrasion by adjacent branches provide plentiful wounds. A small ash gray canker is produced at the invaded wound. Within 4 to 6 weeks the canker enlarges to encircle and girdle the twig causing the tip blighting symptom. In juniper cultivars that have a purple winter color, shoots infected by *Kabatina* in summer and fall will remain green when the rest of the plant takes on the purple winter color. Blighted shoots turn brown by late winter and remain on the plant, providing a source of infection for the next season's growth.

Small, black, fungal fruiting bodies are produced on the canker and later throughout the blighted twig. In wet weather spores are produced in acervuli and washed to other plant parts.

The ideal control for any plant disease in the landscape is prevention through the use of disease-resistant cultivars. Unfortunately, many junipers that are resistant to *Phomopsis* are susceptible to *Kabatina.*

Control strategies for these two diseases are different. *Phomopsis* tip blight is controlled well with several fungicide sprays applied in the spring and repeated into early summer to maintain a protective coating on the susceptible new growth.

In field tests, no fungicide spray program has been highly effective against *Kabatina* blight. Because *Kabatina* cannot invade tissues without wounds, control of insect infestations often provides partial control. Prompt removal of bighted shoots also will help by reducing the amount of *Kabatina* spores produced. In some cases, removal of badly diseased plantings and replacement with a resistant cultivar is the best solution.

Phytophthora root rot and canker. Rhododendrons are more susceptible to *Phytophthora* root rot than most other woody ornamentals. Plants may be killed at any stage from propagation through growth in production and in the landscape.

Probably the most important species of *Phytophthora* on rhododendrons is *P. cinnamomi*, while other species also occur. The fungus produces swimming spores called zoospores, which can be carried in water. The disease is always more severe in poorly drained soils.

The fungus also makes resting spores, called oospores, which can remain in the soil for many years. Thus once a site is infested by *Phytophthora*, it will remain infested. The symptoms seen will vary from only slightly poor growth through wilting and death. Usually chocolate brown discoloration of the cambium of roots and stems is present. This brown discoloration usually extends under the bark beyond obviously cankered areas for several inches.

In nursery production strict sanitation and the use of fungicide treatments provide good control. In the landscape, cultural methods are more appropriate. Start with healthy plants. Modify the planting site to provide excellent soil drainage. Use bark soil amendments, and plant in raised beds or mounds if drainage is a problem. Avoid high nitrogen fertilizer, which stimulates very succulent growth that is more susceptible to disease.

Powdery mildews. There are over 1,100 species of closely related fungi that cause powdery mildews on ornamentals as well as vegetables, fruits, cereals, and turf. The amount of damage caused by powdery mildews depends on several factors: the degree of resistance of the plant cultivar, the health and vigor of the plant, and weather conditions.

Powdery mildews start as small spots of white, powdery surface mold on leaves or shoots. The spots may enlarge rapidly to form white patches of felty, powdery growth. Young leaves and shoots may be twisted and malformed, or turn yellow and die. Flower buds may fail to open and flowers and fruit may be deformed. Later in the season these sparkling white patches may turn tan and be dotted with small dark structures embedded in the mealy fungal growth. Powdery mildew often appears rather suddenly and spreads rapidly among susceptible plants during weather that is favorable for mildew. Weather conditions that are favorable for powdery mildews are warm days and cool nights, with plentiful rainfall and dew. Very dry weather or cool overcast rainy weather is less favorable.

In landscapes, the best control is the use of mildew-resistant cultivars when they are available. Fungicide sprays may be needed to preserve the aesthetic value of susceptible plants. Sprays are usually applied at the first sign of mildew. Generally no control is needed for powdery mildews that appear late in the season on trees and shrubs. Cultural practices that reduce the severity of powdery mildew include improving air circulation around plants and pruning and destroying mildewed plant parts.

Diseases Caused by Bacteria

Crown gall. A wide variety of woods and herbaceous ornamentals may be damaged by crown gall, caused by the bacterium *Agrobacterium tumefaciens*. Crown gall is common on brambles (such as blackberry and raspberry) grapes, roses, fruit trees (apple, apricot, cherry and peach), some shade trees (especially willow), and on many shrubs, vines, and perennial and annual flowers.

Crown galls usually are located at a graft union or on roots, but may also be found on branches or anywhere on vines. The galls are rounded with a corky, irregular surface, and may range in size from 1/2 inch or smaller up to several inches across, sometimes much larger. For these bacteria to infect a plant, a wound must already be present. The bacteria stimulate the plant to produce galls. The bacteria may persist in soil for a year or two after the diseased plant is removed.

Nursery stock with crown galls should be rigidly excluded from the landscape. Highly susceptible plants should not be planted in sites where crown gall infected plants were recently growing. Care should be taken to avoid wounding plants near the soil line. In nurseries, strict sanitation in all steps of grafting and transplanting must be observed. A biological control for crown gall is available for some ornamental plants.

Fire blight. The fire blight bacterium, *Erwinia amylovora*, can only attack plants in the family Rosaceae, and usually is most serious on apple, crabapple, pear, quince, amelanchier, hawthorn, mountain ash, pyracantha, raspberry, and strawberry.

Young shoots, leaves and blossoms suddenly wilt, turn dark brown to black and die, remaining attached to twigs. The bark is shrunken, dark, and may be blistered with gum oozing out. In warm humid weather bacteria ooze from blighted twigs and may be carried by insects or on windblown rain to other plants. The fire blight bacterium persists in cankers over the winter.

In orchards where susceptible cultivars must be grown, frequent spraying (starting at bloom) and stringent pruning out of all cankered wood help control fire blight.

In the landscape the best control is the use of resistant cultivars. Cultural practices may reduce fire blight. Avoid heavy applications of nitrogen fertilizer because succulent tender plant growth is more susceptible to fire blight. Apply needed fertilizer in the fall. Prune out all cankered wood in the fall and winter.

Insect and Mite Pests of Ornamentals

Plant-damaging insects and mites have mouthparts adapted to chew plant tissue or to suck plant juices. As pests, the insects and mites may be categorized according to the specific type of damage they cause. Examples are discussed below, along with discussions of their life history and control. For more specific information on chemical control, see University of Maryland Cooperative Extension Bulletin 258.

Chewing Insects

These pests have hardened jaws capable of damaging leaves, flowers, fruits, and wood depending on the species' habits. Chewing insects include beetle adults and larvae (grubs), moth larvae (caterpillars), sawfly larvae, and fly larvae (maggots). Damage includes defoliation, leaf mining, and boring.

Defoliators. These pests eat holes in leaves. In heavy infestations, entire leaves may be consumed.

• *Bagworm.* The adult female never leaves her bag. She is wingless and grublike, with tiny, useless legs. The male is a small, black, hairy moth with clear wings. The overwintering stage is the egg within the mother's bag. Eggs hatch in May and June, and the young caterpillars drop from the bag on a slender silk thread.

Bagworm in bag

Such small worms may 'balloon" for short distances on this long thread. Before the young worm feeds, it secretes silk and forms a bag. Bits of plant tissue become enmeshed in this bag when the worm feeds. As the worm grows, the bag enlarges, reaching about 2 inches when complete. It is fastened to the plant by silk manufactured whenever the worm rests or molts. In August, the worms mature and change into the pupal stage. During August and September, male moths emerge from their bags to mate with females.

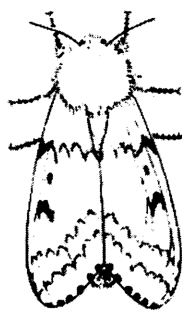
Bagworms feed on many trees including maple, boxelder, sycamore, willow, black locust, elm, linden, poplar, oak, apple, wild cherry, sassafras, and persimmon; but the preferred hosts are conifers. Arborvitae and juniper are highly susceptible. A single bagworm does relatively little damage. Yet because females do not fly, populations often are dense, and excessive defoliation may actually kill conifers within one or two seasons. Damage is most noticeable on ornamental plantings rather than in forests and woodlands.

When practical, bagworms can be removed with scissors or a sharp knife. Bagworms are parasitized by several ichneumonid and chalcid wasps. Low winter temperatures and bird predation on small larvae also are limiting factors. Chemical control is effective, particularly in June and early July when the bags are small. Sprays in August and later are not effective.

• *Gypsy moth.* Adult males are about 1 inch long, brown, with large feathery antennae. Females are about 1 1/2 inches long, white, with black spots. Each egg is light yellow, about 1 mm long, and each mass of about 500 eggs is covered by yellowish hairs from the adult female's abdomen. Newly hatched first instar larvae are entirely black, second instars have a light brown stripe down the back, third instars have yellow spots down the back and instars four, five, and six look alike. They have five pairs of blue spots and six pairs of red spots. Mature caterpillars may reach 2 inches in length. The black, teardrop-shaped pupa is about 1 inch long, and covered with a few loose silken threads.

Egg masses overwinter in protected sites such as bark crevices. Eggs hatch from late April to early May. Young caterpillars feed at night and hide on the trunk or ground during the day. In July the resting pupa stage is formed. During mid-July to mid-August, adult moths appear. Females mate, lay eggs and die.

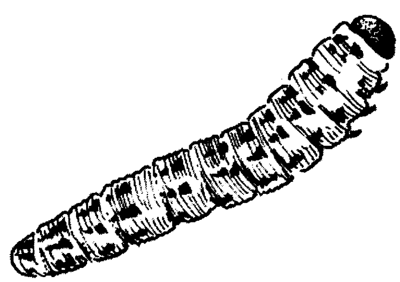
Ballooning Young Caterpillar



Adult Female

Outbreaks usually occur only where oaks are the dominant tree species. After feeding on oaks in early instars the older caterpillars can feed on most plants, including pines. Entire trees can be stripped of their leaves by mid-July. This kills conifers and seriously weakens or kills deciduous trees as well.

Outbreak populations are best controlled by aerial applications of insecticides. Individual trees receive some protection if caterpillars and pupae are collected and destroyed from some type of tree trunk band.



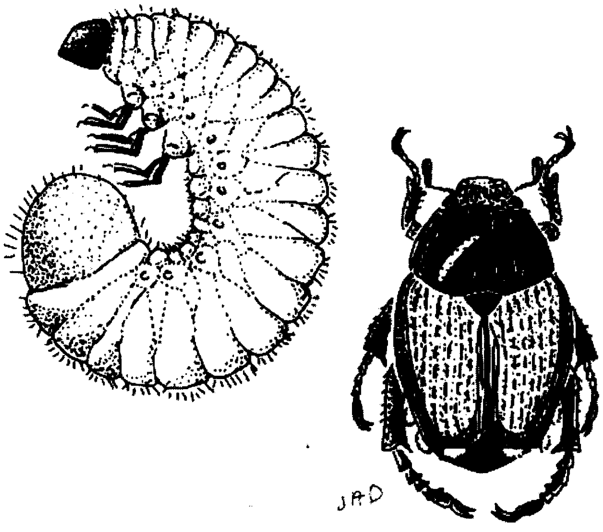
Larva

• *Redheaded pine sawfly.* The adult sawfly has four wings and varies from 1/5 to 1/2 inch in length. The female is robust. Her head and thorax are reddish brown, and her abdomen is black. The smaller male is more slender and entirely black with broad, feathery antennae. The egg is whitish, smooth, shiny, and translucent. The newly hatched larva is about 1/4 inch long with a whitish body and a brownish, transparent head. When fully grown, the larva is nearly 1 inch long and has a bright red head. The body varies from pale whitish yellow to deep yellow and is marked by two to four rows of black spots on each side of the abdomen. The last abdominal segment has a large, black patch on each side. The pupal stage develops in a reddish-brown, papery, tough cocoon that is cylindrical with rounded ends.

Winter is spent as a prepupa in a cocoon spun in the litter or in topsoil beneath the host. Pupation occurs in early spring, and the adults appear in a few weeks. Some prepupae may remain in a resting state (diapause) over several seasons before emerging. Eggs are deposited in the tissues of the current or previous year's needles. A single female lays about 120 eggs, which generally are all placed in the needles of a single twig. Egg laying may occur before mating, the unfertilized eggs producing only male progeny. The eggs hatch in 3 to 5 weeks. The larvae feed in clusters of up to 100 for 25 to 30 days, sometimes completely defoliating a tree, and migrate for several yards in search of new foliage. Fully grown larvae drop to the ground, enter the soil, spin their rough, reddish-brown cocoons, and spend the winter. In the South there may be five generations per year.

Preferred hosts are jack, red, shortleaf, loblolly, slash, longleaf, pitch, and Swiss mountain pines. White pine, larch, deodar cedar, and Norway spruce also may be defoliated, especially when they are growing close to trees of preferred species. Redheaded pine sawflies lay eggs only on hard pines. This insect preferentially feeds on young trees. In the South, it prefers trees in shaded areas. Complete defoliation kills small trees, whereas less extensive feeding results in poor diameter growth and stunted height. Defoliated branches often die.

In forests some natural control is achieved by rodents, which destroy large numbers of cocoons. Diseases and temperature extremes often kill many larvae. Also, 58 species of parasites and predators of the redheaded pine sawfly have been reared in the United States and Canada. When only a few colonies of larvae are present on small roadside, ornamental or plantation trees, they can be picked or shaken from the trees and trampled.



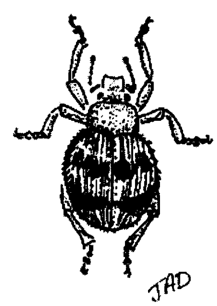
Adult

• *Japanese beetle.* The 1/2-inch-long beetle is shiny, metallic green with coppery brown wings. Six small patches of white hairs appear along the sides toward the rear of the insect. The male and female look alike, but the male generally is smaller and has sharper spines on its forelegs. The larva is a C-shaped white grub with a yellowish-brown head. The larva usually is found in a cell underground. Japanese beetles overwinter as larvae, pupate in late spring, and emerge as adult beetles about 2 weeks later. Adults usually appear from mid-June to early August. They are gregarious, often feeding in masses on flowers, foliage, and fruits of plants in bright sunlight. They fly in broad daylight.

The female selects poorly drained soil, especially in lawns, in which to deposit her eggs. She burrows into the ground and lays several eggs at a time, continuing for a period of days until she has laid 40 to 60 eggs, which hatch approximately two weeks later. Though a dry summer usually reduces the number of live larvae, a severe decrease in rainfall in the fall or spring hardly affects the population because older larvae are resistant to dry conditions. After entering a dormant prepupal stage, the larvae pupate. The beetles tend to become well established in areas of grazing, general agriculture, truck crops, and fruit growing. Usually the beetles are not found in heavily forested land. Though it takes two years for a generation to develop in the beetles' northern limit, only one year is required in most areas.

Both the larvae and adults have chewing mouthparts. The grubs consume roots of turfgrasses, whereas the adults feed on leaves, buds, flowers, and fruits. Since the adults do not eat the leaf veins, infested leaves become skeletonized. Flowers and buds have ragged edges after beetles have been feeding. Over 300 plants are known as food sources for the Japanese beetle. The adults are particularly fond of roses, and they prefer white and yellow flowers to the darker colors.

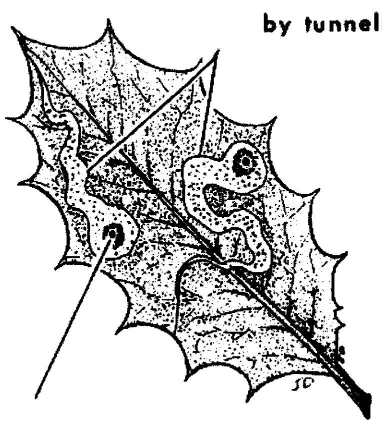
The grubs can be controlled with a specific bacterium known as milky spore disease. Insecticides will not completely protect roses, which unfold rapidly and are especially attractive to adult beetles. When beetles are first noticed on roses, buds should be nipped and the bushes sprayed to protect the leaves; then when the beetles become scarce, the bushes can be allowed to bloom. To protect a limited number of rose blooms, nets or perforated bags can be tied around the blossoms.



• *Two-banded Japanese weevil.* The adult female is light or dark brown with a short, blunt snout. The wing covers (elytra) are striped with indistinct white lines in the grooves, white spots, and a dark-brown or black crosswise band. Adults emerge in June and feed for 2 to 3 weeks before egg laying begins. Eggs are deposited in folds along the margins of leaf fragments or dead leaves, and the free edge is sealed to form a pod. When the eggs hatch, the larvae burrow into the ground and feed on the roots. These weevils have fused wing covers and thus are unable to fly. They feed during the day and, if disturbed, drop to the ground and remain motionless. There is only one generation each year.

Japanese weevil larvae feed on plant roots but the adults do more serious and apparent damage. The adult weevils feed extensively on new leaves, shoots, and inner foliage. As a result, infested plants are tattered and unhealthy in appearance. Damage is a characteristic notching of leaf margins. Some of the plants attacked by the Japanese weevil are ash, azalea, barberry, burr marigold, camellia, dogwood, elm, fern, hemlock, holly, lilac, mountain laurel, privet, rhododendron, rose, spirea, strawberry, and weigela. Insecticide sprays should be timed to kill newly emerging adult beetles before they lay eggs.

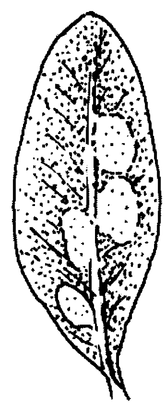
Leafminers. Winding tunnels or blotches are formed by larvae chewing through leaf tissue.



• *Native holly leafminer.* The adult is a small black fly. The first two segments of the antennae are gray, and the third segment is black. The native holly leafminer female generally is more active than the male. The pale, yellow, legless larva is a maggot that is tapered from front to back, with its head retracted into its body. There are three larval stages in the life cycle of this fly, the last of which overwinters. In March and April the larvae pupate, and adult flies emerge throughout May. Individual flies have a brief lifespan; females live 3 days, males only 2. Eggs are inserted into the underside of newly formed leaves, causing tiny, green blisters to appear on the leaf bottoms. Most eggs are laid near the tips of the leaves, close to the midveins. Eggs hatch in about 4 days. The larvae mine into the leaves, remaining there for 9 to 10 months. The mines are yellowish brown and usually contain only one larva each. Each serpentine mine eventually broadens into a blotch, which contains the pupa. Just before each larva pupates, it prepares a circular exit hole covered by a thin layer of leaf cells.

This is the most injurious insect pest of holly in the eastern United States. The larval leaf-mining can cause partial defoliation, especially during a dry season; and the mines make the trees unattractive. Moreover, the females insert their ovipositors into the leaf tissues of tender new growth causing wounds from which sap flows. Both females and males then feed on the sap. In heavy infestations this wounding deforms the leaves. This leafminer prefers new growth. The native holly leafminer has infested American, Japanese, Chinese, English, and yaupon hollies. Other hosts include winterberry (black alder) and inkberry (bitter gallberry) and their varieties. The fly is particularly damaging to the American hollies.

If only a few plants are damaged, picking the mined leaves and burning them gives some control. Otherwise, an insecticide must be used.



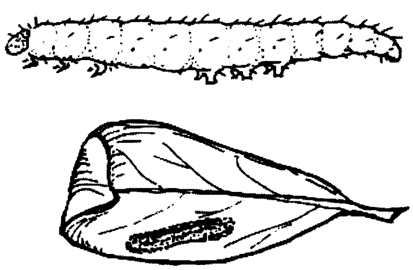
Damage

• *Boxwood leafminer.* The mature boxwood leafminer is a yellow to orange-red fly. Mosquito-like but smaller, it can often be observed swarming around boxwoods during the time weigelas are in bloom. The larva is a small lemon-yellow maggot. The elongated pupa is yellow to brown. Close examination reveals legs and wings pressed to the body surface.

Adult flies attack the new growth by inserting their eggs into the leaves' lower surfaces. Tiny larvae hatch and mine in the leaves as they feed. The leaves first acquire a water-soaked appearance at the feeding site. Soon, blisters develop on the lower leaf surface; one to several larvae may develop in a single leaf. Leafminers spend the winter in the blisters as larvae. In spring, the blisters develop a translucent "window" through which pupae protrude from the lower leaf surface. Adult flies emerge from the pupal skins over a 2-week period in early spring, shortly after the boxwoods have put out their new growth. Each adult fly lives only a few days. Only one generation occurs each year.

Mining in the foliage, this pest causes the formation of small blisters on the undersurface of leaves. Infested leaves usually become yellowish and are smaller than uninfested leaves. As a result, heavily infested plants assume an unsightly appearance. All boxwoods may be infested, but more slowly growing English varieties are less susceptible than American varieties.

To control this pest, contact insecticides should be applied when adults are first observed. Systemic insecticides should be applied in June to kill young larvae in mines.



Larva, rolled and mined leaf

• *Azalea leafminer.* The adult azalea leafminer is a small yellow moth with purplish markings on the wings. The wingspan is about 1/2 inch. The leaf mining larva is yellowish and about 1/2 inch long. It has three pairs of prolegs found on abdominal segments three, four, and five.

Eggs are deposited singly on the underside of azalea leaves along the midribs, usually one to five per leaf. The young caterpillars hatch in about 4 days, mine into the leaves, and feed inside them. At this stage, the leaves appear to have blisters. If a leaf is held up to the light, the larva can be seen inside. When about one-third grown, the larva emerges, moves to the tip of a new leaf, and rolls it up for protection while feeding and growing. When nearly grown, the larva rolls up the margin of a leaf and spins a cocoon inside. The moth emerges from the cocoon, mates and deposits eggs for another generation. Under greenhouse conditions, the larvae may be found at any time during the year. The insect overwinters outdoors as a larva or pupa. Adults appear and females begin to lay eggs about the time plants bloom in the spring.

This leafminer larva has little effect on plants grown outdoors, but it may do considerable damage to cuttings in the greenhouse. Seriously injured leaves usually turn yellow and drop, thereby causing an unsightly plant.

Because the larva protects itself by mining into and rolling the leaf, this insect is not easy to control. Several insecticide spray mixtures have yielded satisfactory control when applied at the first sign either of the adult moth or of foliar injury by the larva. One or two applications, 1 or 2 weeks apart, usually are sufficient.

Borers. Some caterpillars chew tunnels beneath the bark, sometimes into the heartwood.

• *Dogwood borer.* The basic color of the moth is dark blue, appearing almost black, with occasional yellow markings on the body. The dark thorax is marked with yellow lines and a yellow patch below. The abdomen is dark with yellow bands on the second and fourth segments. The wings are clear toward the base and have a span of about 1/2 inch. Off-white to cream colored, the larva has a reddish-brown head. The hard shield behind the head characteristically has two reddish-brown dorsal spots. The caterpillars range in length up to 1/2 inch or more when mature. There are six stages. Adult emergence occurs from late April to late October, peaking in mid-May. Eggs are laid singly on bark. A female may lay up to 116 eggs. Incubation usually requires 8 to 9 days. Newly hatched larvae become established only if they encounter a broken bark wound, a cracked callous area, such as a canker, or some site affording immediate protection. Feeding, confined to the cambium and bark, continues until winter. The dogwood borer then hibernates in the larval stage within its tunnel. Pupation takes place the following spring. Although there is only one generation per year, borers may be found in various stages of development throughout most of the year because eggs are laid over a period of several months.

Flowering dogwood is the preferred host, but the dogwood borer also has been collected from oak, chestnut, hickory, elm, willow, and pecan. On dogwood, attack is apparently confined to the trunk and limbs. In a single year one borer can completely girdle and kill a tree 4 inches in diameter, but death is more often brought about by the combined activity of several larvae and by successive infestations. Cultivated trees usually are more heavily infested than those growing in wooded areas.

Dogwood borer larvae often enter the tree through bark wounds around the base. To avoid mechanical injury to the trunk, mulch around the base of the tree. This will reduce injury associated with weed control and lawn mowing. A spray of a residual pesticide should be applied in early May.

• *Nantucket pine tip moth.* The adult is about 1/4 inch long, basically copper colored, with silvery markings on its wings. The tiny caterpillar is cream to brown colored with a black head. The mature larva is light brown to orange and approximately 1/2 inch long. In the southeast, Nantucket pine tip moths overwinter as pupae within the damaged tips of pines. Adults emerge and mate from late April to mid-May. They lay eggs on needles, in the axils of needles and stems, and on developing tips or buds. The egg stage lasts about 30 days in cool spring weather and 5 to 10 days in summer. Newly hatched larvae either feed on the surface of new growth, causing shallow injuries, or bore into the needle bundles. Later they migrate to the shoot tips, construct a protective web at the base of the buds, and begin to bore into the bud or stem. Feeding continues inside these tissues until larvae are fully grown (3 to 4 weeks). Pupation then occurs within the cavities formed by the larvae. A second generation occurs in July.

Damage by larva

Within its range, the Nantucket pine tip moth feeds on nearly all species of pine except longleaf and eastern white pines. Slash pine also is somewhat resistant, but it is occasionally attacked. In the southeast, loblolly and shortleaf pines are preferred hosts. This pest causes the retardation of height growth, crooking or forking of main stems, reduction of cone crops, and occasionally the death of the tree. Attacks generally are restricted to trees under 15 feet tall and to young plantations, through severe attacks on commercial-sized trees have been reported in dry years. The Nantucket pine tip moth is an important pest of pines grown in plantations in the eastern United States. Because the establishment of large pine plantations is becoming increasingly popular, the importance of this insect is increasing.

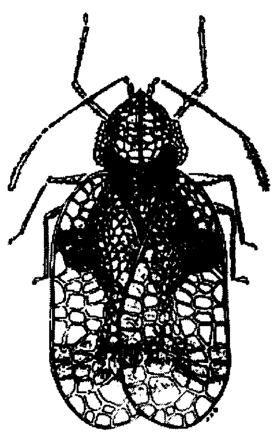
Cultural practices are the most effective means of control. Before outplanting, seedlings should be inspected and injured buds and twigs should be destroyed. Infested trees should be pruned in winter well below the dead part because larvae normally feed in the green tissue there. In areas with a history of heavy infestation, planting of loblolly and shortleaf pines should be avoided except on sites most suitable for quick growth. Anything that encourages rapid development, such as vigorous tree strains or ideal sites, helps reduce damage. Seedlings on barren soil along roadside fences are heavily infested throughout the South. Since these trees are sources of infestation for nearby young plantations, they should be cut and burned. Some natural control of the Nantucket pine tip moth exists. More than 30 known species of parasites, as well as several predatory insects and birds, attack this pest.

Large-scale use of insecticides usually is not recommended. Such use may be justified, however, in areas of high value, such as seed orchards or forest or Christmas tree nurseries, where power sprayers can be used and the high cost of application is not prohibitive. To obtain control throughout the season, spraying may be necessary for each generation of the moth. The spray should be directed at the young larvae, which feed on the exterior of the shoot for several days after hatching. Larvae begin to hatch 5 to 10 days after peak adult emergence. When cool weather follows this peak in early spring, spraying should be deferred for about 14 days.

Sucking Pests

These pests have "beaks" through which they slide slender tubes to pierce plant tissues and suck the sap from leaves, fruit or wood, depending on the species. Sucking insects include the nymphs and adults of thrips, true bug,s and Homopterans. The last is a very diverse group containing leafhoppers, whiteflies, aphids and scale insects, among others. Sucking pests damage plants by stippling, causing leaf stunting and/ or wilting, and producing honeydew, which attracts sooty mold.

Stippling insects. Feeding by these pests removes chlorophyl, causing small white spots or streaks on upper leaf surfaces. In heavy infestations the spots fuse, and leaves turn yellow and die.



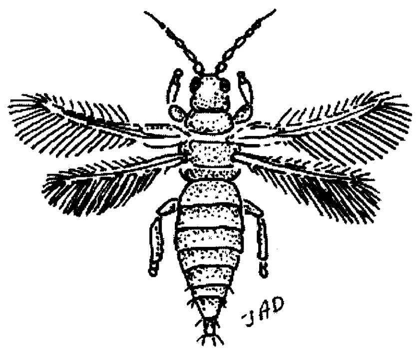
• *Azalea lace bug.* The ¼-inch-long adult has lacy wings with brown and black markings, and light brown legs and antennae. Commonly found on the underside of a leaf, the nymph is almost colorless at birth but soon turns black and spiny. It molts six times; after the fourth molt, wing pads show distinctly.

Female lace bugs lay groups of eggs on the underside of the leaves, most often along the midribs. This egg laying takes place over an average period of 2 weeks. These eggs require an average of 2 weeks for hatching. Colorless at first, the spiny nymphs hatch from the eggs, gradually darken, and go through five growth stages before becoming adults. Because of the extended oviposition period, it is quite possible to find all stages together on the underside of the leaves at the same time. Several generations are produced in a year. The insect overwinters in the egg stage. In early spring these overwintered eggs start hatching and may build up dense populations. Additional broods come along in July, August, and September. During early August eggs are laid. By the middle and last week in September, many adults of this brood are present. The overwintering eggs are deposited on leaves at this time and during the first part of October.

Injury is caused by the nymphs and adults as they extract sap from the undersurface of the leaves. The damage shows as small white spots (stipples) on the upper surfaces of the leaves. In severe infestations, the leaves become almost white. Many of them dry out completely and drop off. The underside of the leaves are also disfigured by the black excrement spots and skins cast by the insects. The evergreen azalea varieties are preferred by azalea lace bugs, although the deciduous varieties may be attacked. Mountain laurel also is subject to infestation.

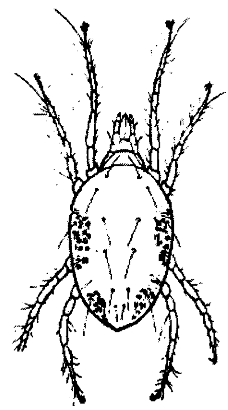
One of the most important control methods for lace bugs is to maintain plant vigor by planting in the proper location. For example, azaleas are shade-preferring plants. Planting them in full sun all day will greatly increase their risk of lace bug attack. Before treating a plant for lace bugs, the infestation must be confirmed by the presence of black fecal spots on the undersurface of the leaves. On evergreen shrubs infestations can be detected in early spring by examining the previous year's foliage. Chemicals should be applied when feeding stages are first observed. Systemic insecticides are preferred. If contact insecticides are used, coverage must be thorough including the undersurface of leaves. Treat infested plants only. Repeated applications of some insecticides may be needed to control lace bugs effectively. The first application should be made as soon as nymphs appear in the spring and be followed with a second application 7 to 10 days later, if needed. Applications should be repeated as needed at monthly intervals. Thorough coverage is essential when applying sprays if good control is to be expected. The underside of the leaves must be covered.

• *Flower thrips.* The small-winged adult flower thrip is about 1/16 inch long, yellowish brown to amber with an orange thorax. The male is slightly smaller and lighter in color than the female. The tiny young trips are lemon yellow, resembling the adult except for its lack of wings.



Flower thrips generally are found at the base of the flower's petals. They reproduce throughout the growing season in Maryland, with the majority of their several generations occurring during the warmer months. Newly emerged females begin to lay eggs within 1 to 4 days in summer. In summer the adult stage is reached in about 11 days. Flower thrips pass through egg, to larval, prepupal, pupal, and adult stages. The eggs are inserted into flower or leaf tissue, and the prepupal and pupal stages are spent in the soil. In summer, flower thrips may live 26 days, though overwintering thrips may live all winter. Flower thrips can overwinter as far north as North Dakota in grass clumps and other sheltered refuges. Flower thrips are one of the most numerous insect pests of ornamental crops. In warm periods, this species often flies in late afternoon in swarms of tiny, orange insects. Thrips can bite people, causing a noticeable stinging sensation. Their large numbers account for considerable and rapid damage to flowers, especially those with light-colored petals. Yet thrips contribute to pollination, an unexpected benefit. Flower thrips have been collected from 29 plant orders, including various berries, cotton, day lilies, field crops, forage crops, grass flowers, legumes, peonies, privet hedges, roses, trees, truck crops, vines, and weeds. They prefer grasses and yellow or light-colored blossoms. Roses are most susceptible in June.

Flower thrips are consumed by green lacewings, lady beetles, and insidious plant bugs, yet control of thrips is difficult because of their constant migration from weeds, grass, flowers, and trees. The destruction of old rose blossoms and the application of pesticides at close intervals can help reduce damage.



Stippling mites. Because the mouthparts of spider mites are much smaller than those of insects, the stippling they cause is much finer. However, the end result in large infestations is the same; leaves yellow and die.

• *Spruce spider mite.* Almost black with a pale midstripe, the adult female resembles a small spider but is only 1/50 inch in length, about the size of a period on this page.

Its body and eight legs are pale brownish pink. The two red eyespots are conspicuous. The male is similar but smaller. The larva has six legs and is pale brownish pink. Except for its smaller size, the nymph resembles the adult.

Spruce spider mites overwinter as eggs usually laid at the base of needles. In April and May the eggs hatch, and larval mites begin to feed on the previous year's growth. The mites develop through a series of nymphal stages, reaching the adult stage in 4 to 5 weeks. As the season advances, so much overlapping of generations occurs that all stages are present at once. Spruce spider mites seem to be "cool weather mites," maximum feeding and reproduction taking place in spring and fall. Virtually inactive in hot weather, they are subject to attack by predaceous insects and mites, which usually decimate the population during the summer.

The spruce spider mite is regarded as the most destructive spider feeding on conifers in the United States. This pest causes needles to yellow or brown and drop off prematurely. With a serious infestation, the plant may be webbed. After several years of the mites' heavy feeding, the plant may die. Spruce spider mites feed on spruce, hemlock, arborvitae, pine, Douglas fir, Fraser fir, and various conifers in nurseries and foundation plants.

Because the spruce spider mite is most active in cool weather, infestations should be treated at the end of summer or winter for maximum effectiveness. Control in the dormant season can prevent serious buildup in the spring.

• *Two-spotted spider mite.* The eight-legged adult can be rusty green, greenish amber, or yellow. The overwintering female, however, is orange. Usually having two (sometimes four) black spots on top, the adult is about 1/50 of an inch. The six-legged larva is colorless to pale green or yellow. Similar to the adult except in size, the pale green to brownish green nymph has eight legs. A large spot of black may develop on each side of the body.

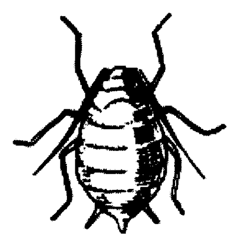
Two-spotted spider mites overwinter in the soil or on weeds. In the spring, larvae hatch from eggs and develop into nymphs, which pass through two nymphal stages. After each larval and nymphal stage, there is a resting stage. The adults mate soon after emerging from the last resting stage, and in warm weather the females soon lay eggs. Each female may lay over 100 eggs in her life and up to 19 eggs per day. Development is more rapid during hot, dry weather. Depending on the temperature, a single generation may require from 5 to 20 days to reach adulthood and begin producing offspring.

Two-spotted spider mites pierce the host plant leaf with their sharp, slender mouthparts. When they extract the sap, the inner tissue of the leaf collapses in the area of the puncture. Soon a white spot forms at each feeding site. After a heavy attack, an entire plant may become yellowed, or bronzed or it may die. The mites may spin so much webbing over the plant that it becomes entirely covered.

These mites occur as important pests on more crops than any insect pest. Two-spotted spider mites have been reported on over 180 host plants, which include over 100 cultivated species. Violets, chickweed, pikeweed, wild mustard, and blackberry are common foci from which infestations develop on nearby crops.

During hot weather susceptible plant species should be inspected weekly for mite buildup. The resting stages and eggs of the two-spotted spider mite are more tolerant to pesticides than the motile forms. Consequently, in heavy infestations a second application of pesticide may be necessary at a 4- or 5-day interval in hot weather (a 7- to 10-day interval in cool weather) to kill those mites that may have survived the first application. Horticultural oil sprays in the summer and dormant season kill eggs and motile forms.

Leaf stunting and/or wilting, and honeydew production. Nymphs and adults of aphids and of some scale insects cause terminal leaves to twist down or fail to enlarge (stunting). The leaves may then wilt and die. These insects also may produce honeydew, a sweet sticky excretion that builds up on leaves and on structures under plants. The honeydew buildup attracts a black sooty mold fungus, and is thus undesirable on ornamentals.



• *Melon aphid.* The melon aphid is typical of the aphids that feed on ornamental and agricultural plants in Maryland. The wingless adults are soft-bodied and yellow to dark green. The adults that are lighter in color tend to be smaller and have fewer antennal segments than the darker adults. The winged adult also is soft-bodied and yellow to dark green. It has a black head and thorax with the wings held rooflike over the abdomen. The nymph is smaller than, but similar in shape and color to, wingless female adults.

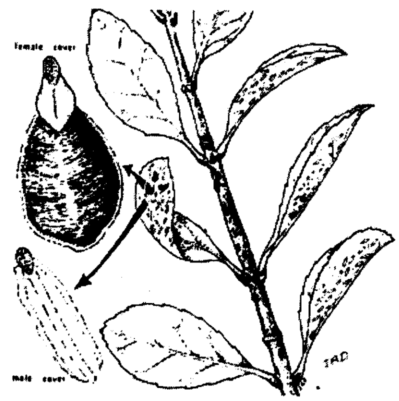
Aphids in Maryland overwinter as black eggs on needles or bark. The eggs hatch in the spring as new leaves open. Winged females fly to suitable host plants and give birth to living young. Each female produces about 100 nymphs. Under favorable conditions, a nymph will mature in about 5 days and begin producing its own young. Most nymphs develop into wingless adults. However, when crowding occurs or food becomes scarce, winged adults develop and fly to new host plants. Many overlapping generations are produced each year.

The melon aphid is an important pest of both agricultural and ornamental plants. On woody ornamentals, such as gardenias, feeding is confined to new growth in the spring. The melon aphid feeds by piercing the plant surface with the threadlike mouthparts to suck out plant juices. This feeding causes distorted growth, decreased yield, reduced quality of yield, and prematurely ripened fruit. The fruit may be covered by the feeding aphids' honeydew and by cast skins. The melon aphid transmits several important plant viruses, including cucumber mosaic, onion yellow dwarf, citrus quick decline, lily symptomless diseases, and lily rosette. Melons and other cucurbits, cotton, okra, hops, strawberries, beans, spinach, tomatoes, clover, asparagus, citrus, catalpa, violet, hydrangea, begonia, ground ivy, gardenia, and weeds are some of the hosts of melon aphids. They have been discovered feeding on plants in 25 plant families including many ornamentals.

Syrphid maggots and ladybird beetles and their larvae feed on melon aphids. Braconid wasps parasitize the aphids, and ants feed on the honeydew excreted by feeding aphids. Shrubs should be sprayed thoroughly when aphids are noticed building up in the absence of predators or parasites on new growth in the spring.

• *Euonymus scale.* The male cover is elongate and white; the mature male is a tiny, two-winged insect. The female cover is dark and shaped like an oyster shell. Adult females, eggs and crawlers are all yellow.

This armored scale insect usually has two generations per year in Maryland. The males emerge as tiny, two-winged flies and mate with the females, which shrivel as they lay eggs under their protective shells. The tiny crawlers hatch and emerge from the mother's shell in May, July, and September; female adult euonymus scales do not leave the protective covering. Another brood hatches in late summer, and a partial third brood may appear even later. As a result, all stages of development are present most of the year. Males usually are more numerous than females in dense infestations. Clusters of the snow-white male covers on the leaves and twigs are clearly noticeable.



Scale covers

Euonymus, pachysandra, and celastrus are attacked by this scale. The first visible damage is yellow spotting on the leaves. The stems may become so encrusted with the scales that whole branches or the entire plant dies.

Euonymus scale is difficult to control on *Euonymus japonica*. This plant should be replaced with the resistant species *Euonymus kiautshovica* whenever possible.

Weeds in Nursery and Landscape Plantings

Management Options

In a landscape, any plants other than those planned for in the landscape development may be considered weeds. In nurseries, some weed growth may be acceptable unless the level of competition with desirable plants is high enough to reduce plant growth. Maintaining proper fertilization and irrigation helps reduce potential losses through competition. If an herbicide treatment is necessary, identification of the weed species is essential for choosing the correct herbicide and obtaining good control. The pest manager must be especially careful in the choice and placement of herbicide applications because of the likelihood of phytotoxicity to desirable plants.

In view of the problems associated with the application of any herbicide to irregular landscape plant beds, mechanical weed control is safer and highly recommended where practical. Of the methods of mechanical control most widely used, hoeing and cultivation are probably the least satisfactory. Results are only temporary because these methods remove only the existing weed growth. On deep-rooted perennial weeds only the foliage layer is removed, allowing regrowth.

The use of mulches is a more desirable method of mechanical weed control. Mulch is basically a layer of peat moss, shredded bark, or any similar material spread on the soil surface under and around desirable plants. Mulches are functional as well as attractive. The most common reason for using a mulch is elimination or retardation of weeds. Few weeds will grow where the mulch layer is deep enough.

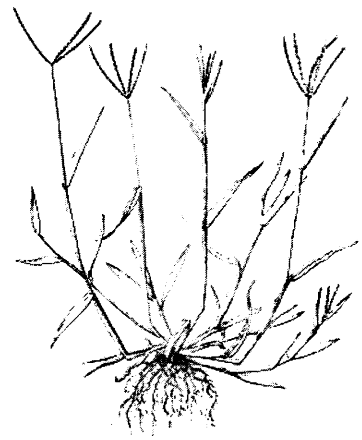
Herbicide–mulch combinations can provide better weed control than the use of either tactic alone. Also, the period of effectiveness is extended by these combinations. They can be used around landscape shrubs planted balled-and-burlapped or in containers. Herbicide–mulch mixes permit easier distribution of the herbicides on small beds, and they reduce the landscaper's maintenance costs. Herbicide–mulch combinations should not be applied to areas underplanted with ground covers or annual and perennial flowers or foliage plants. Steep banks or areas where the mulch is likely to be removed by runoff water also should be avoided.

Following are weeds typical of nursery and landscape plantings. For more information on their identification and control, consult other sources of information available from your local county extension.

Annual Weeds

Summer annuals include such species as crabgrass, goosegrass, pigweed, and lambsquarter. It is best to apply preemergence herbicides in the spring to control these weeds.

• *Crabgrass* is tufted, with stems mostly prostrate and freely branching. The tops of the flower clusters are four- to seven-fingered, radiating outward from the main stem. The small individual flowers appear in rows on one side of the flattened stalk. Seeds are long, oval, finely granular and light yellow. Large and small crabgrass are the two common species. Leaves of large crabgrass are somewhat hairy.



Crabgrass seeds germinate in the spring to early summer. Flowering occurs in midsummer as the plant matures. Rooting can occur at the nodes of prostrate stems. Crabgrass is found in gardens, fields, lawns, and waste areas. It grows well under hot, dry conditions and will germinate throughout the summer if moisture is available.

Winter annuals include annual bluegrass, chickweed, and henbit. Preemergence herbicides applied in the fall are best to control winter annuals.

• *Chickweed* reproduces by seeds and roots at the nodes of the creeping stems. The root system is shallow and fibrous. Stems may be branched, creeping, or ascending to heights of 12 inches. Leaves are small, opposite, single, broadly ovate, smooth, and pointed at the tips. Petioles have a line of hairs on one side. Flowers are small and white with five deeply notched petals. The seed pod is cylindrical, breaking into five segments at maturity. Seeds are small, dull, reddish brown, nearly round, and roughened by curved rows of tiny projections.

Seeds germinate in fall and early winter, growing rapidly until extreme cold sets in. Flowering begins in the fall and proceeds during warm spells in the winter, becoming profuse in the spring. Growth and seeding usually stops during extremely hot weather and seed will shatter to the ground. Chickweed most often is a problem in areas of low maintenance.

Perennials

Woody perennials include trees, shrubs and vines. They are best controlled by spraying on mature foliage or by direct injection into the stems.

Herbaceous perennials are those species whose tops die back to the ground at the end of the growing season. The roots, however, remain alive and the roots, tubers, rhizomes, bulbs, and corms serve as storage and reproductive organs to ensure growth the following spring. These include many grasses, sedges, vines, field bindweed, dandelion, milkweed, and Canada thistle. These species are best controlled by applying postemergence herbicides soon after flowering.

• *Dandelion* reproduces by seed. It has a thick, fleshy, branched root. New sprouts can come up from roots or root segments. The stem produces a rosette of leaves that are simple, variously lobed, 3 to 10 inches long, with a milky sap. Flower heads are smooth and hollow. They are borne on a long stalk from the crown with yellow flower buds, which develop into yellow flowers 1 to 2 inches in diameter. Seeds are about 3/16 inch long. They are brownish, ending in a long, tufted tip.

Seeds germinate in late summer or early fall. In the first spring, a single flower may develop, but thereafter many more flowers are borne per plant. The seeds are carried by wind to infest new areas. Hand weeding generally is ineffective unless the root is cut at least 2 inches below the soil surface.

Application Equipment

Multipurpose Sprayers

Multipurpose sprayers are designed to handle most spraying needs. The sprayers have plunger- or piston-type pumps that deliver 3 to 8 gallons per minute at pressures up to 800 pounds. Tanks range in size from 50 to 800 gallons. The spray material is mechanically agitated.

Skid-mounted models are powered by an auxiliary engine. Wheel-mounted models may be powered by an auxiliary engine or by the tractor's power takeoff.

Hand gun and hose are standard equipment; field booms, usually 20 to 35 feet in length, are available as optional equipment.

Sprayer booms are commercially available in lengths of 15 to 60 feet. The most common boom length is between 20 and 35 feet. Even with a 20-foot boom, it is essential to have some means of protecting the boom from damage if a tree or other obstacle is encountered. The most common boom is made in three sections—one rigid section in the middle of the machine and a folding section extending out on each side. These outer sections are hinged at their inner ends and are supported from the center of the machine by a rope or light chain. This type of construction gives a 20- to 35-foot boom adequate support, and provides the versatility necessary in irregularly shaped areas and the mobility required when moving the sprayer through narrow gateways.

The height of the sprayer boom must be easily adjustable so the nozzles can deliver the chemical uniformly. Boom supports should be made so the boom can be set at any height from 12 to 48 inches above the surface being sprayed.

Boomless sprayers have a central nozzle or nozzles that are designed to produce a very wide spray pattern resulting in a wide swath similar to that laid down by a boom type sprayer. They may be calibrated to spraying a known acreage with water and refilling.

There are four variables that you can adjust to govern the amount of spray delivered by boom sprayers. These are

- nozzle spacing on the boom,
- nozzle tip orifice size,
- pressure, and
- ground speed of the sprayer.

Usually your equipment will already be set up to meet your local needs, so you will make minor changes in spray delivery by changing the speed and/or pressure, and major changes by using larger or smaller nozzle tips. Routine checks of your sprayer should be made to make sure that the nozzles are not badly worn and have uniform output, uniform appearance of spray pattern, and equal fan angle. Replace any nozzle tips having a flow of 10 percent more or less than required or having obviously different fan angles or patterns.

Nozzle bodies. A complete nozzle assembly consists of the body, screen, cap and tip or orifice (opening) plate. The function of the nozzle body is to attach the screen and tip to the boom. Several different nozzle body designs are available. All designs perform adequately, but each design has advantages for specific spraying jobs.

Nozzle screens. The screen is placed behind the nozzle tip and in the nozzle body to help eliminate, or at least reduce, the frequency with which the nozzle orifice becomes plugged. The size of the nozzle opening and/or the type of chemical being sprayed dictate the size and type of nozzle screen that should be used. For most general herbicide spraying, a 50-mesh monel or stainless steel nozzle screen can be used. When wettable powder suspensions are being applied, a 50-mesh monel or stainless steel nozzle screen should be used.

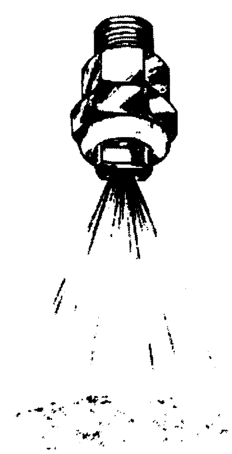
When the boom must be turned off frequently, nozzle "dribble" may be a serious problem. A nozzle screen with a check valve in it will help eliminate dribble and will not affect the operation of the sprayer. Some care must be taken to make certain that the ball bearing does not become glued to its seat or that dirt or chemical particles do not hold the ball bearing off its seat.

Nozzle tips. A nozzle is an atomizing device that spreads the liquid droplets in a definite direction to form the spray pattern. Nozzles are made to accommodate a variety of replaceable tips or discs to meet different spraying requirements. Manufacturers of sprayer nozzles can supply data sheets for the delivery rate (usually in gallons per minute at different pressures for their nozzles). The application rate cannot be specified on these data sheets unless the forward speed of the sprayer and the spraying pressure are specified. Never operate nozzles at high pressures to compensate for selecting the wrong nozzle size. Unnecessarily high pressures increase the rate of nozzle wear and increase the drift hazard.

Nozzle tips and discs are made of aluminum, brass, ceramic, plastic, stainless steel, or tungsten carbide. Tungsten carbide discs and stainless steel tips are more resistant to abrasive wettable powders, but they are more expensive than steel discs and brass tips. No single material is the least expensive, most corrosion resistant, and most durable for spraying all agricultural chemicals.

Fan or flat pattern nozzles. The spray droplets are arranged in a fan shape as they leave the nozzle. The orifice in this type of nozzle is elliptical. Herbicides are best applied with this type of nozzle because

- when a series of these nozzles is properly mounted on a boom, the spray material is more evenly distributed than it would be with any other type of nozzle; and
- at 30 to 60 pounds per square inch, the flat-pattern nozzle delivers small to medium droplets that do not drift excessively.

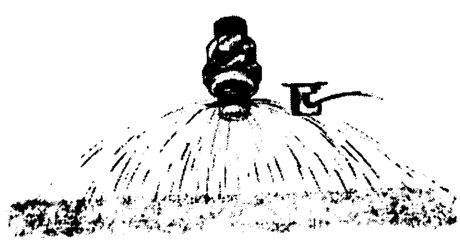


The most commonly used flat-pattern nozzles have a spray angle of 65, 73, or 80 degrees; the most commonly used pressure is 40 pounds per square inch.

For most herbicide spraying done with a relatively short boom (20 to 35 feet), the 80-degree flat-pattern nozzle is best. It is possible to keep the boom relatively low to reduce the drift hazard, and give a uniform distribution of spray material over the entire length of the boom.

The flat-pattern nozzle is available in brass, plastic, stainless steel, and hardened stainless steel. The brass nozzle is inexpensive and satisfactory for spraying chemicals in solution. The hardened stainless steel nozzle is the most durable, but it is not as corrosion resistant. When using any wettable powders, it is essential to calibrate the sprayer frequently, because as a nozzle wears, the quantity of the spray material delivered increases.

Broadcast or boomless nozzles. The broadcast nozzle is made of one or more nozzles in a cluster. These nozzles deliver a flat fan-like pattern that covers a swath up to 70 feet wide. The spray droplets range in size from very small to very large. Broadcast nozzles are convenient for spraying areas in which a uniform distribution of spray material is not essential. Never use a broadcast type of nozzle when there is any breeze.



Flooding fan. This is a broadcast-type nozzle that has been modified to be mounted on a boom. The nozzle spacing usually used is 40 to 80 inches. The small- to large-sized spray droplets are not distributed as uniformly as the droplets from a flat-pattern nozzle. The flooding-fan nozzle is available in brass or stainless steel. Its main use is for surface application of herbicides that are immediately incorporated into the soil.

Calibration. Manuals usually come with the sprayers. If a manual is not available, the equipment can be calibrated to deliver the amount of spray desired. Follow these steps.

1. Measure the distance traveled, in feet, in 1 minute at the speed you will use in applying the pesticide; use this value for L in step 5.

2. Measure the width, in feet, of the swath that will be covered by the pesticide (measure the width from end to end even though the pesticide will be applied only in narrow bands across this width); use this value for W in step 5.

3. Count the number of nozzles that will be used; use this value for N in step 5.

4. Collect and measure the spray, in liquid ounces, delivered in 1 minute from several nozzles at the approximate settings that you will use, or use equation 1 to determine this. Determine the average amount delivered in one minute from these nozzles and use this value for A in step 5.

5. Determine the gallons per acre delivered by a sprayer using the following equation:

$$\text{Gallons per acre} = \frac{340\ NA}{WL}$$

(340 is a constant that will convert ounces per square foot to gallons per acre.)

Example:

Tractor speed (L) is 176 feet per minute

Eight 36-inch rows covered (W = 24 feet)

Eight nozzles used (N = 8)

Twenty liquid ounces of spray per nozzle per minute (A = 20)

$$\text{Gallons per acre} = \frac{340 \times 8 \times 20}{24 \times 176} = 12.88$$

High Pressure Sprayers (Hydraulic), Hand Gun and Hose

These machines are commonly used in turf, ornamental and shade tree spraying as well as for orchards and as boom sprayers for heavily foliaged vegetable crops. Usually they have piston pumps and mechanical agitators and are solidly built, long-lasting machines.

Usually a high pressure hose and a hand-held spray gun are used when treating foundation plantings and other ornamentals, shade trees or nursery blocks, but a spray boom may be used when applying turf insecticides or fungicides.

Foundation plantings, nurseries and turf can be treated with hydraulic sprayers of moderate pumping capacity such as 6 to 10 gpm at 400 to 500 pounds per square inch. Tall shade trees require high pressure, high volume pumps capable of 35-60 gallons per minute at 650 pounds per square inch. Spray mixtures used for ornamentals and shade trees are dilute, either suspensions or emulsions, and the proper concentration of spray mixed in the tank is applied to the point of runoff.

Calibration of single-nozzle hand sprayers

1. Mark off an area 10 feet x 10 feet.
2. Fill sprayer with water to known mark and spray area.
3. Refill sprayer, measuring the amount of water required to refill to original level.
4. Determine per acre rate of spray delivery from the following chart:

Nozzle discharge per 100 square feet		Amount of spray delivered per acre (gallons)
1/2 pint	=	27
1 pint	=	55
1 1/2 pint	=	82
1 quart	=	110

1 pt/100 ft^2 = 55 gal/A, or
1 gal/800 ft^2, or
3 gal/2,400 ft^2 or 24 x 100

Calibration of knapsack sprayers

1. Lay out a square rod area 16 1/2 by 16 1/2 feet or equivalent area with other dimensions.
2. Determine time in seconds to spray this area in normal manner.
3. Catch the spray from the nozzle or nozzles used for the time period determined in step 2.
4. Calculate rate per acre as follows:

Pints caught x 20 = gallons per acre

Pints of spray	Rate in gallons/acre
¼	5.0
3/8	7.4
½	10.0
5/8	12.5
¾	15.0
1	20.0
1 ¼	25.0
1 ½	30.0
1 ¾	35.0
2	40.0

Mist Blowers

Mist blowers are airblast sprayers that are economical and effective for use against many pests of ornamentals and shade trees. They vary in size from small backpack blowers, which are powered by 2-cycle engines that move a few hundred cubic feet of air per minute (cfm) at velocities up to 200 miles per hour, to large truck- or trailer-mounted machines that move up to 60,000 cubic feet per minute at velocities near 100 miles per hour. They may have single or multiple nozzles that inject the pesticide into a single air outlet. Usually the backpack models depend on the shearing effect of the airblast to break the pesticide into fine, mist-like droplets. Larger mist blowers may pump liquid under varying pressures through nozzles to initiate breakup, but these models also depend on the airblast for final breakup into fine droplets.

Since mist blowers depend on a column of air to carry the pesticide to the tops of tall shade trees, they must be operated in little or no wind. Under good conditions there is no difficulty in reaching the tops of the tallest trees. However, operations should cease when the wind exceeds 4 to 5 miles per hour. Otherwise, not only will it be difficult to reach treetops, but excessive drift of pesticide will also result.

Emulsions commonly are used in mist blowers although wettable powders can be used. Some pesticides are available only as wettable powders or flowables. Usually relatively high concentrations of pesticides are used in mist blowers; a rule of thumb is 30 times dilute concentration. One or 2 quarts of concentrate often is sufficient for a large tree. The insect pests best controlled by mist blowers are those that move to some degree, such as cankerworms and other worms and caterpillars, leaf beetles, and lace bugs. Pests such as mites, scales, and fungi can be controlled but it is advisable to lower the concentration and increase the gallonage per tree accordingly.

Mist blowers are advantageous over hydraulic sprayers in that they are lighter in weight, use far less water and are physically easier to operate.

Calibration procedures. Mist blowers must be calibrated before using on ornamentals and shade trees. You do not apply pesticides in high concentration to the point of runoff as you do with hydraulic sprayers. In fact, it is difficult to see the usual mist blower deposit. Consequently, it is very easy to overdose. You must know the amount per minute of pesticide that your blower is delivering to the target and then time your application so that the right amount of spray concentrate is applied. Larger mist blowers normally are nozzled to deliver 1/2 to 2 gallons per minute. Thus, if a tree requires 2 quarts of 3 percent carbaryl spray and your blower delivers one gallon per minute, you should treat the tree in 30 seconds. Your core manual tells you how to determine the delivery rate.

1. Make sure that the fan and pump are operating at the speed indicated in the operator's manual and that all strainers, nozzles, and similar equipment are clean and in good condition.

2. Check the liquid pressure at the nozzle position on the discharge manifold. Pressures must be within limits set in your operator's manual and/or nozzle performance table.

3. Determine the effective airblast. Effective airblast is that part of the airblast actually used in covering the trees.

4. Make a diagram of the air outlet and liquid manifold. Indicate the effective airblast, nozzle positions, and upper one-third of effective airblast.

5. Determine:

   a. gallons per acre to be applied,

   b. distance between rows, and

   c. speed at which the sprayer is to be operated.

6. Use a calibration slide rule provided by the manufacturer or the following formula to calculate gallons to be discharged from one side of the machine.

$$\text{gal/min (per side)} = \frac{\text{gal/acre x mph x ft}}{1{,}000}$$

For example, if one selects 200 gallons/acre and 2 miles per hour in an orchard 25 foot row spacing (distance between rows):

$$\text{10 gals/min} = \frac{\text{200 gal/acre x 2 mph x 25 ft}}{1{,}000}$$

7. Divide gallons per minute per side by 3. In step 6 this would mean 10 divided by 3 equals 3.33. Two-thirds of this volume or 6.7 gallons. should be discharged through the upper 1/3 of the effective airblast and 1/3 of the volume or 3.3 gallons should be discharged through the lower 2/3. Now consult a manufacturer's chart that matches the nozzles and nozzle pressure that you are using and select the appropriate sizes to give the desired rate of delivery for each position on the manifold. Spray coverage will be more satisfactory if nozzle sizes are selected that will give a gradual decrease in volume from the top to the bottom of the effective airblast, still maintaining the patterns of 2/3 of the liquid being discharged in the upper 1/3 of the airstream.

8. Install the desired nozzles in their appropriate positions. Unused nozzle positions above the effective airblast should be shut off, but may be fitted with intermediate size nozzles for use during poor spraying conditions or for covering trees larger than those for which the sprayer was calibrated.

9. Fill the tank at least one-quarter full, turn on the newly nozzled side and check the time it takes to empty the tank. Calculate the gallons discharged per

minute. The example given in step 6 indicated 10 gallons per minute as the desired delivery rate. At this rate the tank should empty in 5 minutes if one-quarter full is 50 gallons. Your allowable error should not be greater than 5 percent or 15 seconds. This means that a range from 4 minutes and 45 seconds to 5 minutes and 15 seconds is within desired limits. If the delivery rate falls within this range, nozzle up the other side and go to work. If not, go back over your calculations to find the error. If there is no error in your calculations the problem may be a faulty pressure gauge, wrong nozzle size, or obstructions that may have developed in strainers or other parts of the liquid system.

Most of the effort to calibrate and adjust a sprayer is lost unless it is operated at the right speed. Travel speed may be checked with a special speedometer, an engine tachometer (if proper adjustment is made for tire slippage), or by finding the number of trees you should pass per minute at the desired miles per hour. Use the formula

$$\text{trees passed/min} = \frac{\text{mph x 88*}}{\text{tree spacing in feet}}$$

1 mph = 88 feet per minute

If your trees are planted 25 feet apart and you plan to travel at 2 miles per hour, then using this above formula you should spray 7 trees per minute.

$$\text{7 trees/min} = \frac{\text{2 mph x 88}}{\text{25 ft}}$$

If you are spraying more than 7 trees per minute you are traveling too fast; less than 7 trees per minute, too slow. Adjust your speed accordingly.

After the newly calibrated sprayer is operating satisfactorily, make periodic maintenance checks to ensure continued high performance. This should include checking the engine or PTO revolutions per minute, wear on the nozzles, strainers, pressure and possible partial clogging of pipes and/or the hose lines and nozzles.

Sometimes it is necessary to apply a specified amount of pesticide per acre with a mist blower, for instance, in treating nursery blocks or golf course fairways and greens. You can calibrate by the same general procedure followed for those used to treat trees. Slight variations in the procedure are as follows:

$$\text{Gal/min} = \frac{\text{gals/acre x mph x swath width in feet}}{500}$$

1. The swath width in row crop spraying is the distance between passes made across the field. The formula to calculate gallons to be discharged from one side of the machine then becomes:

$$\frac{\text{176 ft}}{88} = \text{2 mph}$$

2. The most effective liquid discharge pattern within the airstream varies from one machine to another. In most cases it is necessary to discharge a large part of the liquid in the upper part of the airstream to assure proper deposits at the more distant parts of the swath. See manufacturer's operation manual for suggested nozzle sizes and arrangement.

3. You can check your speed by measuring the distance your sprayer travels in 1 minute and dividing by 88 (feet per minute traveled at 1 mile per hour). Suppose you travel 176 feet in 1 minute:

Broadcast Applicators for Granules

These applicators may be of the full width hopper type with sliding gate openings or augers, or those using air, or spinning disks to cover swaths much wider than the machines.

With the full width sliding gate and auger types one should check the evenness of distribution from all the openings by setting the gate at a particular opening, turning the drive mechanism and comparing the output over a given time from each opening. Use the actual pesticide to be applied and a preliminary setting as recommended by the equipment operator's manual for the pounds per acre desired.

For the air and spinning disk types, select a preliminary setting as recommended by the operator's manual for the application rate desired. Select and determine your actual travel speed, then check the distribution pattern in the field. Containers deep enough to keep the granules from bouncing out should be placed on two foot centers across the swath at several intervals along the first pass. Then by vision, volume or weight, compare the output at each station. This will alert you to any correction needed and allow you to select the best swath width.

Calibration. To check the application rate, fill the hopper, settle the material in the hopper, then refill. Treat a known acreage using at least 10 percent of hopper contents and determine the pounds of granules required to refill. Then:

$$\text{pounds per acre} = \frac{\text{amount used (in pounds)}}{\text{acres covered}}$$

If the pounds per acre used are within 10 percent of that desired, treat another acreage and recheck the delivery rate, then make minor adjustments to correct the rate to within 5 percent and frequently recheck the delivery rate during application.

If the amount used is more than 10 percent in error, then change the applicator's rate settings and recalibrate. Keep calibrating until the rate is correct to within 5 percent.

Remember most units require that speed be held almost constant to keep the application rate constant. Also weather conditions can markedly affect granular flow rates so be alert to such changes.

Band or Row Applicators for Granules

These applicators should have tubes to the spreader that are not too long or too shallow. Some use a flexible metal hose to carry granules from the hopper to the ground. The hose must not be too long for even flow or the application rate will vary along the row. Careful adjustment of the hose position or length may be necessary to provide uniform flow.

Banders should spread the bank evenly even when on 10 or 15 percent slopes. Chain drives should use sprockets of eight teeth or more to keep the drive speed uniform. Design should be such that the flow of granules stops when the drive stops even when the outlets remain open. The drive should be strong enough to turn and not break when restarted after road travel even when the hopper is full of granules.

Care must be taken to ensure the placement of the granules over the row or in the row as the pesticide label directs. Proper placement in some cases is as important as proper calibration.

Calibration. Band applicators should be calibrated in the field just like broadcast granular applicators, after first calibrating in a manner similar to row or directed sprayers (outlined below).

1. Set each individual applicator to apply the desired amount per acre as suggested in the equipment operator's manual.
2. Fill hoppers at least half full, turn on applicators and run until all begin feeding.
3. Disconnect nozzle of spreader and attach container under each tube.
4. Travel a measured distance (at least 1/8 of a mile or 660 feet) at the speed you wish to apply in the field.
5. Weigh the amount recovered for each band separately and record. Use an accurate scale such as a postal or kitchen scale.
6. Calculate the application rate for each unit using Equations 1 and 2 where the band width (in feet) is the swath width.

Equation 1:

$$\text{acres covered} = \frac{\text{distance traveled (ft) x swath width (ft)}}{\text{43,650 (ft}^2\text{/acre)}}$$

Equation 2:

$$\text{application rate (lb/acre)} = \frac{\text{amount used (lb)}}{\text{acres covered}}$$

• This is the broadcast rate per acre and the rate the pest is subjected to in the banded area. The amount used per crop acre will be reduced by the ratio of band width to distance between rows.

• For some pesticides such as soil insecticides the recommended rate is in pounds per crop acre in which case use row spacing (in feet) for swath width in Equation 1 and your answer will be in pounds per crop acre directly.

• If the recommendation is in pounds per 1,000 feet or row, then:

$$\text{lb/1,000 ft of row} = \frac{\text{lb. collected x 1,000 ft}}{\text{distance traveled (ft)}}$$

7. If the delivery rate is not within 5 percent of that recommended on any unit, adjust it accordingly and repeat steps 3 to 6 until it falls within the 5 percent.
8. Use the method described for broadcast application during the first part of each application to check the delivery rate. Adjust the settings accordingly.

Soil Fumigation Equipment

Equipment used for applying liquids or fumigants to the soil varies considerably, but all such equipment uses one of two basic methods of metering out the liquid fumigant. The method of metering does not affect the efficiency of the material. Preferences of metering equipment usually are based on cost, simplicity, accuracy, practicality, and the specific needs of the applicator. There are two methods of metering.

Orifice size is selected to restrict flow from a system that maintains constant pressure at the orifice. Constant speed is necessary to maintain uniform application rates. Pressure regulation varies with the equipment but usually is one of three types.

• Constant head gravity flow. These units use a closed drum or tank with a special breather to establish a constant head of about 1/2 to 1/4 pounds per square inch, depending on height differences between breather inlets to tank and the vented orifice. Needle valves, orifice plates, and capillary coils are used to control flow rate. Capillary coils can vary in both length and diameter, but for any one application must be all the same length and diameter for equal pressure and delivery at the outlet.

• Pump and pressure regulator. Gear, roller, diaphragm, or similar pump units use either a power takeoff or other power source. They generally operate at low to moderate pressures (5 to 20 pounds per square inch).

• Gas pressure. This method generally is used with highly volatile fumigants such as methyl bromide. Pressure approved storage tanks and pressurized nitrogen cylinders are used and a constant pressure in the fumigant tank is maintained with one of a variety of pressure regulation devices operating at 5 to 35 pounds per square inch depending on the fumigant and metering system used.

Metering pumps are driven from a ground wheel and are geared to the pump. Full output of the pump or pumps is forced out of the orifices. Changes in output are adjusted by changing the gear ratios and/or the length of the pump stroke. Uniform output is independent of tractor speed. Piston pumps are most common but gear, roller, diaphragm, or similar pumps can be used.

Principal methods used for soil treatment are:

Injection systems. These are used for fumigants but can be used for other liquid soil pesticides.

• Chisel cultivators, blades or shanks with volatile materials may be 8 inches or more apart; with nonvolatile materials, banding or 1- to 2-inch spacing between chisels is necessary.

- Sweep-type cultivator shovels.
- Planter shoe.
- Plow.
- Transplant water.

Surface treatment and soil incorporation. This method is used mostly for low or nonvolatile materials. Mixing usually is shallow, 5 inches or less. The simplest method is to spray soil, turn it in with disks and compact with a drag, float, or cultipacker. Rotary hoes or weeders also are used. Nonvolatiles sometimes are applied as granules.

Drenching and flooding. These methods usually are used before prior to planting, but material also may be applied by irrigation water.

Calibration. Fumigation equipment can all be calibrated in the same manner as boom broadcast and band sprayers. However, fumigant labels usually specify the desired flow rate as fluid ounces per 100 or 1,000 feet of travel, or as feet traveled per pint of fumigant. A simpler technique is described below:

1. Establish the speed to be used in application by setting the equipment at depth to be used, and then, leaving fumigant valves turned off, drive across a tilled field at a rate that allows a constant travel speed. This speed is determined in feet per minute and converted to feet per second by dividing by 60. If the tractor has a speedometer, its speed per second can be calculated by multiplying miles per hour by 1.45.

2. Determine collecting time:

$$\text{collecting time (sec)} = \frac{\text{distance suggested on label (ft)}}{\text{speed m ft/sec}}$$

For example, if the label lists "X" ounces to apply per 1,000 feet and speed is 8 feet/second, then:

$$\frac{1{,}000 \text{ ft}}{8 \text{ ft/sec}} = \text{125 seconds necessary to apply "X" ounces}$$

3. With the orifice pressurized and constant speed units, keep the unit stationary and with pump or pressure system operating at some preliminary setting:

   a. Collect the output for the collection time calculated in step 2.

   b. If the amount is more than 5 percent above or below the ounces per 100 or 1,000 feet recommended on the label, change the pressure or orifices until the right amount is collected.

There are tables available that approximate the output for each fumigant over a range of pressures and orifice sizes.

4. With ground-wheel-driven metering pump units:

   a. Determine the circumference in feet of the tire on the ground-driven wheel.

   b. Divide the calibration distance by the circumference to obtain the number of turns needed for that distance.

   c. Turn the wheel the calculated number of turns while collecting the output from one or more of the outlets. If the amount is not right, change the gears or sprockets in the drive or change the length of the piston stroke and then recheck the delivery until it is within 5 percent of the amount recommended on the label.

5. Once field application is started, check the application rate immediately and often thereafter by comparing the amount used and the acreage covered.

Note: Row treatment rates and calibration can be kept less confusing by remembering that flow rates per outlet usually are the same as for broadcast fumigation.

Injection and Implantation

The application of insecticides, fungicides, and nutrient elements directly into shade and ornamental trees by injection and implantation are relatively new aspects of practical tree care.

Injection. Solutions are fed by gravity or pressure into holes (drilled or punched) in the trunks or root buttresses just above the soil line. Ordinarily, injections are made a few inches around the trunk of a tree in order to ensure distribution of the chemical into all the major branches. Pressure usually is provided by compressed air, as from the tank of a hand-operated, compressed-air sprayer. Pressures of 10 to 40 pounds per square inch are effective. Best uptake of solutions occurs on warm sunny days when trees are in leaf. Most movement of injected chemicals is upward; injections are not used for pests and diseases of roots. Suspensions containing insoluble particles are not satisfactory for injection because the particles tend to clog the water-conducting vessels of the wood.

Depth of injection is important. Holes that extend deep into the wood are not desirable. The most effective transport of the pesticide occurs in the outermost sapwood. That is where the injector should deliver the chemical. Injection into deeper lying wood results in failure of much of the injected chemical to reach the target-wood of the current season, bark or leaves.

Diameter of the injection hole also is important. The smaller the better. Small holes heal quickly.

Because healing processes in trees occur in both the wood and the bark after a tree is wounded for injection, an injection site can be used only once. Within several days after a hole is drilled into healthy sapwood, the tree reacts by isolating the wood from healthy tissues. This occurs before visible evidence of healing. Liquids can neither move into or out of a tree through such a wound.

• *Advantages of injection.* All or nearly all of the pesticide is placed inside the tree where it is more or less rapidly distributed upward to the fine branches and leaves. There is little waste, and hazard of environmental contamination is minimal. Heavy, expensive equipment is not required.

• *Disadvantages of injection.* Internal distribution of injected chemicals is not uniform. Some branches may receive more chemical than is needed, while others get little or none. For some pesticides applied by injection, the margin between effective dose and phytotoxic dose is small. The proper total dose depends on tree size and must be determined for each tree to be treated. Bleeding of sap or resin from injection sites sometimes occurs, especially in spring, or if holes have been drilled deep into the wood.

Implantation. Solid chemicals, usually in water-soluble capsules (or plastic capsules with soluble membranes over perforations) are inserted into holes drilled into the outer sapwood. Sap from the living wood dissolves the capsule or membrane and the chemical. This allows the chemical to be carried upward in the sap stream.

Capsules are inserted so that the outer ends are flush with the surface of the wood, and are not removed.

In comparison to injection, implantation has the advantage that a tree need be visited only once for application of the pesticide, and no specialized equipment is necessary. The main disadvantage is that the technique can be used only when applying small amounts of chemicals.

Care of Application Equipment

Operating precautions for pesticide equipment

- Never use a pin, knife, or other metal object to unplug a nozzle. Use compressed air, an old toothbrush, or a brush with soft bristles. Never blow into a nozzle to clean it.
- Never allow dirty water or debris to enter the tank.
- Control spray drift by:
  - using the largest nozzles and the lowest pressure that will apply the pesticide properly,
  - keeping the boom as low as permissible, and
  - spraying on days without wind or breeze.
- Do not use corrosive fertilizer solutions in an ordinary weed sprayer. Parts made of brass, copper, steel, aluminum or even galvanized materials may be severely damaged, unless the sprayer is cleaned carefully.
- Never operate a sprayer with any of the screens or filters removed. If the screen constantly becomes plugged, replace it with a screen of the proper mesh and capacity.
- Never fasten a power takeoff driven pump solidly to the tractor. The chain provided will keep most sprayer pumps from rotating. Fastening the pump with a bar usually causes rapid bearing wear.
- Never allow any sprayer pump to run without water, even for a short time; pump seals, bearings, and other working parts may be severely damaged.
- Always pump a large amount of clean water through the sprayer at the end of the day or when changing from one pesticide to another. Clean all nozzle tips and screens at the same time. This helps reduce the gummy deposits or the accumulation of wettable powders in the sprayer.
- Airblast or mist sprayers are designed to apply insecticides and/or fungicides. They should never be used to apply herbicides.

Cleaning the sprayer. There is no satisfactory way to completely remove all traces of a herbicide from a sprayer. Traces of chemicals in solution cannot be completely removed from porous tanks, or from hoses, pressure regulators, selector valves, or screens. If an herbicide sprayer must be used to apply an insecticide or fungicide, do not apply the insecticide or fungicide to plants that may be damaged by the herbicide. Chemicals in suspension may not be as difficult to remove from the sprayer, but traces may still be present unless all parts are thoroughly cleaned.

At the end of the day or whenever wind or weather conditions force you to stop spraying, clean the sprayer to prevent gum or powder deposits in the pressure regulator, selector valve, nozzle tips, and screens.

Follow these steps:

1. Rinse the inside and outside of the tank three times with clean water.
2. Put in a moderate amount of clean water and spray it out. A small amount of liquid detergent added to the water will help clean the inside of the sprayer system.
3. Clean the nozzles, nozzle screens, and suction screens with compressed air or a soft brush. Replace the screens and nozzles.

Caution: Never clean a sprayer near susceptible plants or where the rinse water could contaminate sewers, ponds, streams, or other supplies of water.

Storing the sprayer. When you store your sprayer properly, you add years to its useful life.

1. Clean the sprayer thoroughly.
2. Completely lubricate all moving parts according to the manufacturer's recommendations.
3. Make a list of all faulty parts and order the new ones to be ready for the following spring.
4. Fill the tank with water and add the recommended quantity and type of rust inhibitor or new light oil (see your instruction manual). Drain the tank. Leave all tank openings uncovered for ventilation, but screen them to keep out dust debris, insects, and animals.
5. Clean all nozzle tips and screens with compressed air or a soft brush and kerosene. Store the tips and screens in a jar of new light oil or kerosene.
6. Take the weight off of any tires.
7. Remove, clean and drain the pump. Fill it with the light oil, antifreeze, or rust inhibitor recommended by the pump manufacturer. Seal all pump openings to keep out dust, dirt, insects, and animals.

Note: Make sure that no water is left in the pressure regulator, selector valve, or boom. These parts will be severely damaged if water freezes in them.

Common Sprayer Troubles

Problem	Cause	Remedy
Loss of pressure	1. Pressure regulator improperly adjusted or stuck open. 2. Suction screen plugged. 3. Suction hose cracked or porous. 4. Pump worn.	1. Adjust pressure regulator. 2. Clean screen thoroughly. 3. Replace hose. 4. Replace or recondition pump according to manufacturer's instructions.
Excessive pressure	1. Pressure regulator improperly adjusted or stuck closed. 2. Bypass hose plugged or too small. 3. Gauge faulty.	1. Adjust pressure regulator. 2. Unplug the hose or replace it with a larger one. 3. Replace gauge.
Pressure gauge needle jumps excessively	1. Gauge too sensitive. 2. Air cushion for the surges in liquid flow is gone (surge tank is waterlogged).	1. Replace gauge or mount a flow restrictor or needle valve. 2. Admit air into the pump's air chamber, or install an air chamber on the pressure side of the pump.
Plugged nozzles	1. Nozzle screen too coarse. 2. Water, chemical, or tank not clean. 3. Nozzles too small. 4. Boom plugged.	1. Replace with the proper mesh screen. 2. Drain tank and clean thoroughly; check suction screen for holes. 3. Replace with the proper nozzles for the chemical being used. 4. Remove the plugs in the ends of the boom section to clean the boom.

CHAPTER 3

TURF

If you are a commercial applicator, you should study this chapter if you wish to become certified in the Turf subcategory of Category 3, Ornamental and Turf Pest Control.

Turf Management

Pest control in turfgrass includes good cultural practices as well as chemical applications. Turfgrass problems often result from causes other than pests. Be sure to consider these factors when diagnosing and treating turfgrass problems.

Factors Influencing Pest Problems

Fertilization. Both low and high nitrogen conditions can render grasses more susceptible to attack. Knowing how individual turfgrasses respond to weather and fertilization is essential.

Soil type and pH. The number and type of microorganisms present is influenced by soil type and pH. These microorganisms, together with the actual physical and chemical characteristics of the soil, can greatly influence pest prevalence.

Thatch. Many insects and disease agents find a favorable environment in a heavy thatch area, whereas the turfgrass itself is adversely affected because of decreased air and water movement through the thatch. Pesticide efficacy may be reduced because of the difficulty of penetration of the chemical through the thatch.

Mowing. Dull blades can cause turfgrass injury, leaving the grass susceptible to attack by fungi and nematodes. The optimum height of mowing differs for different turfgrass varieties and should be paid close attention.

Irrigation. Either overwatering or underwatering can predispose turfgrass to weed and disease problems, and can render damage from almost any other cause more severe. Good surface and sub-surface drainage must be maintained. Air movement in waterlogged soils is severely hindered, and roots will suffer from lack of oxygen.

Weather. Disease problems are particularly affected by weather conditions. Knowing when infection periods are likely to occur is an important part of disease management.

Turfgrass variety. The variety of turfgrass selected for a particular site is of utmost importance. Varieties known for resistance to diseases commonly encountered in your area should be chosen. Take into account temperature, mowing height, moisture, and weeds that must be competed against.

Traffic. Excessive traffic can result in damaged turfgrass and soil. This can in turn affect water movement and root development.

Air circulation. The adverse effects of too little air movement in the soil have already been mentioned. Air movement across the surface of the turfgrass can have a cooling and drying effect that deters the development of many diseases.

Competition. Weeds and roots from trees and shrubs may out-compete turfgrass in some areas for water and nutrients. Such weakened grass is more prone to attack by fungi.

Turfgrass Diseases

Turfgrass diseases are abnormal alterations in the structure or physiology of the plant that can be caused by a wide range of factors. Causal agents of diseases can be either infectious or noninfectious (for example, mechanical injury or environmental extremes); however, most discussions on turfgrass diseases focus on infectious agents, such as viruses, bacteria, and fungi. In Maryland, fungi are by far the most important group of infectious turfgrass diseases.

Disease development in turfgrasses is a complex interaction among environmental conditions, the turfgrass plant, and the fungi involved. Most turfgrass diseases occur under a certain type of environmental situation, such as hot and humid weather or cool weather with high soil moisture. In addition, cultural practices, such as deficient or excessive nitrogen fertilization, can strongly exacerbate the rapidity and level of disease development. Many varieties of the various turfgrass species, however, have been developed with greatly improved resistance. Careful selection of varieties when establishing a new area or overseeding an existing area can be the most important factor in reducing potential disease problems.

If a disease develops that may warrant control measures, it is critical that the disease be properly identified first. To identify the disease, familiarity with the symptoms of disease, the conditions under which it typically occurs (including temperature, humidity, soil moisture and soil fertility levels), and the type of grass on which the disease is occurring is needed. Once the disease has been properly identified, corrective management measures can be taken and, under more extreme conditions, proper fungicide selection can be made. Fungicides may be preventative or curative; contact or systemic; have a short or long residual; may need to be watered in or not watered in; and have a broad or narrow spectrum of activity. Thus, after you have identified the disease, it is important to understand the fungicide thoroughly if it is to be used successfully.

Diseases Caused by Fungi

The following are descriptions of two types of common diseases in Maryland: 1) leaf spot, which occurs most commonly in cool, wet weather, and 2) brown patch, which typically occurs in hot, humid weather.

Leaf spot is perhaps the most common and widespread disease problem in Maryland. Virtually all turfgrass species found in Maryland can be affected by various types of leaf spot. This disease, commonly known in the past as helminthosporium, is actually a complex of different diseases caused by species of the fungi *Drechslera* or *Bipolaris*. The following are descriptions of the symptoms and life cycles of leaf spot diseases of Kentucky bluegrass, tall fescue, and bermudagrass.

• *Kentucky bluegrass.* Perhaps the most important springtime disease of Kentucky bluegrass is leaf spot caused by *Drechslera poae. D. poae* is a cool weather pathogen that is most active during the spring (especially April and May), and autumn (especially September and October). *D. poae* causes disease that may occur in two phases: the leaf spot phase, and the melting-out phase. Typically, distinct oval-shaped, purplish-brown, leaf spot lesions are produced on leaves and sheaths of affected plants. In a heavily infected stand, the turf appears yellow or red brown in color from a standing position.

If favorable environmental conditions for disease continue, particularly overcast, cool and drizzling weather, successive layers of leaf sheaths are penetrated by the fungus, and the crown is invaded. Once the crown is invaded the disease enters the melting-out phase. During this phase entire tillers are lost, and the turf loses density. Hence, it is the melting-out phase that is most injurious to plants. As temperatures increase in late spring and early summer, the activity of *D. poae* subsides. *D. poae* may again become active with the advent of cool, moist weather in the fall. Generally, disease severity is greater in the spring than fall.

In summer, Kentucky bluegrass and fine leaf fescues may decline because of invasion by *Bipolaris sorokiniana*. This fungus also may cause a leaf spot, and melting-out phase. *B. sorokiniana* normally is most severe when temperatures exceed 85°F and humidity is high. This disease generally is aggravated when turf is subjected to drought stress and where excessive thatch layers exist. In Maryland, the fine leaf fescues frequently are more severely damaged in summer by this fungus than Kentucky bluegrass. This is principally related to the development of resistant cultivars of Kentucky bluegrass, whereas highly resistant cultivars of fine leaf fescues are not yet available.

• *Tall Fescue and Perennial Ryegrass.* Leaf spot of tall fescue and perennial ryegrass is now called net-blotch, which is caused by another of the helminthosporia, *Drechslera dictyoides. D. dictyoides* is another of the cool, wet weather pathogens that attack turf primarily during spring and fall. Initially, symptoms appear as minute purple-brown specks on tall fescue leaves. As the disease advances, a dark brown net-like pattern of transverse lines of necrotic lesions develops on leaves, providing a net-blotch appearance. These net-blotches may coalesce, and leaves turn brown or yellow, and die back from the tip. On leaves of perennial ryegrass, numerous oblong, brown lesions are produced. Under ideal environmental conditions, the fungus may invade crowns of perennial ryegrass, causing a melting-out of the stand.

• *Bermudagrass.* Bermudagrass can be severely damaged during warm, dry periods by *Bipolaris* *cynodontis*. This pathogen induces brown lesions to develop on leaves and under ideal disease conditions will cause a severe crown, stolon and root rot.

Much can be done to minimize leaf spot problems through cultural means. Of greatest importance, particularly with Kentucky bluegrass, is selecting cultivars that are known to have excellent leaf spot resistance and avoiding those, such as the common Kentucky bluegrasses, that are known to be extremely susceptible. Also of great importance is the avoidance of spring and summer applications of nitrogen fertilizer, especially avoiding single applications greater than 1 pound of nitrogen per 1,000 square feet on turfgrass stands that are known to be susceptible to the disease. Other important cultural considerations include avoiding light, frequent irrigation or excessive irrigation, raising the mowing height, and controlling excessive thatch levels.

There are both preventative and curative chemical control methods for leaf spot. Because of the wide variety of effective chemicals available and the different methods of use, it is important to contact an extension specialist for guidelines on use of any specific product. Generally, chemical control is not necessary on tall fescue.

Brown patch. With the increasing use of tall fescue and perennial ryegrass in Maryland, the disease summer brown patch (caused by the fungus *Rhizoctonia solani*) has become increasingly prevalent. Although most species of turfgrass in Maryland can be affected by this disease, it is on the two aforementioned turfgrass species and bentgrass where most problems are reported. Unlike the leaf spot diseases, summer brown patch problems are most severe under hot, humid conditions.

Environmental conditions that favor disease development are day temperatures about 85°F and high relative humidity. A night temperature above 70°F is perhaps the most critical environmental requirement for the development of the disease. Although textbooks underscore the importance of high surface or high soil moisture in disease severity, the disease appears to be most damaging to drought stressed tall fescue and perennial ryegrass in Maryland.

The symptoms of the disease vary according to the host species. On closely mown bentgrass turf, affected patches normally are circular and range from 3 inches to 3 feet or greater in diameter. The outer edge of the patch may develop a 1- to 2-inch wide smoke ring. The smoke ring is blue gray and is caused by mycelium in the active process of infecting leaves. Smoke rings are not always present and patches may have an irregular rather than circular shape. Close inspection of leaf blades reveals that the fungus primarily causes a tip dieback. This tip dieback gives affected turf its brown color.

In tall fescue and perennial ryegrass turfs, affected areas are frequently irregularly shaped and smoke rings are occasionally present. Circular patches, however, often are observed in brown patch affected tall fescue and perennial ryegrass turfs. *R. solani* produces distinctive and often greatly elongated lesions on tall fescue leaves. The lesions are a light chocolate brown color, and are bordered by narrow, dark brown bands of tissue. In perennial ryegrass, similar but normally smaller leaf lesions are produced and tip dieback is common. During early morning hours, when the disease is active, the cobweb-like mycelium is observed easily on leaves in the presence of water or heavy dew. Occasionally, black sclerotia (compacted masses of fungal mycelium) are produced between the leaf sheaths of infected plants.

Although careful cultivar selection of tall fescues and perennial ryegrasses may help reduce brown patch resistance somewhat, selection is not nearly as important as it is for Kentucky bluegrasses and leaf spot resistance. Of greater importance is careful attention to fertility and irrigation practices.

There are both preventative and curative chemical control methods for brown patch. Because of the wide variety of effective chemicals available and their different methods of use, it is important to contact an extension specialist for guidelines on use of any specific product. Generally, chemical control is not necessary in tall fescue.

Diseases Caused by Nematodes

The ability of nematodes to cause substantial damage is determined to a large extent by their feeding ability, the size of the population, and the initial vigor of the grass. This is an important point to remember, for the reduction in nematode-incited disease severity in established stands of turfgrass with presently available nematicides is brought about by reducing population pressure, not by complete elimination of the nematode species from the soil.

Plant pathogenic nematodes feed only on living host cells. On the other hand, many of them are not too selective of host species.

With the root-feeding nematodes, the aboveground symptoms vary somewhat with the turfgrass and nematode species involved. In general, foliar symptoms are those caused by an improperly functioning root system. The affected plants may show various shades of light green to yellow, with the overall areas varying in shape from serpentine streaks to sharply defined patches, and in size from a few inches to several feet in diameter. Affected plants lack vigor, and consequently have a reduced ability to withstand drought, low fertility, extremely high air temperatures, and other adverse growing conditions.

The best way to identify nematode problems is with a laboratory analysis of soil and plants. Contact your local county extension office for help in obtaining a proper sample.

Insect Pests of Turf

When examining turfgrass for insects, look for thinned grass stands; dead or dying patches; withered, discolored, chewed or frayed blades; frass or webbing; small holes, mounds or burrows; the presence of adult moths or beetles; or a large amount of bird and animal droppings. Vertebrate animals may damage large areas of turfgrass while searching for grubs or other soil-dwelling insects. Control of turfgrass-damaging insects may be effective in the control of vertebrate animals such as skunks, moles, mice, squirrels, and birds. However, such control measures are costly in terms of economic feasibility and ecological balance, and provide mixed results. Physical/mechanical barriers or repellants are better alternatives for controlling these indirect vertebrate pests of turfgrass.

Insects that attack turfgrass at or below the soil surface can be controlled only by directing the pesticide at the soil surface and watering it in to contact the pests. However, watering in an application directed at foliage feeders will move the insecticide below the area where the insect pest is feeding and the desired control will be lost.

In some areas, preventive applications of insecticides will minimize damage from soil insect pests. More than one pest may be causing damage at the same time. Each may require different timing and placement of insecticide for control. Be sure to consider this when you develop a treatment schedule. Your local extension educator can help you identify pest problems, select the correct pesticide, and advise the optimum time for application.

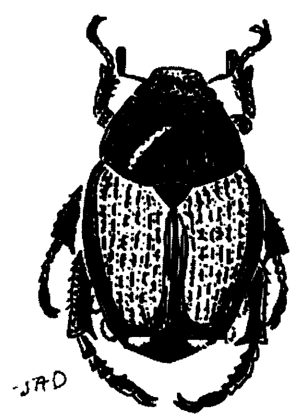
Chewing Insects

Major insect pests of turfgrass in Maryland cause damage by chewing rather than by sucking.

Japanese beetle. The adult is an oval-shaped beetle about 1/2 inch long. The head and body are metallic green; the wings are copper brown. The adults feed in groups and attack more than 275 kinds of plants. Damaged foliage takes on a lacy appearance because the adults consume only the tissue between the veins.

The larva is a C-shaped white grub. Grubs feed on grass roots, causing the grass to dry out and die, leaving large brown dead patches of sod that can be rolled back from the soil.

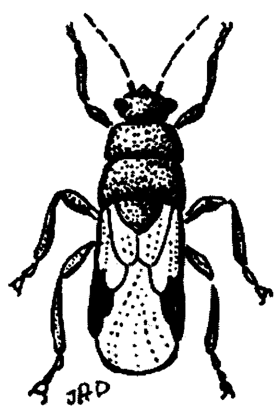
The entire cycle requires about one year. Peak emergence period for adults occurs in early July in Maryland. Beetles emerge and remain active for about 4 to 6 weeks. Most of the egg laying occurs in July and tapers off rapidly by the first week in August.



After emerging from the soil, adults mate and feed for a few days. The females then go back into the soil and lay four to eight eggs before leaving to feed for several more days. Egg laying continues until a total of 40 to 60 eggs have been deposited. Eggs hatch in about 10 days. Root feeding by grubs during July, August, and early September may be so extensive that the turf can be rolled back from the soil like a rug. By late September, the grubs (measuring about 1 inch long) move down into the soil 6 to 18 inches. Here they remain inactive until the next spring. In late March or early April, they again start their upward movement and feed on roots until late May. Then they change into a pupal stage and all feeding stops until they emerge as adults.

Control of adults remains primarily chemical, although some suppression or baiting away from the host can be accomplished with the newer floral plus female pheromone beetle traps. Milky spore disease is still the best and safest option for long-term suppression. The larvae ingest the spores as they feed on grass roots. They become sick and die before reproducing. Milky spore disease, a biological insecticide, is environmentally safe because it only attacks Japanese beetle, but this leaves other species free to move into the area. Refer to Entomology Leaflet 78 for additional information on chemical control.

Chinch bug. Adults are black, about 1/6 inch long. The immature nymphs are reddish or reddish-brown with white bands on their backs. The adult differs from the nymph in having fully developed wings, which fold over and lie flat on the abdomen. The adults and nymphs can easily be confused with several beneficial bug species that also inhabit the thatch layer.



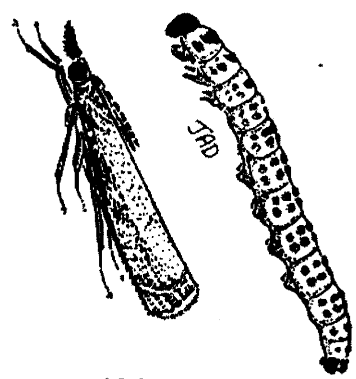
However, chinch bugs produce a strong pungent odor when handled, unlike most of the beneficial species. Most of the damage is caused by the nymph's sucking the plant sap from the grass stems. This type of feeding will cause the grass to turn yellow before dying. The turf will not recover from this type of injury.

Adults and older nymphs overwinter in the thatch or areas adjacent to the lawn that provide cover (such as leaf litter and bark mulches). Eggs are laid in the thatch or folds in the grass blades. Chinch bugs require 30 to 40 days to complete their development. These generations generally overlap but in Maryland there are three or sometimes four generations between May and October.

Hot, dry weather and sunny locations are optimal for chinch bug development. Extended periods of rain or cool wet weather favor a fungus disease that will frequently control chinch bug populations. Damage may be present, but the bugs are killed off and an insecticide will not be required.

Detection of chinch bugs 2 to 3 weeks after the damage has occurred may be due to chinch bug control by a natural enemy, the big-eyed bug. Unfortunately, people often mistake this beneficial insect for the real pest.

During May 25 to June 15 (first generation) and again from July 25 to August 10 (second generation), apply an insecticide if chinch bug nymph and adult counts exceed 20 per square foot, or when yellowing or brown damage first appears. Refer to Entomology Leaflets 30 and 75 for more information.



Adult and larva

Sod webworm. Several species of webworms are present in Maryland, but the larger sod webworm appears to be one of the more important species. The adult moth is whitish or gray, about 5/8 inch long, and characteristically rolls its wings around its abdomen. Adults cause no injury to turf grasses; however, their abundance and flight activities can be used in predicting outbreaks.

The larval stage, or caterpillar, has several growth stages or instars. The mature caterpillar is about 3/4 to 1 inch long. The larva is light tan, usually with black or reddish-brown spots. The caterpillar characteristically constructs a horizontal silken tube in the thatch layer.

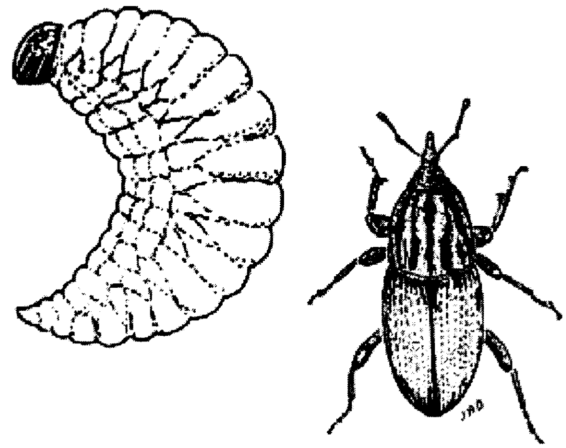
The larger sod webworm has three generations per year. The caterpillars and eggs overwinter in the thatch. The larvae feed primarily at night and withdraw into their silken tubes during the day.

An insecticide should be applied if larval counts exceed one per square foot. The first generation (May 25 to June 10) rarely causes heavy damage and in most years does not require control. The second generation (July 25 to August 20) is very important and, if not controlled, may cause severe injury or loss of sod. Damage by third generation larvae (September 5 to 20) frequently is masked or mixed with the late, second generation injury. Thus, the potential for severe injury will continue until frost. When heavy adult flight activity is extended over a 7-week period in July and August, a spray in July and a second spray application in the last week of August or early September may be necessary for complete protection. Mow the lawn before spraying and do not water for 3 days after treatment. Some varieties of turfgrasses will recover from a heavy defoliation if watered and fertilized to stimulate new growth.

Birds are a natural enemy of the sod webworm, and they may keep the population under control without insecticides. However, they will eat webworms dying from insecticides, and thus may be at risk themselves. For further webworm control information, refer to Entomology Leaflets 75 and 30.

Bluegrass billbug. The adult is a weevil about 1/4 inch long, black or dark brown with a long "snout." Adult feeding injury appears as small puncture wounds in the grass stems or a "ragging" of the newly emerging grass blades. The injury caused by the adults is much less important than that caused by the larval stage.

The larva is a legless, white to cream-colored grub with a brown head. Early season injury appears in turf as small, round, brown patches usually 1 to 4 inches in diameter. These dead patches are easily pulled out from thatch. Young larvae feed inside the grass stems, hollowing out the stem and crown, leaving very fine



sawdust-like excrement (frass) inside. Larger larvae feed on roots below the thatch layer. This type of feeding looks identical to that caused by Japanese beetle.

In Maryland, there usually is one generation per year. The adult weevils overwinter in the thatch and become active between March and May. Eggs are laid inside the stems. The young larvae feed inside, killing the stems, then exit through the crown into the soil during June. The greatest damage by the larvae occurs from early July to early September. Where grass is killed, the thatch appears loose and is lifted easily from the soil. The billbugs pupate from late August into September. The adults are active for a short period from September to the end of October.

Control of this pest is difficult once the eggs have been laid inside the grass stems. The best time to apply insecticide is late April to late May to kill the overwintering adults before they lay eggs. Application of insecticides for grub control during July, August, and September may or may not provide good control. Optimum effectiveness usually is achieved only by following the insecticide application with 1 to 2 inches of water in order to flush the material into the top 2 to 3 inches of soil. If grub infestations are light to moderate (one to two grubs per square foot), it is probably best not to apply an insecticide—only water and fertilize to stimulate new growth. Refer to Entomology Leaflets 75 and 30.

A fungus disease of the adult is common in Maryland. Frequently it controls the pest effectively during the spring.

Weeds in Turf

Weeds, which are plants growing in areas where they are not desired, present numerous problems when growing in a turfgrass stand including

- decreasing the uniformity of the stand and increasing the frequency of needed mowing,
- increasing the injury risk of athletic and recreational turfs by causing poorer footing and resiliency,
- attracting stinging insects when flowering, which can pose a serious health risk to sensitive individuals, and
- crowding out desirable species.

The most effective long-term solution to minimizing weed encroachment is through proper establishment and maintenance of the turfgrass stand. Weed seed germination, growth, and survival can be minimized by maintaining good stand density. Key cultural factors that aid in maintaining good stand density include the following:

- Select turfgrass species and varieties that are well adapted to Maryland environmental conditions, to the anticipated use, and to the expected management level.
- Use high quality, weed-free seed or sod.
- Correct soil acidity problems and soil deficiencies in phosphorus and potassium determined by soil tests.
- Apply the recommended amounts of nitrogen at the proper time for the species of grass being grown.
- Mow at the recommended heights and frequencies.
- Irrigate thoroughly only when needed.

Even when good management practices are used, weeds may become a problem due to excessive wear of an area, extremes of environmental conditions, thatch buildup, or inappropriate varieties. In these cases, herbicides may be necessary to reduce excessive weed populations. The control strategy using herbicides depends on the particular weed problem.

Grass Weeds

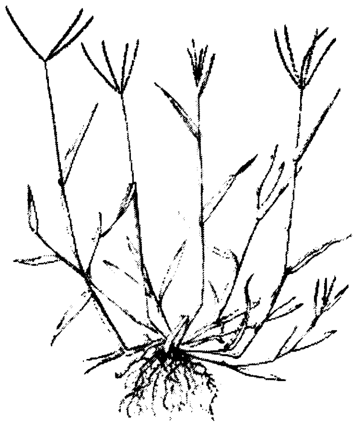
Perennial grasses are those that live more than 2 years, often spreading by stolons, rhizomes, and seed. Examples include quackgrass, orchardgrass, and common bermudagrass.

• *Quackgrass* is a blue-green, course-textured, cool season rhizomatous perennial grass. It spreads vigorously in turfgrass stands by means of a very aggressive and deep rhizome system. It is a weed in turf because of its coarse texture, its formation of an open rather than dense sod, and its poor summer performance.

As with most perennial grass weeds, the most effective control strategy is to prevent introduction of the grass. Thus, use of topsoil that is free of perennial grass weeds or use of sterilized or fumigated topsoil is vital during turf establishment. Use of quackgrass-free seed or sod also is critical. Once quackgrass becomes established in turf, little can be done through management practices to reduce its spread.

There are no selective chemical control measures for most perennial grasses in turf. The only means of eliminating quackgrass is through the use of nonselective herbicides that are systemic— they move through the entire plant and kill all plant parts including roots and rhizomes. Keys to successful use of these herbicides include applying when quackgrass is actively growing, when soil moisture is adequate, and no rain is forecast for the next 24 hours. Also, the treated area should not be mowed for 48 hours before or after application.

Annual grasses are those that germinate, grow, produce seed, and die within the same year.



• *Smooth crabgrass* is a yellow-green to green, coarse-textured, bunch-type grass that roots at the nodes. Seed germinates in early to midspring when air temperatures reach 70°F for a period of 7 to 10 days. Plants grow rapidly throughout late spring and summer, particularly in open turf. Seedheads are produced in midsummer and continue to develop until the first frost in the fall. Plants are killed by cold weather in the fall, usually after the first or second frost.

Reducing the amount of light reaching the soil surface by maintaining good turf density through proper management and using cutting heights higher than 2 inches is most important. Abstaining from frequent light irrigation, and avoiding spring and summer aeration or de-thatching also helps prevent annual grasses from flourishing.

Two approaches may be used in chemical control of annual grasses. Herbicides applied before weed seed germination are called preemergence herbicides. These kill plants as they germinate. Herbicides applied to actively growing weeds are called postemergence herbicides.

Preemergence control usually is the most effective and reliable means of controlling annual grasses. Important keys to the successful use of preemergence herbicides follow. Apply the herbicide at least 1 week before annual grass germination. Water the herbicide in or apply when rain is forecast within 48 hours. Use repeat applications for those products requiring them for season-long control. Applications made after annual grass germination will not provide effective control.

Postemergence control is usually not as effective and may cause some discoloration and thinning of sensitive desirable grasses. New materials are being developed, which are more effective and have fewer undesirable side effects. Keys for successful postemergence control with older postemergence materials include applying the herbicide to younger (one- to three-leaf stage) annual grass plants when soil moisture is adequate and no rain is forecast for 24 hours. Many products require repeat applications in 7 to 10 days for effective control.

Broadleaf Weeds (Dicots)

Perennial broadleaf weeds live more than 2 years and spread by stolons, rhizomes, and/or seed. They often have large taproots. Dandelion, plantain, oxalis, and ground ivy are examples of perennial broadleaf weeds.

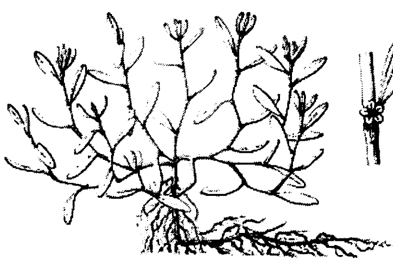
• *Dandelions* grow in a prostrate rosette form, have long leaves with jagged "teeth," have an extensive taproot that may be 2 to 3 feet deep, and produce bright yellow flowers predominantly in the spring. Growth is most active in spring and fall, and tops may die back in the winter.

Maintaining stand density as previously outlined will help minimize encroachment. Physical removal of weeds is feasible for limited populations, but the entire taproot must be removed or the plant will recover. Maintain mowing frequency during the flowering period to help reduce seed spread.

Several herbicides and mixed herbicide products effectively control dandelions postemergently (after weed seed has germinated and seedlings are present). Keys to their successful use include applying herbicides when both young and mature dandelions are growing actively in the spring, late summer, or fall when soil moisture is adequate and air temperatures are less than 85°F. Some broadleaf herbicides can be absorbed through the roots of trees and shrubs, so read labels carefully and avoid application of such materials anywhere near potential root zones of these ornamentals.

Summer annual broadleaf weeds germinate in the spring, produce seed in late spring or summer, and die in the fall after frost. Knotweed and prostrate spurge are examples.

• *Knotweed* seed germinates as soil temperatures warm in the spring. Plants soon begin to branch out to form a low growing, mat-like mass of stems, which radiate from a central taproot. White flowers produce much seed throughout the summer. Plants begin to die after the first frost in the fall.



Knotweed usually occurs on infertile and compacted soil. Thus, correcting soil fertility problems and relieving compaction through aerification, and buildup of organic matter may help reduce knotweed infestations. As knotweed often occurs where foot traffic is concentrated, techniques that will help spread traffic or increase the traffic area may also help reduce knotweed.

Knotweed plants are controlled most effectively by postemergence broadleaf herbicides when they are young, preferably in the three- to four-leaf stage. Chemical control becomes increasingly difficult as the plants mature, and some herbicides are not effective as the plants reach maturity. Using a sprayer with a fine droplet size can increase effectiveness.

Winter annual broadleaf weeds germinate in the fall, produce seed in the spring, and die in late spring or summer. Henbit and common chickweed are examples.

• *Common chickweed* germinates from late fall through early spring. It has a creeping habit with a shallow root system and numerous multibranched stems that root at the nodes. Dense patches form, particularly in moist and shady areas. Seeds from small white flowers are produced throughout the spring. Plants die when high temperatures occur in late spring or early summer.

In cool season grasses, common chickweed occurs most readily in open turf. Thus, maintaining good stand density through proper management will help minimize infestations.

Avoid late fall aerification if the problem is especially severe and no herbicide treatments are planned. In warm season grasses, such as zoysia, which are dormant in the winter and early spring, little can be done through management to reduce infestations, although problems will be fewer on denser turf. Postemergence control of common chickweed can be achieved with broadleaf herbicides when it is actively growing. Herbicide selection is important as some materials are much more effective than others. Due to the small leaf size of common chickweed, smaller spray droplet sizes result in better control. Since plants begin to die in hotter weather, herbicide applications past mid-spring are usually not justified.

Pesticide Application Equipment for Turf

Sprayer Selection

No one commercial-size sprayer now available can meet all the demands of the turfgrass industry. For any specific task, many sprayers are suitable. It takes an understanding of types available, capabilities, types of mounting, power sources, pumps and tanks, guns and hoses, blowers, and other accessories to make a wise choice.

Most power sprayers in use today can be classified as one of two general types—the hydraulic sprayer, and the airstream mist blower. Both types have the following basic sprayer elements in common: tank with agitator; pumps with pressure regulator; unloader or relief valve and pressure gauge; power source; self-contained engine or power takeoff connection; framework for mounting the sprayer; strainers, screens, and control valves; and interconnecting piping, including leads to the distribution system.

The distribution system of the two types, however, is fundamentally different, each having characteristics that make it preferred for specific spray jobs. In hydraulic sprayers, the spray material usually is distributed through a hand-held nozzle gun, or through a multiple-nozzle spray boom, or both. The force or energy required to carry the spray droplet from a handgun to distant foliage comes from the pressure developed by the direct action of the pump on the spray liquid.

In the air-mist sprayer, the distribution system contains a fan or blower that creates a continuous blast of air to carry the spray droplets from the nozzle to the surface to be treated. This airblast can be directed upward or downward to spray hillside turf, or horizontally for mass coverage of level turf. The air-mist sprayer is known as a concentrate sprayer because the use of the air stream as the propelling and dispersing force permits the use of spray materials in concentrated form. This results in significant savings in hauling and handling water.

Hydraulic Sprayers

A large variety of types and models of hydraulic sprayers is available with many accessories. Consider the types of jobs you must do and then select the most appropriate sprayer.

One of the larger sprayers (when equipped with the usual 20-foot spray boom) would cover about 10 acres of golf course fairways or other turf in 1 hour of travel at 4 miles per hour. If this were an application of herbicide, which usually is put on at the rate of about 10 gallons per acre, the sprayer would apply about 100 gallons of spray material per hour. Assuming the fairway covers about 3 or 4 acres, the sprayer, equipped with a 200-gallon tank, would have to be filled about twice to cover the weeds on the fairways of a nine-hole course. Booms and nozzles are easily modified in most instances.

Since turf spray often is applied at pressures of 40 to 60 pounds per square inch, a 5-gallon-per-minute pump would be adequate for the 200-foot boom because it would require only 2 gallons per minute equipped and operated as described.

Some turfgrass managers select larger than minimum-size pumps to provide greater flexibility for other uses. With such a pump and higher pressure capacity, the sprayer may be suitable also for shade tree spraying, with some limitations. The maximum reach with any long-distance handgun, and most nozzles, is obtained at pressures of about 250 pounds per square inch at the nozzle. At higher pressures, the spray droplets are broken up more finely and tend to drift. At a pressure of 250 pounds per square inch, a sprayer equipped with a pump capacity of 5 to 10 gallons per minute would be able to reach the top of 40- to 45-foot trees.

Two important points to consider in selecting the hydraulic sprayer best suited for the types of jobs to be done are mounting and power source.

Mounting. Often self-contained units are mounted on two-wheel trailers. Those with extra-large tanks may require oversized tires or four wheels. The same basic units also are available on skid mounting for transport on a truck or other vehicle. Some special units are designed for direct mounting on the rear of a tractor with a three-point hitch.

The choice between trailer and skid models will depend on the frequency of use of the sprayer, the types of jobs to be handled, and the possible additional use of vehicles or tractors available for transporting them. Skid models mounted on flatbed trucks are used most often in large-scale tree spraying or roadside turf weed spraying. On large golf courses, a unit widely used is the trailer-type, which, if desired, can be powered from the tractor power takeoff. New skid models that fit special golf course vehicles are handy for frequent greens maintenance. A permanent hoisting mechanism for easy loading and unloading of skid models is desirable.

Power source. Trailer-mounted sprayers are often powered by the power takeoff from the tractor. This saves initial investments in engines; however, a self-contained power source allows sprayer use with any vehicle that can pull the sprayer.

Airstream Mist Blower Sprayer

The use of air as a carrier for spray chemicals began in the 1920s with the introduction of boom-type row crop dusters. Large strides in air spraying were made after 1946. The success of concentrate sprayers in orchards created interest in the use of this equipment for other crops. Interest in air-mist sprayers on golf courses is increasing every year. However, these sprayers are not suitable for herbicide application because of drift hazard.

Effective control with air spraying can be achieved with:

- effective spray materials,
- adequate amounts of chemical,
- accurate timing of applications, and
- even and thorough distribution of chemicals on and throughout the foliage canopy.

These same factors are equally important for hydraulic boom spraying. Since acreage covered per day is higher with air equipment, more effective timing is possible with air machines. However, the basic problem is distribution of material and the effect of wind conditions on even and thorough distribution.

To attain the same utility level as boom equipment, air sprayers must be able to operate in varying wind conditions. To justify the additional investment, they must reduce overall spraying costs as well as achieve pest control levels comparable with hydraulic booms.

Subsequent research has verified that these goals are suitable if

- the effective area to be sprayed is limited to that point in the air jet where air velocity is no less than 15 to 17 miles per hour. (Spray material must be driven into the foliage with turbulent force.);
- the airspraying equipment in question is able to handle chemicals in suspension as well as liquid emulsions;
- a satisfactory deposit is obtained on the side sprayed into the wind; and
- the spray swath is not overextended. (With the smaller air sprayers, a wider swath is attained than with the larger spray booms. Even with this advantage, many people tend to overextend the swath reach of these machines. A certain amount of overlap should be allowed at the swath extremity for effective control.)

Two primary types of air sprayers exist—the one-way turntable outlet, and the fixed two-way discharge. Each has advantages. The advantages of the one-way outlet are limited to the smaller machines (up to 60-foot swath). For swath widths of more than 60 feet, the two-way sprayer will consistently deliver the spray deposits required to justify the investment in the larger sprayer.

Total air jet throw is 40 percent greater when a given volume of air (at the same velocity) is divided and discharged from two outlets in opposite directions than when it comes from one source.

For effective pest control the spray should be driven into the turf foliage with turbulent force. The effective swath is the length of the moving air column where air velocity is 17 miles per hour (1,500 feet per minute) or more.

The larger, one-way sprayers often depend on the wind to drift the swath to their advertised width. Spraying with the wind usually causes the deposit to be dropped onto the foliage rather than driven into it, at the swath extremity. If the distance of the swath from a one-way machine is extended beyond recommendation, a lower velocity of air reaches the swath, causing the larger, heavier droplets to settle short of the target.

The longer an outlet is in relation to its width, the greater the intake of free air surrounding the outlet. As more air is taken into the jetstream, the jet velocity is reduced; consequently, the air jet throw is decreased.

One very important factor, easily overlooked, is the shape of the air outlet. Surrounding free air, induced into the jetstream, reduces the velocity of the air pattern. Hydraulically, the most efficient outlet shape is circular.

Wind velocity increases with height. The outlet on some sprayers is mounted high and is located in this high-velocity wind area. On other sprayers, the air outlet is placed low, thus removing it from high-velocity wind area. Angling air discharge vanes down produces an airstream beneath this high-velocity area, and will consistently produce wider spray swaths in windy conditions. The resulting rolling air pattern gives superior coverage on both sides of the grass leaf, and may even give better control on the prevailing upwind side.

Many factors have to be considered when determining the work rate of air sprayers. Variables such as type of terrain, groundspeed, wind, and swath length and width all have a bearing on the spray rate.

Sprayer performance is one factor in a total pest-control picture. Weather, chemical effectiveness, and operator skill also are all important.

The three most common mistakes in air spraying techniques are

- excessive rates of travel,
- overextension of swath reach, and
- lateral or upward air discharge rather than downward into the turf foliage.

The correct rate of travel is very important since it has an effect on the total swath reach. Generally, the rate of travel should be limited to 1 1/2 to 2 miles per hour. An operator should check the deposit over the swath frequently to make sure that sufficient coverage is being obtained. If coverage is questionable, the rate of travel or the coverage spacing should be reduced.

Some applicators in extremely flat sites resort to night spraying to reduce the wind factor. This may not always be practical, but certainly extends the availability of equipment. A spotlight, mounted above the air outlet and directed laterally, allows a continual check of the spray swath.

Air pattern control vanes should be adjusted downward to direct the air jet under the wind and into the foliage. Many applicators have found that they obtain consistently longer swaths this way and no longer need to make in-travel adjustments of the vane angle.

For most golf turf areas, the sprayer should travel down one side and back the other with the spray pattern overlapping the center.

The most commonly used spray volume dilution is 40 gallons per acre. A practical downward limit is probably 10 gallons per acre. Although fine droplets are necessary to obtain adequate distribution with low gallonages, they must be large enough to give a deposit on foliage. This balance between droplet diameter and the deposit obtained requires a minimum volume limit in the range of 10 gallons per acre.

Liquid pesticides are most popular for large areas, but pesticides may be applied dry as dusts or granules. Dusts are being used less and less each year, especially as turfgrass treatment. Granules may be applied with either drop-gate or spinner spreaders. The drop-gate is somewhat easier to calibrate because it uses a catch pan for full recovery of the trial run material. With spinner spreaders, the calibration is similar except that it may be accomplished by either the refill procedure or by building a specially designed trapping box to catch the complete output from the spinner. Because of the unique physical properties of each granule formulation (depending on the carrier) the spreader must be calibrated with the active pesticide to be used rather than pure water as can be done with sprayers.

Drift Hazard

Spray drift can be a hazard to both the operator and to other persons in the area. With herbicides, especially the hormone-type materials, a severe drift hazard is present to nontarget plants. Do not apply herbicides with air-mist sprayers.

Two operational techniques will keep drift hazard to a minimum. First, by angling the air pattern downward into the foliage, the smaller droplets will more likely fall on the foliage. This reduces the possibility of wind currents carrying the smaller droplets into nontarget areas. Second, the target area should always be sprayed from the outside toward the center. This technique eliminates misses in the turnaround area and provides a buffer zone to reduce spray fallout outside the target turf area boundary.

Pesticides may be applied in liquid form with helicopter and fixed-wing aircraft. These are primarily of use in sod farm turfgrass production, although helicopter application is beginning to be used more frequently for golf course pesticide treatment. The pilot must be a certified commercial aerial applicator.

Large Acreage Sprayer Calibration—Optional Methods

Method 1

- Measure 660 feet.
- Determine the amount of spray put out in traveling this distance at the desired speed.
- Use this formula:

Method 2

- Fill spray tank and spray a specified number of feet.

$$\text{gallons per acre} = \frac{\text{gallons used in 660 feet x 66}}{\text{swath width in feet}}$$

- After spraying, refill tank and measure the quantity of material needed for refilling.
- Use this formula:

Method 3

- Measure 163 feet in the field.

$$\text{gallons per acre} = \frac{\text{43,560 x gallons delivered}}{\text{swath length (feet) x swath width (feet)}}$$

- Time tractor in crossing 163 feet. Make two passes to check accuracy.
- At edge of field, adjust pressure valve until you catch 2 pints (32 ounces) of spray in the same amount of time it took to drive the 163 feet. Be sure tractor is at the same throttle setting. You are now applying 20 gallons per acre on a 20-boom spacing.
- For each inch of nozzle spacing on boom, increase time by 5 percent or reduce the volume by 5 percent.

Granular Pesticide Application Calibration for Small-area Treatment

Dry granular herbicides, fungicides, insecticides, and fertilizers usually are applied with spreaders that meter the formulation through adjustable discharge ports in the bottom of the spreader. Many of these spreaders give approximate settings because it is practically impossible for a manufacturer to provide rate settings for products other than their own granular materials.

The metered application rate at any given setting will vary for different materials. Density, particle size, and flowability are common material characteristics that vary and affect the application rate. Finely powdered material that tends to pack often can be applied only with those spreading devices equipped with special agitators. If there is a considerable variation from bag to bag in particle size and product density, or if the forward speed of the spreader changes appreciably during application, rates will be affected.

Parts of spreaders, particularly the metering mechanism, will wear. Worn mechanisms require adjustments to maintain the rate of application according to standards or tolerances set by the original manufacturer. This adjustment, or calibration, usually can be done only by instructions from the manufacturer.

Generally, it is necessary to establish a spreader setting that will apply a desired amount of granular material per square foot of soil surface, usually calculated per 100 square feet, or per one acre. This is called "establishing the rate."

To establish the rate by which granules will spread from an applicator, equipment measurements and a treatment area (100 square feet) must be determined for use as standards.

1. Measure the width of the spreader in feet.
2. Divide 100 by the width; this will give the number of linear feet that the spreader must travel to cover 100 square feet.
3. Select an area of turf to be treated and mark off the number of linear feet as calculated.

Application Rate Adjustments

Now that a standard treatment area has been marked, the rate of discharge for V-shaped hopper spreaders may be established by one of three methods.

Method 1. Fill the spreader halfway with granules. Weigh both the spreader and the granules and record their total weight. Adjust the spreader's output rate to an approximate setting and operate it over the linear feet marked for the test plot. Again, weigh the spreader and its contents. Subtract the second weight from the first; the result will be the number of pounds of granules you applied on 100 square feet. If the weight of material applied is more or less than the desired or recommended rate, readjust the spreader's output and make another test run until you establish the correct setting.

Method 2. Construct a lightweight metal pan 2 inches deep, 6 inches wide, and of sufficient length to fit between the wheels of the spreader. Drill a hole in each corner of the pan and fasten a piece of wire in each hole. This pan then can be hung beneath the spreader and should catch all of the granules. Next, determine the desired rate of product application (from the label) per 100 square feet, reset the spreader and make another test run until you establish the correct setting.

Method 3. Agitators of most hand-pushed spreaders are driven by one wheel only. Find the wheel that drives the agitator and drill a 1/4-inch hole near its outside edge. Fasten a 1/4-inch bolt 3 inches long into the wheel so it can be used later to turn the wheel. Measure the circumference of (distance around) the wheel in feet. Divide this figure into the linear feet the spreader must travel to cover 100 square feet; this determines the number of wheel revolutions required for the spreader to cover 100 square feet. Now fill the spreader halfway with granules and estimate its rate setting. Place the spreader over a large sheet of paper or cloth; raise the drive wheel side of the spreader about 1/2 inch off the ground. Next, open the spreader, and by using the bolt as a crank, rotate the wheel the same number of turns as required to cover 100 square feet. Crank the wheel at the approximate speed at which it would move under normal applications. Weigh the material on the paper. If the amount collected is more or less than the recommended rate per 100 square feet, reset the spreader and repeat the test until the desired rate is achieved.

Some spreaders are designed and manufactured specifically to apply granulated materials accurately. Other spreaders are designed primarily for fertilizer applications where accuracy is not as important. Generally speaking, those multipurpose spreaders that are made to apply herbicides and insecticides as well as fertilizers are of necessity manufactured for greater accuracy than are typical fertilizer spreaders.

Hose Applicator Sprayer Calibration for Small-area Spray Application

Applying liquid pesticides uniformly to a given surface can be done with a special sprayer operated on the end of a garden hose, using adequate water pressure. A hose applicator varies in rate of application depending on water pressure, width of swath covered, and speed of walking. To accurately apply a pesticide, you may calibrate rate of application as follows:

1. Measure off an area of 1,000 square feet. (For example, this could be an area 100 by 10 feet, or 50 by 20 feet.)
2. Spray on one place on the pavement or dry ground. Note the width of the spray pattern. Double spraying is desirable to increase uniformity of application; if the sprayer covered an area 6 feet wide, moving each swath over 3 feet provides double spraying.
3. Set stakes, rocks or other markers at this interval (the width of the spray pattern) along two opposite sides of the measured 1,000 square feet.
4. Fill container with water to a mark near the top.
5. Spray the marked-off 1,000 square feet. Kick down the stakes as each swath is covered.
6. Measure the amount of water needed to fill to the original level. This volume is crucial to the calibration.
7. Mix the amount of the pesticide to be applied per 1,000 square feet in the amount of total mixture applied from the container. For example, if 6 fluid ounces of liquid were applied from the sprayer reservoir to the 1,000 feet and you want to apply 0.75 fluid ounce of pesticide, then you would mix 0.75 fluid ounce of pesticide with 5.25 fluid ounces of water to make 6 fluid ounces of spray solution in the sprayer reservoir.
8. Apply this mixture with similar water pressure, speed, and swath width as calculated.

CHAPTER 4

GREENHOUSE ORNAMENTALS

Pest Management in Greenhouses

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

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

Early detection and prompt action form the basis for successful management programs. If a pest is detected before it has an opportunity to spread or build up in large numbers, control measures can be applied with generally satisfactory results. Such early action depends on correct identification of the cause of the problem. This may be a simple matter, such as seeing the pest on the plants (for example, aphid or powdery mildew infestations). In some cases, however, the pest may be invisible to the unaided eye. This usually is the case when dealing with disease-causing agents. In these instances, the symptoms or the damage done by the pests must be recognized.

Even symptoms may not be totally revealing. Some symptoms are very general and can result from a number of causes (for example, stunting of growth from root-rotting microorganisms or root-eating weevil larvae). In these cases, knowledge of the life cycles of the pests and of the environmental conditions that allow them to flourish will help in making a correct diagnosis of the problem.

All greenhouse growers should practice preventive pest control, which involves much more than "insurance" applications of pesticides. Non-chemical control methods should not be overlooked, particularly preventive measures such as making sure not to introduce infested plants into production areas. Providing optimum growing conditions does a great deal toward preventing pest problems. Often keeping the plant under the best growing conditions takes advantage of any natural resistance it might have against insects or disease. Good greenhouse sanitation does much to keep crops free of pests. Weeds and excess plants left around can harbor pests and may be a source of reinfestation. Manipulating the greenhouse environment so it does not favor pests also aids greatly in preventive pest control.

Diseases of Greenhouse Crops

Diseases of greenhouse plants are difficult to diagnose because most of the pathogens that cause the diseases are microscopic. Diagnosis is further complicated by the number of environmental conditions (for example, excessive soil moisture or salt toxicity) that produce symptoms similar to those caused by plant diseases. However, correct identification of the plant disease and the pathogen involved is crucial if effective control decisions are to be made. Many greenhouse crop diseases may be identified accurately by carefully observing symptoms exhibited on affected plants; by examining plants for signs of the pathogen involved (for example, rust pustules on lower leaf surface); by noting the pattern of symptom development in the greenhouse; and by noting the environmental conditions favoring development of the disease. Diseases of greenhouse crops may be caused by fungi, bacteria, viruses, and nematodes. The following descriptions of common greenhouse diseases caused by these various pathogens should help growers diagnose disease problems in the greenhouse.

Soilborne Fungal Diseases

The fungi responsible for soilborne diseases may cause seed decay, damping off (death of young seedlings), cutting rots, root and stem rots, and wilt diseases. Seed decay, damping off and various rots may be caused by the water molds *Pythium* and *Phytophthora* or other soil fungi such as *Rhizoctonia, Fusarium, Cylindrocladium, Thielaviopsis*, or *Sclerotinia*. Symptoms of root rots on aboveground portions of affected plants include a general decline in plant vigor, failure to respond to fertilizer, wilting and yellowing of foliage, and eventual death of leaves and stems. To check for root rots, remove plants from their containers so the root systems can be examined. Look for discolored (black or brown), poorly developed root systems with few fine feeder roots.

The fungi *Fusarium oxysporum* and *Verticillium* cause wilt diseases of a number of greenhouse crops. These fungi invade through the root system and grow in the vascular (water-conducting) tissues of the plant. Typical symptoms are wilting of affected plants, yellowing of leaves, and a brown discoloration of the vascular tissues of the plant. Root rot also may be evident.

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

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

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

If the soil is steamed, then stacked in large piles in a moist condition, there is considerable danger of the formation of nitrites, which are toxic to plants. This is particularly true if manure is used. The amino acids and proteins in the manure are converted to ammonium by microorganisms. Under conditions of good aeration, the ammonium is changed to nitrites, then quickly to nitrates. However, if the soil is unduly moist, there may not be sufficient oxygen except near the surface of a soil pile, for conversion of nitrites to nitrates. To avoid nitrite formation, the soil should be stacked neither in large piles nor in an unduly moist condition. Tile or perforated pipe should be placed at intervals in the soil pile to permit air to enter.

Certain chemical fumigants also are being used as energy efficient methods of ensuring good soil sanitation. When using a fumigant, the temperature of the soil being treated should be 60°F or higher and the soil should be loosened and watered prior to fumigation. Let the fumigated pile stand undisturbed for 24 to 48 hours. Then remove the cover and let the media aerate for at least 72 hours. After 1 day, it can be worked or turned to speed aeration. Some of these materials are extremely toxic to plants and should not be used near living plants. Residues left in the soil after use of certain fumigants may cause poor germination and poor growth of a number of greenhouse plants. Once the soil, sand or mix has been treated, great care should be taken to avoid re-inoculation or contamination of the treated material.

Sanitation and cultural practices. Good sanitation practices are crucial in preventing soilborne diseases of greenhouse crops. Good sanitation practices include the following:

- cleaning and disinfecting pots, flats, benches, and tools;
- keeping treated soil or equipment clean;
- keeping feet off benches;
- hanging up watering hoses;
- cleaning up walkways and under benches; and

- keeping animals out of greenhouses.

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

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

- use disease-free seed or stock plants,
- use new seed or properly stored seed,
- plant at proper depth,
- handle seedlings and young plants carefully,
- fertilize properly, and
- water properly.

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

Leaf Spots

Fungal leaf spots may vary in size, shape, and color. Spots may develop on leaves, flower parts, petioles, and stems. These lesions may coalesce to form larger areas of dead tissue. Some of the more common leaf and flower spotting fungi are *Alternaria, Botrytis*, and *Septoria.*

Alternaria usually strikes after seedlings are transplanted to growing flats. Petunia, zinnia, verbena, and a few other species are especially susceptible. *Alternaria* causes tan to bleached spots on the margin of the leaves. These spots enlarge, often showing concentric rings of dead leaf (target spot), and may kill the entire leaf or stem. The fungus sporulates in the spots; in moist weather the spores appear as fine, dark dust on the spots. The spores may be splashed or carried by air currents to other parts of the same plant or other plants. A film of water on the leaf surface is needed for the spore to germinate and cause a new leaf spot. Keeping foliage dry helps prevent these diseases.

Botrytis blight, caused by the fungus *Botrytis cinerea*, is commonly called gray mold because of the fuzzy, gray growth that it produces across blighted plant surfaces. The numerous spores of *Botrytis* are splashed or carried by air currents to other plants. *Botrytis* is favored by high humidity and warm temperatures. It is frequently a problem on wet plant surfaces and where plants are crowded.

Septoria is a slightly different type of leaf spot disease. *Septoria* produces small, tan to light brown spots on the leaf, petioles, or stem. The fungus produces spores in flask-shaped structures called pycnidia. The pycnidia are formed in the centers of the small, tan spots and look like grains of pepper embedded in the spot. Under moist conditions, the spores will ooze out of these pycnidia and be splashed or wind blown to other plants.

All of these leaf spot and blight diseases are favored by high humidity, free moisture on the leaf surface, and warm temperatures. The most efficient means of control is manipulating greenhouse conditions to avoid extended periods of high humidity. Venting greenhouses in the early evening to reduce humidity can be crucial in controlling these diseases. It is also important to avoid splashing water on leaf surfaces when watering. Water early in the day so water can dry and plant surfaces do not remain wet for extended periods of time. Increasing air circulation by proper spacing of plants will help reduce humidity and prevent spread of diseases. Strict sanitation also is important because many of these leaf spot and blight fungi can survive in plant debris. Finally, there are a number of fungicides that are effective against leaf spot and blight diseases.

Powdery mildew is one of the easiest plant diseases to identify. Powdery mildew forms a whitish, powdery growth on surfaces of leaves, stems, and flowers. The white, powdery material is composed of chains of spores. Millions of spores are produced, and these spores are detached easily and carried by air currents to surrounding plants. On some plants (for example, dahlia, zinnia and phlox), infection is commonly limited to older foliage late in the season. On other hosts, such as roses and delphiniums, the young foliage and stems may become severely distorted as well as covered with mildew. Powdery mildews are favored by cool temperatures, moderate to high humidity, and infrequent foliage wetting. Powdery mildews may be controlled by manipulating the greenhouse environment to reduce humidity and increase air circulation. There are several chemicals effective in controlling powdery mildews. However, when selecting chemicals for mildew control, it is important to use a material that is specifically labeled for powdery mildew. Many of the fungicides effective against leaf spots and blights will not control powdery mildews.

Rusts. Typical symptoms of rusts are blister-like areas on the leaf surface. These blister-like areas rupture to release numerous spores visible as a reddish-brown powder. These spores are air-disseminated or water-splashed to spread the disease to other plants. Generally rusts are very host specific. This means that the fungus that causes geranium rust attacks only geraniums. As with other diseases caused by fungi, control of rust diseases includes manipulating greenhouse conditions to reduce humidity and free moisture on the leaf tissue. Cultural practices, such as proper spacing of plants, early watering and proper watering as well as good sanitation, also are important. If a fungicide is chosen, it is important to select one recommended specifically for control of rusts.

Bacterial Diseases

The most commonly encountered bacterial diseases of greenhouse crops include bacterial soft rot of cuttings, corms and bulbs, bacterial leaf spots, and bacterial wilts. Bacterial soft rot, caused by the bacterium *Erwinia chrysanthemi*, is characterized by a soft, wet rot of affected plant parts. Bacterial leaf spots, such as *Xanthomonas hederea* on English ivy, cause small light green, water-soaked spots on the foliage. These spots may enlarge and become brown to blackish-brown and dry. Bacterial blight (caused by *Xanthomonas pelarogonii*) is a serious disease of geraniums. The bacterial pathogen invades the roots, stems and leaves of infected plants, colonizing the water-conducting tissues of the plant. What makes this an especially difficult disease to control is the fact that complete colonization of the plant may occur without the appearance of any symptoms. Symptoms are particularly suppressed during periods of cool weather.

Once bacterial diseases are introduced into a greenhouse, they are very difficult to control. Therefore, control of bacterial diseases must be through preventive measures including proper cultural practices and good sanitation. The use of disease-free planting material from reliable sources is most important. Equipment, pots, flats, and benches must be kept clean and disinfected. Bacterial cells are readily spread by splashing water when crops are watered. If bacterial diseases have begun to develop, avoid overhead watering, avoid splashing water during watering, minimize periods of free moisture on plant surfaces, and space plants as far apart as possible. Most chemicals used in greenhouses for disease control are fungicides and will have little effect on bacterial diseases. Situations may occur when the use of a bactericide or a copper-containing fungicide may be warranted.

Viral Diseases

Symptoms produced by viruses range from a mottling or mosaic of foliage, vein clearing, flecking or spotting to a distortion of plant parts, or stunting of the entire plant. Most viruses are spread in infected plant material, by plant contact or by sucking insects such as aphids.

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

Diseases Caused by Nematodes

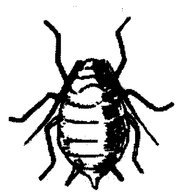
There are several types of nematodes, very small roundworms, that cause diseases on greenhouse crops. Lesion nematodes (*Pratylenchus*) and pin nematodes (*Paratylenchus*) cause plant stunting and poor growth because their feeding weakens the plant's root system. The root knot nematode (*Meloidogyne*) causes nodules to form on roots, thus damaging roots and stunting the plant. The foliar nematode (*Aphelenchoides*) lives within the leaf tissue of many flower crops and causes death of leaf tissue, resulting in brown blotches on leaves. Laboratory tests of soil or growing media and plant samples usually are necessary to identify these nematode diseases. The principal means of controlling these nematode diseases is through good sanitation. Soil sterilization with fumigants or steam will kill nematode adults or eggs present in the soil. If nematodes are detected in a greenhouse crop, certain nematicide treatments can be applied.

Insects and Mites in the Greenhouse

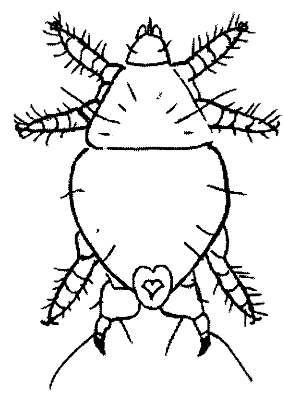
This portion of the manual will discuss common insect and mite pests. Emphasis is on recognition, damage symptoms, life cycles, habits, and common plants attacked. The pests are divided into categories depending on their sites of attack, above- or belowground. Pests attacking the foliage are further divided into sap feeders, which have sucking mouthparts, and leaf feeders, which have chewing mouthparts. General control comments, including nonchemical measures where appropriate, are provided for each pest group.

Sap Feeders

Aphids are small, soft-bodied, sluggish insects found on virtually every greenhouse crop. A number of different aphid species occur, differing in size, color and food preferences. Aphids often are found on the growing terminals, buds, and upper leaves of plants. Sap feeding by aphids may cause plant stunting, leaf curling and other deformities. Aphids also may transmit plant diseases caused by viruses. Honeydew, a sugary liquid excreted by aphids, clogs stomates and permits the growth of sooty mold on leaf surfaces. This in turn reduces photosynthetic efficiency, and may make plants unsalable. Aphid populations may increase explosively since individuals can mature and begin to reproduce in as few as 7 days. Although aphids have many natural enemies, heavy use of insecticides makes it difficult for these enemies to keep pace with aphid populations in the greenhouse. The concerned pest manager might wish to consider release of predators or parasites as part of the control program.

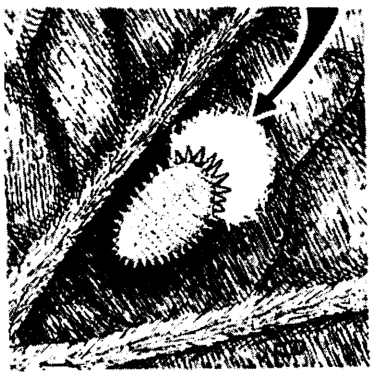


Aphids can be controlled with many types of insecticide formulations including foliar sprays, aerosols, fogs, or soil-applied systemics formulated as granules or drenches. Careful inspection is needed to determine when aphid controls are to be applied. Careful, frequent inspection should be made after application to evaluate control efficacy and need for retreatment.



Cyclamen mites. These very tiny (1/100 inch), translucent mites rarely are seen without the aid of a hand lens, but their damage is obvious and frequently extensive. Unlike spider mites, cyclamen mites prefer high relative humidity (above 80 percent) and lower temperatures (60°F to 80°F). They most commonly are found in plant crowns, between unexpanded leaves, in buds, or flowers. Damage consists of growth distortion including curling, stunting, deformity, and tissue blackening. Plants commonly attacked are cyclamen, African violet, ivy, mum, snapdragon, and begonia. Chemical controls are difficult because of the mite preference for protected sites. They usually are controlled with repeated foliar spray applications.

Mealybugs. These common pests attack numerous greenhouse crops from flowers to woody foliage plants. They are sluggish insects about 1/10 inch long, oval, with short white spines on the body margin and a covering of white, powdery wax that is the source of their name. Sap feeding by mealybugs reduces plant vigor and also may cause distorted growth and leaf drop. Black, sooty mold often grows on the honeydew excreted by these insects. Wingless mealybug females

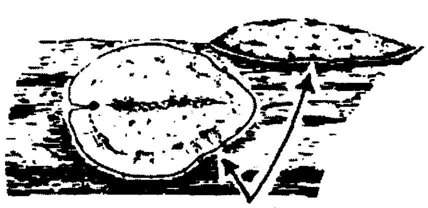


Adult female

lay eggs in masses of cottony, white wax. Tiny yellow crawlers leave the egg mass and move actively about the plant seeking protected feeding sites. Adults can appear within 6 weeks of egg hatch.

The mealy white wax covering and egg mass are water repellent and help protect the insects from insecticide sprays. This is one reason mealybugs are difficult to control. The newly emerged crawlers are more susceptible to control attempts but repeated applications are essential to control those that hatch after spray residues are gone.

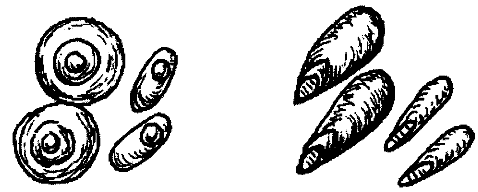
Scale insects. Scales are related closely to mealybugs and whiteflies and cause similar damage. Two types are common on greenhouse plants.



Brown Soft Scale

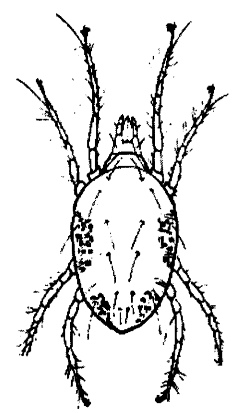
• *Soft scales* grow to slightly less than 1/4 inch in length. Adult females lay their eggs under their bodies. They are soft when young, but after the eggs are laid, the females die and become brittle, protecting their eggs with their dead bodies.

• *Armored scale insects* have a hard, shell-like covering that they secrete as they feed and grow to about half the size of soft scales. This cover provides protective coloration and also makes it virtually impossible to contact the insect directly with insecticides. Eggs produced by the female are concealed beneath the shell.



The newly hatched yellow nymphs, called crawlers, emerge from beneath the female's cover to seek a suitable location to settle and begin feeding. Once they settle they immediately begin producing a cover. Females do not move again but remain and develop in one location. The length of the life cycle varies considerably with each scale species, ranging from two to eight generations per year in the greenhouse.

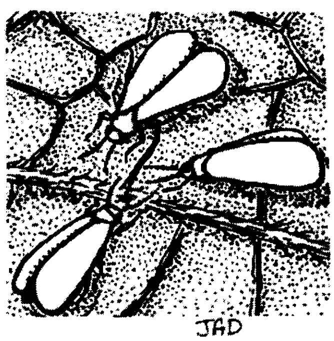
Control of scales can be very difficult because of the protection afforded by the waxy covering. All formulations of insecticide can be used for scale control. Foliar sprays must be timed to kill the newly emerging crawlers. A practical solution to scale infestations is to destroy plants when only a few of them are infested.



Spider mites. Although commonly referred to as red spiders, these are neither spiders nor insects. The two-spotted spider mite is the most common. Spider mites attack a wide range of greenhouse crops by feeding on plant sap, generally from lower surfaces of leaves.

Damage characteristically appears as tiny white spots called stipples. In light infestations, mottling of the foliage occurs; in heavy infestations, leaves may turn brown and drop off. In severe infestations, the plants may be covered with webbing.

Spider mites are able to complete the cycle from egg to adult in as few as 7 days during hot, dry conditions. Each female may deposit up to 100 eggs, giving the mites the capacity for rapid population increase. Chemicals specifically labeled for mites must be used to ensure control. Early detection is essential. All formulations of miticide application are used in spider mite control, especially soil systemics and foliar sprays. Pesticide resistance is a serious problem with spider mite control. Using miticides from different chemical classes is advisable to delay the onset of resistance.

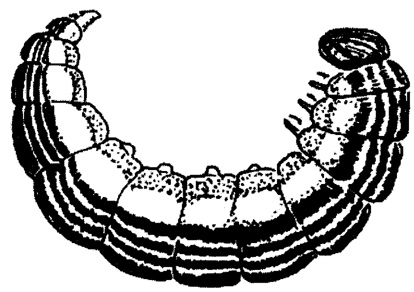


Whiteflies. The greenhouse whitefly is a very common pest of many crops. These tiny, white insects are not true flies; they are close relatives of scales, mealybugs, and aphids. The damage they cause is similar to that of other sap feeders. Copious quantities of honeydew are produced by all stages of the whitefly except the eggs. This can lead to sooty mold problems.

The greenhouse whitefly has a complex life cycle that can be completed in as few as 3 weeks. Eggs usually are laid in circular clusters of about 20 on the undersides of leaves. A crawler stage hatches from the eggs and moves about selecting a feeding site. The crawlers soon settle and change to a scale-like stage that is greatly flattened, nearly transparent, difficult to see, and tolerant to many insecticides. After several molts, a pupal or resting stage is produced. The chalky-white, winged adults emerge from the pupal stage.

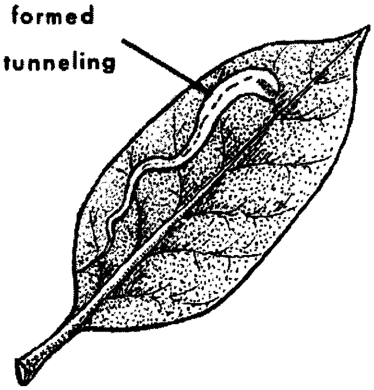
Under greenhouse conditions, whitefly generations overlap and all stages of the insect may be found on infested plants at any time. Since some of these stages are not controlled by insecticide sprays, repeated applications of the recommended pesticides should be applied. As with most of the sap feeders, all formulations of insecticides can be used for whitefly control. Whitefly populations can be monitored by placing yellow sticky boards in greenhouses and checking the boards regularly. The adults, attracted by the yellow color, become entangled in the sticky material. Placing many of the sticky panels throughout the greenhouse may give some degree of control. Tiny wasps that parasitize and kill the immature whiteflies have been incorporated successfully into management programs.

Leaf Feeders



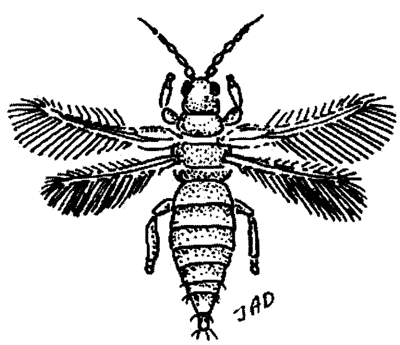
Larva

Caterpillars are the immature forms of butterflies and moths. Included within this diverse group are armyworms, cutworms, leaftiers, leafrollers and loopers. Many enter the greenhouse during the summer when vents and doors are open. Some adults are attracted by lights at night. Only the caterpillar stage is damaging. Their chewing mouthparts tear off large pieces of foliage, stems, and flowers. These caterpillars are exceptionally variable in size, appearance, and life cycle. All undergo complete metamorphosis, but the size, duration, and location of the various stages will vary with the species. Many bore into buds or stems, or tie leaves together with silk. Caterpillars usually are controlled with foliar sprays. Microbial insecticides are effective against some species.



Leafminers. A number of species of leafminers attack greenhouse crops. The most common are tiny fly maggots that feed between the upper and lower leaf surfaces, leaving narrow winding trails or mines. The adults are small flies (less than 1/8 inch long) that puncture leaves to feed and lay eggs. These activities can give foliage a speckled appearance, further reducing plant value. Larval feeding is completed in about 10 days. The larvae then chew their way out of the leaf and drop to the soil to pupate. New adults emerge about 10 days later to repeat the life cycle.

Because of the development of resistance to a variety of insecticides, control of leafminers has become difficult, especially on chrysanthemums. Repeated applications of foliar insecticides usually are necessary to control leafminers. The best prevention against leafminer infestation is refusing to accept infested plant material and maintaining strict weed control in and around the greenhouse.



Adult

Thrips are small, slender insects about 1/10 inch long. They can complete their life cycle in two weeks in warm temperatures. Their rasping feeding action on flowers and foliage causes a streaked, silvery appearance. They often feed in protected places such as buds, leaf axils, and flowers. Black dots of excrement are also a clue to thrips infestation. Foliar sprays, aerosols,s and fogs usually are used for thrips control.

Soil Dwellers

Fungus gnats are tiny, fragile, black flies that frequently are abundant in greenhouses. The larvae normally feed on fungi and organic matter in the soil. When abundant, the larvae may feed on roots, root hairs, or storage organs such as bulbs. The objectionable presence of numerous gnats usually is worse than any physical injury caused by larvae. Soils or artificial mixes high in organic matter and moisture retention properties are more prone to fungus gnat infestations. Aerosols or fogs are used to control the adult flies. Also, a soil drench or application of spray to the soil surface where the adults rest is used sometimes.

Springtails. These very small insects are another nuisance pest found in moist, high organic matter soils. Soil sterilization or soil drenches for control of other pests will help reduce populations of this relatively harmless insect.

Non-insect Soil Dwellers

Slugs, snails, sowbugs (pillbugs), and ***millipedes*** are additional nuisances likely to be encountered on soil surfaces, around pots and benches, or on the ground under the benches. Sowbugs and millipedes occasionally can cause damage to seedlings and cuttings when present in high numbers. It may be necessary to treat the ground and benches for control of these pests. Slugs and snails eat ragged holes in foliage and leave behind a silvery slime trail as they move. This trail may further detract from plant appearance. Slugs and snails must be controlled with special bait, sprays, or dusts specific to this group of organisms.

Weeds in the Greenhouse

Weed Management in Greenhouses

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

Nonchemical control. The most practical form of weed control is to prevent the source of weeds, the weed seed, from entering the greenhouse. There are several methods by which seeds may move into the building. Common sources are potting soil contaminated with weed seed or the use of crop seed containing weed seed. Much labor can be saved by locating sources of seed and soil free of weed seed. Procedures that sterilize soil to prevent plant diseases also should be effective in killing weed seeds.

Another source of weed seeds is weeds growing in the vicinity of the greenhouse. These seeds can be carried into the greenhouse by the wind or on workers' clothing. Controlling weeds in areas surrounding the buildings will remove the source of the majority of these weed seeds.

Although eliminating these sources of weed seeds will greatly reduce the numbers of weeds in the greenhouse, a few weeds inevitably will continue to become established inside the building. Eliminating these weeds before they mature and produce seeds will reduce the occurrence of weeds in the future. A single plant of certain weed species may produce several thousand seeds. These seeds remain viable for several years and will provide a source of weeds for many years. Removing these weeds by hand is usually the most effective and safest means of control, although in some situations a herbicide may be necessary.

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

- The physical condition of a greenhouse-grown plant differs from that of an outdoor plant. The warm, humid conditions frequently found in greenhouses tend to produce tender, succulent plants. This type of plant generally is highly susceptible to herbicide injury.
- Volatility is the second limiting factor. Volatility is the tendency of a herbicide to produce vapors that move from the soil or plant surface into the atmosphere. When herbicides vaporize outdoors, they normally are diluted in the atmosphere and do not cause any problems. In the greenhouse, however, this dilution mechanism is eliminated and the herbicide can accumulate into phytotoxic concentrations. Only those herbicides with recommendations for greenhouses listed on their labels should be used. A few herbicides are recommended for use under benches. Always follow label instructions to ensure safety to the applicator and plants.

Pesticide Application in Greenhouses

Pesticides are available in various formulations for application by different methods. In some cases, only one or a few application methods may be registered for use of a specific active ingredient. Effective application of pesticides depends on proper timing to treat susceptible pest stages; favorable treatment conditions in terms of temperature, humidity, moisture, time of day, and plant condition; and thorough coverage.

Methods of Application

Foliar treatments leave a residue that prolongs control but may be unsightly. Extra applications usually are required.

Aqueous sprays, also called dilute sprays, are applied with hydraulic sprayers (pressurized tank sprayers or high-pressure, powered spraying machines). The spray consists of EC or WP mixed with water. WP sprays are less likely to cause phytotoxicity than EC sprays but EC sprays provide the longest lasting residual deposits and the most resistance to washing off. Addition of surfactants, wetting agents, or spreader/stickers may improve application efficacy. Thorough coverage of upper and lower leaf surfaces is essential for all but the systemic sprays. Systemics are absorbed and transported throughout the plant.

Mists. In a mist treatment, also called concentrate spray or ultralow volume (ULV), very small quantities of a highly concentrated pesticide are diluted with air for delivery to the target. Special equipment is needed, such as motor-driven or electric mist machines. These also are called mist blowers. Mist application is a complex technique requiring skilled operators. The ideal droplet size for most ULV applicators is 50 to 100 microns. For best results, droplets should be of uniform size. Overdosing is easy and can result in serious plant injury.

Dust treatments are dry formulations of pesticide diluted in a carrier such as talc for application to foliage. Few dust products are available for commercial uses and this is not a common treatment. Dust residues are especially visible.

Fine droplet application. Special equipment can produce very small droplets that will disperse throughout a closed greenhouse and slowly settle onto upper surfaces of plants. These applications are simple to apply but provide little accumulation of residue. Application should be done on calm days and the greenhouse should be sealed to eliminate drafts and air leaks. Rates of application are based on air volume in the closed greenhouse. It is important to keep the greenhouse closed for the appropriate length of time followed by adequate prescribed ventilation. Inhalation protection is required for applicators.

Aerosols. In an aerosol application, small droplets of 15 to 20 microns are dispersed from cylinders that have been pressurized with a propellant. This is commonly called a "bomb" application. Aerosols work best when temperature is 70 to 80°F and the foliage is dry. At temperatures above 85°F, plant injury can occur. Coverage is inadequate below 60°F. Also, some aerosols break down in sunlight and should be applied in the evening.

Fogs. Small droplets of 10 to 60 microns are produced when oil-base carrier preparations are dispensed through special fogging devices or machines that use heat to vaporize the insecticidal liquid. These fogs are similar to an aerosol application and a white, visible fog is produced. Fog application should not be directed toward foliage.

Vapor treatments also are called smoke applications. Vaporization of the pesticide is accomplished using flame or hot pipes as a heat source. Only a few products are available for this simple application. As with aerosols and fogs, vapor treatments should not be used at temperatures below 60°F or above 85°F.

Soil applications. Insecticides or fungicides can be applied directly to the root media to control medium-borne pests. This simple method can also provide systemic insect control.

Drenches. There are a few pesticides made to be used as a water formulation applied to the soil.

Granules can be applied to pots, beds, or benches. Large-area application is made with mechanical spreaders. Small areas or individual pots are treated with small volume measures such as a teaspoon. This method generally provides long residual control. Many granular insecticides are highly toxic; great caution should be exercised by both applicators and workers handling the plants after treatment.

Plant Injury

Phytotoxicity is a term referring to plant injury caused by chemicals, particularly pesticides. Greenhouse plants seem to be especially prone to this problem, in part because of the wide variety of plants often grown or held in one area. Signs of phytotoxicity include

- tip or marginal bum of leaves;
- chlorosis in spots, at tips or on margins of leaves;
- leaf distortion, including curling, twisting, or cupping;
- stunting or growth reduction in the size of entire plants or certain parts; and
- abnormal or excessive growth of certain parts.

Flower parts and bracts are especially sensitive to many chemicals. New growth is most commonly affected when systemic chemicals are used improperly. Soil drenches and granular treatments may cause root injury resulting in decline, stunting, and damage to older leaves.

Precautions

Pesticide injury to the crop can be avoided by reading the cautions on the pesticide label and by using the recommended concentrations. Other precautions follow.

- Be sure the pesticide is labeled for use in greenhouses.
- Read all of the label directions every time you use each pesticide.

- Apply sprays in the mornings between 6 and 10 a.m.
- Apply pesticides when foliage is dry and conditions are conducive to drying.
- Use wettable powders rather than emulsifiable concentrates when possible.
- Keep nozzles of aerosols or mist blowers at least 18 to 24 inches from plants when treating.
- Clean sprayer, tank, pump, hose, and gun after each use.
- Do not apply pesticides to plants under stress.
- Avoid spraying under very sunny, humid conditions.
- Avoid treating when temperature extremes are likely.
- Do not mix pesticides without prior experience; check compatibility.
- Never spray insecticides in equipment (such as tanks, pumps, hoses, and guns) that has been used for applying herbicides.
- Do not let spray mixes stand in the sprayer; do not expose spray concentrates to extreme heat or freezing.

Applicator Safety

Handling treated plants in a greenhouse is unavoidable. Due to the high toxicity of some greenhouse pesticides, the relatively closed environment and the potential for developing allergic reactions in this type of situation, greenhouse workers should take special care. Review your *Pesticide Applicator Core Manual* for a discussion of toxicology and personal safety equipment. All routes of entry (dermal, ingestion, and inhalation) must be protected adequately during greenhouse pesticide use. Especially important is respiratory protection (gas mask or respirator) during application of mists, aerosols, fogs, or vapors. Dermal protection (rubber gloves and boots) and eye protection (goggles or face shield) are essential when handling highly toxic materials.

Delivery Calculations

It is essential that the recommended dosage of a pesticide be applied in all pest control treatments. If the dosage applied is insufficient, materials are wasted, time is lost and the desired control is not attained. This may lead to additional pesticide applications that will accelerate the buildup of pests resistant to the chemical and increase the hazards to humans and the environment. Dosages that are larger than recommended can be equally wasteful and injurious.

Information needed for calculations. To ensure that the correct dosage is applied, the following information must be available.

- Know the labeled dosage rates.
- Know the size of the area to be treated—greenhouse volume in cubic feet for fumigations (such as smoke, fog, mist) or square feet of planted area and type and height of plant for sprays, dusts, aerosols, and soil application.
- Know the capacity in pounds or gallons of the equipment to be used, or, as in the case of smoke generators, the volume in cubic feet covered by each unit.
- Know the extent and characteristics of the insect population.

Dosages for most WPs and ECs used in the greenhouse are given on the labels in ounces per 100 gallons of water and the resulting spray formulations are applied to plant material up to the run-off point. Aerosol labels indicate the length of time the nozzle should be directed at the plant for the delivery of the necessary dosage. Smoke labels state the volume in cubic feet of greenhouse covered by one generator.

Once the rate of pesticide has been established by reading the label, the volume of the greenhouse or the area requiring treatment must be determined if using smoke generators, foggers, and mist generators.

When using sprays and aerosols, or when making soil applications of pesticides, determine the square feet of planted area to be treated. This is established by determining the total bench space or production floor area that will be treated. *Note*: If plants will be treated with a spray to the run-off point, calculation of the area involved may not be necessary. But, for the same area, the volume of spray required for proper coverage will vary with the type and height of the plant material. Aerosol directions often indicate the number of seconds the generator should be directed at a given type of plant.

After the pesticide rate and the size of the area to be treated are established, the capacity of the equipment must be determined. In the case of smokes and aerosols, pesticide and equipment are self-contained. Foggers and mist blower equipment provide instructions for filling with concentrated pesticide, based on greenhouse volume.

When sprays are involved, equipment capacity must be established. If the gallon capacity of the sprayer tank is not known, one of the following calculations can be used:

Type of Tank	**Calculation of Capacity**
Cylinder tank (circular cross-section)	Multiply length in inches by square of diameter in inches; then multiply by 0.0034.
Tank with elliptical cross section	Multiply length in inches by short diameter (d2) in inches by long diameter (d1) in inches; then multiply by 0.0034.
Rectangular tank (square or oblong cross-section)	Multiply length by width by depth, all in inches; then multiply product by 0.004329.

After the capacity of the spray tank is established, the correct amount of pesticide concentrate to use must be calculated. Many of the tanks have a capacity of less than 100 gallons, although this is the figure generally mentioned on pesticide labels. The following formula may be used to determine the amount of concentrate to add to a tank of less than 100 gallons.

$$\frac{\text{amount of concentrate (in ounces) recommended for 100 gallons}}{\text{100 gallons}} \times \text{capacity of the tank (in gallons)} = \text{amount of concentrate to use (in ounces)}$$

Equivalent Measures

$$10{,}000\ ft^2 = 0.2295\ acre$$
$$1\ gal = 128\ fl\ oz$$
$$1\ lb = 16\ oz$$

Example 1: If 3 pounds of a wettable powder are recommended for 100 gallons of spray, how many pounds of WP are required for a 25-gallon tank?

Calculation:

$$\frac{48\ oz}{100\ gal\ X\ 25\ gal} = 12\ oz$$

When a pesticide is given at a dosage rate per acre, the portion of an acre to be treated must first be determined.

Example 2: An insecticide is recommended at 2 gallons per acre. How much should be used on an area 10,000 ft^2?

Calculation:

2 gal/acre X 10,000 ft^2 = the amount recommended for the area you want to cover

or

256 fl oz/acre x 0.2295 acre = the amount recommended for the area you want to cover

(since 1 gal = 128 fl oz, then 2 gal = 256 fl oz)

58.75 fl oz = the amount that should be used on the 10,000 ft^2 area

1 gal = 128 fluid oz
2 gal = 256 fluid oz

Multiply the recommended rate in ounces by the acreage to be covered.

[2 gal x 10,000 ft2] = [256 oz x 0.2295] acre
= 58.75 fluid ounces of pesticide for 10,000 ft^2

Example 3: A granular pesticide is recommended at a rate of 15 pounds per acre. How much should be applied to 100 square feet?

Calculation:

15 lb/acre x 100 ft^2 = the amount recommended for the area you want to cover

or

240 oz/acre x 0.002295 acre = the amount recommended for the area you want to cover

(since 1 lb = 16 oz, then 15 lb = 240 oz)

(since 10,000 ft2 = 0.2295 acre, then 100 ft^2 = 0.002295 acre)

0.5509 oz = the amount that should be applied to the 100 ft^2 area

Study Questions

Chapter 1

1. How do insects and mites differ?

2. How does gradual metamorphosis differ from complete metamorphosis?

3. How do stomach poisons and contact poisons kill?

4. Are systemic insecticides usually more effective against small, sucking insects or large, chewing insects? Explain.

5. Are broad spectrum insecticides generally safe for beneficial insects? Why or why not?

6. List five factors important in determining whether an insecticide will be effective against a particular pest.

7. How do fungi reproduce?

8. How are plant bacteria spread?

9. How can insect and weed control reduce the severity of virus diseases on plants?

10. What is a nematode?

11. List five disease symptoms and give a brief description of each.

12. How do protectant and eradicant fungicides work?

13. How can development of tolerance to fungicides be avoided?

14. How can nematicides be brought into contact with nematodes?

15. What are the differences in life cycles of annuals, biennials, and perennials?

16. Are contact herbicides more effective against annuals or perennials?

17. Explain the differences in time of application of preplant, preemergence, and postemergence herbicides.

18. List 15 factors important in determining herbicide effectiveness.

19. Is cholinesterase testing appropriate for applicators who use herbicides only?

Chapter 2

1. List 10 factors that can affect pest problems.

2. What are the symptoms of herbicide injury?

3. How is the apple scab fungus spread?

4. Does petal blight affect the roots of azaleas?

5. Besides a pomaceous tree (apple, pear, hawthorne, etc.), what other type of tree must be present for quince rust to grow?

6. What type of organism causes crown gall?

7. What is the major weather condition favoring the development of Cytospora canker?

8. Does tree stress contribute to Discula anthracnose on dogwood?

9. Where does Diplodia tip blight of pines persist from year to year?

10. How is the Dutch elm disease fungus spread to healthy trees?

11. How can heavy applications of nitrogen affect the development of fire blight?

12. What weather conditions favor the development of *Lophodermium* needle cast of pines?

13. Do both organisms that cause juniper blight require wounds to be present on twigs for infection to occur?

14. How do control strategies for *Phytophthora* root rot in nurseries and in landscape plantings differ?

15. List three factors important in determining the amount of damage likely to be caused by powdery mildew.

16. List three factors that may control bagworms.

17. What species of tree usually must be dominant for outbreaks of gypsy moth to occur?

18. Do redheaded pine sawflies lay their eggs on both hard and soft pines?

19. What do adult and larval Japanese beetles feed on?

20. At what stage in the life cycle of the Japanese weevil are insecticide treatments most effective?

21. What is the characteristic damage of leafminers?

22. What is a common way that dogwood borer larvae enter trees?

23. What is the most effective way to control Nantucket pine tip moths?

24. Where are adult azalea lace bugs usually found?

25. How can flower thrips be beneficial to plants?

26. When should spruce spider mite infestations be treated?

27. What weather conditions favor the buildup of two-spotted spider mite populations?

28. Do aphids chew plant foliage or suck the juices from them?

29. Can euonymus scales produce honeydew?

30. Where should herbicide–mulch combinations not be applied? Explain.

31. What weather conditions stimulate the growth of crabgrass?

32. When does chickweed germinate?

33. How are woody perennials and herbaceous perennials best controlled with herbicides?

34. What four variables can be adjusted to change the amount of spray delivered by boom sprayers?

35. How can nozzle dribble be eliminated?

36. Why are herbicides best applied with a fan or flat pattern nozzle?

37. Are broadcast nozzles a good choice for spraying when there is a breeze? Why or why not?

38. If you find that your granular applicator is delivering 15 percent less than the recommended rate, should you change the settings and recalibrate the applicator? Why or why not?

39. What are the two methods of metering out liquid fumigants?

40. How can nozzles safely be unplugged?

41. Are mist sprayers designed to apply insecticides, herbicides, and fungicides? Explain.

42. How often should sprayers be cleaned?

Chapter 3

1. How can thatch encourage insect and disease problems?

2. Which group of organisms causes most turfgrass diseases in Maryland: viruses, fungi, or bacteria?

3. How does air circulation affect disease development in turf?

4. What weather conditions favor the development of leaf spot?

5. How does application of nitrogen affect the development of leaf spot?

6. What weather conditions favor the development of brown patch?

7. How can nematode-caused turfgrass problems best be identified?

8. What pests does milky spore disease attack?

9. What effect does an extended period of cool, wet weather have on chinch bug populations?

10. Since adult sod webworms do not damage turf, why is it important to monitor adult populations and flight activity?

11. At what stage in the life cycle of the bluegrass billbug are insecticide treatments effective?

12. List five cultural factors important in maintaining good stand density.

13. When should herbicides to control quackgrass in turf be applied?

14. How does frequent, light irrigation affect the growth of smooth crabgrass?

15. Is preemergence or postemergence herbicide application usually more effective against annual grasses?

16. At what time of year is dandelion growth most active?

17. How does soil compaction affect knotweed?

18. Are herbicide applications made after mid-spring appropriate to control common chickweed? Why or why not?

19. List two important factors to consider before selecting a hydraulic sprayer.

20. List the three most common errors in air-spraying techniques.

21. Describe two techniques to minimize drift hazard.

22. Describe a method for determining the rate of discharge of a granular applicator.

23. List three factors that affect the rate of application from a hose applicator.

Chapter 4

I. What are the symptoms of root rot on aboveground plant parts?

2. List four methods of preventing soilborne diseases.

3. What unwanted effect can residues of soil fumigants have on greenhouse plants?

4. What effect does keeping foliage dry have on *Alternaria*?

5. How is *Botrytis* blight spread?

6. What temperature and humidity conditions favor the development of leaf spots and blights?

7. What conditions favor the development of powdery mildew?

8. What type of organism (virus, fungus, bacterium, or nematode) causes rust diseases?

9. Are most chemicals used to control fungi also effective against bacteria?

10. How are virus diseases of plants spread?

11. Does soil sterilization with fumigants kill both egg and adult stages of nematodes?

12. Why is honeydew undesirable on greenhouse plants?

13. Do spider mites and cyclamen mites prefer similar temperature and humidity conditions? Explain.

14. Why are mealybugs difficult to control?

15. How can whitefly populations be monitored?

16. Why has control of leafminers become difficult?

17. What do the larvae of fungus gnats usually feed on?

18. Describe the two major factors limiting herbicide use in greenhouses.

19. Can small droplet applications be made safely inside greenhouses on windy days?

20. What effect does temperature have on aerosol applications?

21. Should fog applications be directed toward foliage? Why or why not?

22. Describe five signs of phytotoxicity in greenhouses.

23. Generally, what is the best time of day to apply pesticides in greenhouses to avoid phytotoxicity? Explain.

24. List three reasons why greenhouse workers need to take special care when handling pesticides.

25. Is pesticide resistance likely to be encouraged by too low a dosage, or too high a dosage? Explain.

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