FOREST PEST CONTROL
Category 4a

A Guide for Commercial Applicators
Forest Pest Management

A Guide for Commercial Applicators
Category 4a

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Pesticide Properties that Affect Water Quality. Extension Bulletin B-6050. 1997. Douglass E. Stevenson, Paul Baumann, John A. Jackman. College Station: Texas A&M University, Texas Agricultural Extension Service (Figure 2.1).


Sprayers for Christmas Trees. Donald Daum. University Park: Pennsylvania State University (Figures 3.7, 3.8, 4.1, 4.2).
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A Guide for Commercial Applicators

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INTRODUCTION

How to Use This Manual

This manual contains the information needed to become a certified commercial applicator in Category 4a, Forest Pest Management. This manual is intended for use in combination with the Pesticide Applicator Core Training Manual (Extension Bulletin 825), available through the Ohio Department of Agriculture Office. However, this manual would also be useful to anyone interested in learning more about forest pest management.

Category 4a Forest Pest Management covers the management and control of common forest pests in natural stands, plantations, Christmas tree operations, nurseries, and seed orchards. Basic scientific information is presented on forest ecosystems and pest life cycles. Protecting non-target organisms and preventing the development of resistance in pests are also emphasized.

The Category 4a certification exam will be based on information found in this booklet. Each chapter begins with a set of learning objectives that will help you focus on what you should get out of each chapter. The table of contents will help you identify important topics and understand how they relate to one another through the organization of headings and subheadings. As you prepare for the exam, read each chapter and answer the review questions located at the end. These questions are not on the certification exam. They are provided to help you prepare for the exam. Questions on the exam will pertain directly to the learning objectives.

The appendices and glossary, including an answer key (Appendix A); at the end of this manual provide supplemental information that will help you understand the topics covered in the chapters. Terms throughout the manual text that are bold and italicized can also be found in the glossary.

This certification manual benefits the applicator and the general public. By learning how to handle pesticides correctly, applicators will be able to protect themselves, others, and the environment from pesticide misuse.
LEARNING OBJECTIVES

After completely studying this chapter, you should:

- Know the goal of integrated pest management (IPM) programs.
- Be familiar with IPM tools and how they are used.
- Understand the concept of threshold levels as an IPM decision tool.
- Know the various IPM management strategies and under what circumstances they should be applied.
- Understand the importance of evaluating pest management strategies and what kind of information should be recorded.

INTRODUCTION

All parts of a tree—roots, stems, foliage, shoots and terminal leaders—are vulnerable to attack by pests. Pest damage can range from slight damage that has no effect on the value of the harvested product to severe damage that stunts or kills the trees or reduces their market value. Tree pests include insects and mites, diseases, weeds, vertebrates, and nematodes.

Managing tree pests effectively should be based on thorough consideration of ecological and economic factors. The pest, its biology, and the type of damage are some of the factors that determine which control strategies and methods, if any, should be used. Pest management decisions largely determine the degree and amount of pesticide used.

Ultimately, pest management decisions represent a compromise between the value of the product, the extent of the pest damage, the relative effectiveness and cost of the control measures, and the impact on the environment.

INTEGRATED PEST MANAGEMENT (IPM)

The goal of IPM is to use all appropriate tools and tactics to prevent economically important pest damage without disrupting the environment. Information gathering and decision making are used to design and carry out a combination of measures for managing pest problems. IPM is the best approach to manage pests of trees.

Monitoring (scouting)

Monitoring (scouting) forests and newly established plantations will help detect problems early, while there is still time to take action. The information gathered through monitoring is a key element in any IPM program.

For example, when monitoring or scouting an area, examine the center of the area as well as the margins. Note competition levels among trees and other plants. Note types, quantity, and location of weeds. Look for signs of animal activity. Check a representative sample of trees for signs and symptoms of insect and disease problems. Inspect all parts of the tree, from top to bottom and from branch tips to trunk. Depending on the pest, the use of traps or microscopic examination may improve the
information gathered by visual examination. Record your observations. The destructive forms of many insect pests are generally most active from April through August, but infection by many disease organisms is more dependent on weather conditions than on calendar date. Scouting and monitoring for all pests and pest problems must be done regularly and frequently to avoid surprises.

Weather plays an important part in the development of most insect and disease pests. Keeping track of the daily weather conditions (high and low temperatures, humidity, and the amount of rain) will make you better at forecasting pest problems.

Identification

Identification of pests and the diagnosis of pest damage are key elements of IPM. If you find perennial weeds present and/or signs of insect, disease, or vertebrate presence or damage, try to determine:

- What kind of pest is present?
- What stage of the pest is present?
- What is the size of the pest population?
- How much damage has occurred?
- How much damage is likely to occur if no control measures are taken?
- Does the pest or damage require immediate attention, or can control measures be postponed until the trees are near harvest?

Certain tools are useful in carrying out an IPM program. A hand lens is essential for magnifying disease signs, insects, and weed plant characteristics. If pests are in the tops of trees, binoculars may be beneficial. Pruning shears and a pocket knife are needed when probing for insects or disease or collecting weed specimens. Field guides, Extension bulletins, or other references with pictures and biological information on tree ID, weed ID, insects, and diseases will help with identification. Have plastic bags, vials, and containers available in case you have to take samples of the pest or pest damage to someone else for identification. For weed ID, collect as much of the whole plant as possible, including flowers, leaves and stems.

It is important to know where to find help in diagnosing pest problems. The local county Extension office can provide you with forms and instructions for sending samples to Ohio State University for diagnosis.

Threshold Level

Determine the threshold level—the point at which the pest or its damage becomes unacceptable. The threshold level may be related to the beauty, health, or economic value of the tree crop. Once the threshold level has been reached, you must determine what type of control procedure is needed. This decision will be based on the size of the pest population, the kind of damage the pest is causing, and the control measures that are available. It is also very important to consider the cost effectiveness of potential controls. You must carefully weigh the cost of control, the value of the tree, and the impact of the pest damage on the value of the tree.

Management Strategy

Decide on management (control) strategies. Management options may be very different for high-value Christmas tree species than for other lower value trees. The following are some examples of management strategies.
Do nothing

In situations where the pest does not damage the crop value or the crop value is so low it is not cost effective to apply a control measure, no action is needed.

Cultural management

Cultural management manipulates the environment to make it more favorable for the plant and less favorable for the pest. Cultural controls such as good site selection, planting resistant varieties, or selective pruning make it less likely that the pest will survive, colonize, grow, or reproduce. Cultural management can be very effective in preventing pests from building to unacceptable levels.

Mechanical management

Some measures exclude or remove the pest from the habitat. Mechanical traps, screens, fences, and nets can remove the pest or prevent access by the pest. Tillage and mowing are used to mechanically manage weeds.

Biological management

Biological controls include the beneficial predators, parasites and pathogens that kill pests. There are many more known natural enemies of insect pests than there are natural enemies of disease pests. Biological weed control is generally aimed at non-native introduced weeds.

Wasp parasitizing an aphid

Ladybugs, lacewings and certain mites are common predators of insects. Some tiny wasps and some fly species are parasites of insects. Many beneficial parasites are host specific and do not control a wide range of pests. Parasites and predators are often very effective at keeping insect pests at low levels. For example, aphids, scales, and mites rarely build to damaging levels in pine or spruce forests because their populations are controlled by predators and parasites. Insects are also affected by a variety of bacterial, fungal, and viral diseases that affect only insects.

Biological control organisms are very sensitive to pesticides. Pesticide applications to control a pest may have the unwanted side effect of wiping out part of the natural predator and parasite population along with the pest. This, in turn, may cause a population explosion of a different pest in the void left by the predators and parasites.

Pesticides

Pesticides are a very important tool in IPM when large pest populations threaten high-value trees. Knowledge of the pest’s life cycle, selection of an appropriate pesticide, proper timing of the application, and use of the right application equipment will improve coverage and effectiveness. The ability to recognize beneficial bio-control organisms, combined with cultural and mechanical controls, may allow you to reduce, delay, or eliminate pesticide treatment of a minor pest problem.

Evaluation

Evaluate the results of management strategies. It is very important to determine how effective your management and control tactics are. This information will determine whether any follow-up treatment is needed and will improve your management strategies for next year. Return to the area after applying a treatment and compare post-treatment pest activity to pretreatment. This is where a pest management logbook will become invaluable. Include your observations about where pests first showed up, what kinds of natural enemies you observed, where and when specific treatments were applied, and what the results were. Sound IPM practices pay off both economically and environmentally.
MINIMIZING PESTICIDE IMPACT

LEARNING OBJECTIVES

After completely studying this chapter, you should:

- Know the importance of reading and understanding the pesticide label.
- Know where to obtain supplemental labeling and when to have it on hand.
- Understand the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) and the special provision associated with it.
- Be familiar with groundwater, where it is stored, and how it can become contaminated.
- Know how to keep pesticides out of groundwater and surface water.
- Know how to protect bees, birds, beneficial insects, and other non-target organisms from pesticide exposure.
- Understand pesticide resistance, how it develops (including the development of cross-resistance), and how to manage (i.e., prevent, delay, or reverse) resistance.
- Know the requirements for notifying neighbors when pesticides are to be applied.

GUIDELINES FOR SELECTION AND USE OF PESTICIDES

Pesticide use is a serious matter that tree managers must take on responsibly. The pesticide label contains information needed to protect the applicator, the environment, and the crop while maximizing control of the pest. Always read the entire label as well as all supplemental labeling for each pesticide that you consider using. Supplemental labeling is pesticide label information that appears on a separate piece of paper and contains information regarding the site, pest, rate, etc. Supplemental labeling may be supplied at the time of purchase or requested from the dealer. If a pesticide applicator chooses to apply a pesticide according to instructions on a supplemental label, a copy of the supplemental label must be in the hands of the applicator at the time of application.

Supplemental labels include special local need labels (24c), emergency exemption labels (section 18), and supplemental labels issued by the pesticide manufacturer.

Always:

- Understand the label instructions and limitations before use.
- Select pesticides labeled for the crop you wish to use them on and the pest(s) you wish to control.
- Apply the pesticide only for the purposes listed and in the manner directed on the label.
FIFRA and the Use of Pesticides for Pests Not on the Label

The law regulating pesticides in the United States is the Federal Insecticide, Fungicide, and Rodenticide Act, or FIFRA. FIFRA is administered by the Environmental Protection Agency (EPA). In Ohio, it is Ohio Department of Agriculture (ODA) administers FIFRA. FIFRA governs the registration, distribution, sale, and use of all pesticides. A provision within FIFRA allows the use of a pesticide for a pest not noted on the label as long as the application is made to a crop specified on the label. This provision is referred to as 2(ee). All rates and restrictions for the labeled crop, including pre-harvest intervals, must be followed. Please note, however, that the manufacturer will not assume responsibility for product performance, so 2(ee) applications are made at the applicator’s risk. For more information about 2(ee) applications, contact OSU Extension or the Ohio Department of Agriculture.

Surface waters are visible bodies of water such as lakes, rivers, and oceans. Both surface water and groundwater are subject to contamination by point and non-point source pollution. Point source pollution refers to movement of a pollutant into water from a specific site. Non-point source pollution refers to pollution from a generalized area or weather event, such as land runoff, precipitation, acid rain, or percolation rather than from discharge at a single location.

PROTECTING OUR GROUNDWATER

Many people who live in rural Ohio get their drinking water from wells. Well water is groundwater, so it is easy to see why you should be concerned about keeping pesticides out of groundwater. Groundwater is the water beneath the earth’s surface occupying the saturated zone (the area where all the pores in the rock or soil are filled with water). Groundwater is stored in water-bearing geological formations called aquifers. It moves through the aquifers and is obtained at points of natural discharge such as springs or streams, or from wells drilled into the aquifer.

The upper level of the saturated zone in the soil is called the water table. The water table depth below the surface changes during the year, depending on the amount of water removed from the ground and the amount of water added by recharge. Recharge is water that seeps through the soil from rain, melting snow, or irrigation.

Keeping Pesticides Out of Groundwater and Surface Water

A pesticide that does not volatilize (become a gas), absorbed by plants, bound to soil, or broken down can potentially migrate through the soil to groundwater. The movement of groundwater is often slow and difficult to predict. Substances that enter groundwater in one location can turn up years later in other locations. A major difficulty in dealing with groundwater contaminants is that the sources of pollution are not easily discovered. The problem is occurring underground, out of sight.

It is very difficult to clean contaminated groundwater or surface water. Therefore, the best solution is to prevent contamination in the first place. The following practices can reduce the potential for surface and groundwater contamination by pesticides:

Use integrated pest management programs. Keep pesticide use to a minimum by combining chemical control with other pest management practices.

Consider the geology of your area. Be aware of the water table depth and how porous the geological layers are between the soil surface and the groundwater.

Select pesticides carefully. Choose pesticides with the least potential for leaching into groundwater or for runoff into surface water. Pesticides that are very soluble, relatively stable, and not easily adsorbed onto soil tend to be the most likely to leach. Read pesticide labels carefully, consult the MSU Extension pesticide application guides, or seek the advice of an MSU specialist or a pesticide dealer to help you choose the best pesticide for the purpose.

Follow label directions. The container label and any supplemental labeling accompanying the container carry crucial information about the proper rate, timing, and placement of the pesticide. Seek out and consult supplemental labeling as well as the container label before using the pesticide.

Calibrate accurately. Calibrate equipment carefully and often to avoid over- or under-application.

Measure accurately. Carefully measure concentrates before they are placed into the spray tank. Do not “add a little extra” to ensure the pesticide will do a better job.

Avoid back-siphoning. The end of the fill hose should remain above the water level in the spray tank at all times to prevent back-siphoning of chemical into the water supply. Use an anti-backflow device when siphoning water directly from a well, pond, or stream.
Forest Pest Management

Chapter 2

PROTECTING NON-TARGET ORGANISMS

Bees and other pollinating insects can be killed by insecticides. Take the following precautions to reduce the chance of bee poisoning:

- Select pesticides that are least harmful to bees and select the safest formulation. Dusts are more hazardous to bees than sprays. Wettable powders are more hazardous than emulsifiable concentrates or water-soluble formulations. Granular insecticide formulations are generally the least hazardous to bees. Microencapsulated pesticides are extremely hazardous because the minute capsules can be carried back to the hive.

- Do not apply insecticides that are toxic to bees if the site contains a crop or weeds in bloom. Mow the weeds to remove the blooms before spraying.

- Minimize spray drift by choosing different nozzles or adding adjuvant, or postpone spraying if it is windy.

- Time pesticide applications carefully. Evening applications are less hazardous than early morning ones; both are safer than midday applications.

- Do not treat near hives. Bees may need to be moved or covered before using insecticides near colonies.

The best way to avoid injury of beneficial insects and microorganisms is to minimize the use of pesticides. Use selective pesticides whenever possible, and apply only when necessary as part of a total integrated pest management program.

Pesticides harm vertebrates such as fish, birds, and mammals. Fish kills can result from water polluted by a pesticide (usually insecticides). Pesticides can enter water via drift, surface runoff, soil erosion, and leaching.

Bird kills from pesticides can occur when birds ingest the toxicant in granules, baits, or treated seed; are exposed directly to the spray; drink and use contaminated water; or feed on pesticide-contaminated prey.

Endangered and threatened species are of special concern. Under the federal Endangered Species Act, every pesticide posing a threat to an endangered or threatened species or its habitat will have a warning statement on the label regarding its use within the geographic range of the species. The statement will instruct applicators in actions they need to take to safeguard the species.

Consider weather. If you suspect heavy rain will occur, delay applying pesticides.

Mix on an impervious pad. You should mix and load pesticides on an impervious pad. Where spills can be contained and cleaned up. If mixing is done in the field, change the location of the mixing area regularly. Consider using a portable mix/load pad.

Dispose of wastes and containers properly. All pesticide wastes must be disposed of in accordance with local, state, and federal laws. Triple rinse all containers. Pour the rinse water into the spray tank for use in treating the site or the crop on the label. After triple rinsing, perforate the container so it cannot be reused. All metal and plastic triple-rinsed containers should be recycled, if possible. If this option is not available, dispose of them in a state-licensed sanitary landfill. Dispose of all paper containers in a sanitary landfill or a municipal waste incinerator. Do not burn used pesticide containers. Burning does not allow for complete combustion of most pesticides and results in pesticide movement into the air. Contact your regional ODA office or local county Extension office for more information on pesticide container recycling in your area.

Store pesticides safely and away from water sources. Pesticide storage facilities should be situated away from wells, cisterns, springs, and other water sources. Pesticides must be stored in a facility that will protect them from temperature extremes, high humidity, and direct sunlight. The storage facility should be heated, dry, and well ventilated. It should be designed for easy containment and cleanup of pesticide spills and made of materials that will not absorb any pesticide that leaks out of a container. Store only pesticides in such a facility, and always store them in their original containers.

Figure 2.2. Keep hoses out of contaminated water.
POTENTIAL FOR PESTICIDE RESISTANCE

Pesticide resistance is the inherited ability of a pest to tolerate the toxic effects of a particular pesticide. As resistance increases in a pest population, so will the application rate of the pesticide or the spray frequency needed to provide adequate control.

The Development of Resistance

When organisms reproduce, the offspring receive copies of the parent genetic material. The copies are not always perfect—mistakes, called mutations, may appear. Most mutations are either harmful or of no consequence. Sometimes, however, a mutation benefits an organism. An example of such a mutation is one that confers resistance to a pesticide. These resistant individuals survive when we apply the pesticide and at least some of their offspring inherit the resistance. Because the pesticide kills most of the non-resistant individuals, the resistant organisms will make up a larger percentage of the surviving population. With each use of the pesticide, this percentage increases, and eventually most of the pest population will be resistant.

In most cases, pest populations that become resistant to one pesticide also become resistant to other chemically related pesticides. This is called cross-resistance. Cross-resistance happens because closely related pesticides kill pests in the same way (e.g., all organophosphate insecticides kill by inhibiting cholinesterase); if a pest can resist the toxic action of one pesticide, it can usually resist other pesticides that act in the same way.

Resistance Management

Resistance management attempts to prevent, delay, or reverse the development of resistance. You should incorporate the practices described below into your resistance management program.

- Use an integrated pest management program. Combine cultural, mechanical, biological, and chemical management measures into a practical pest control program.
- Where possible, practice crop rotation. By discouraging the buildup of pests associated with any one crop, crop rotation will reduce the number of pesticide applications directed at a given pest. This reduces the advantage that resistant individuals have over non-resistant individuals and will delay or help prevent the buildup of resistance in a population.
- Use pesticides from different chemical families. Try to do this whether you apply pesticides against a pest once a year or several times within a treatment season. This way, pests resistant to the first pesticide will be killed by the second.
- Use pesticides only when needed, and use only as much as necessary.

NOTIFYING NEIGHBORS

Good public relations are extremely important when applying pesticides. It is the joint responsibility of landowner and applicator to see that neighboring landowners are not subjected to acts of trespass or exposed to spray drift. As a matter of courtesy, it is a good idea to inform adjacent landowners and neighbors in advance of any large-scale pesticide application. When applicators anticipate pesticide off-target drift, a management plan to minimize the occurrence and adverse effects of off-target drift is necessary. For more information on the Ohio regulation (901:5-11-02) that requires a management plan, contact the Ohio Department of Agriculture.

Occasionally you may be asked questions about pesticide applications or consequences. If you are unsure of the answer, don't guess. Help is available from your local Extension office.
LEARNING OBJECTIVES

After completely studying this chapter, you should:

- Know the various pesticide application methods and the factors that influence your choice of the appropriate method.
- Know special application methods that are used for forestry and roadside right-of-way weed control and when and how they are applied.
- Know the various sprayer components, how they operate, and what the desirable features are.
- Know the various sprayer types, how they operate, and what the desirable features are.
- Understand proper operation and maintenance of sprayers, before, during, and after spraying.
- Know the various types of granular applicators and application methods, when they are applied, and what they consist of.

A directed-spray application targets pests in a specific area in an effort to minimize pesticide contact with the crop or beneficial insects.

- Foliar application directs pesticide to the leafy portions of a plant.
- Spot treatment is application of a pesticide to small, discrete areas.
- Soil application places pesticide directly on or in the soil rather than on a growing plant.

METHODS OF APPLICATION

The method you choose to apply a pesticide will depend on the nature and habits of the target pest, the site, the pesticide, available application equipment, and the cost and efficiency of alternative methods. Your choice is often predetermined by one or more of these factors. Some common application methods are described below.

Broadcast application is the uniform application of a pesticide to an entire area.

Figure 3.1. Soil application of dry materials.

Soil incorporation is the use of tillage equipment to mix the pesticide with the soil.

Soil injection is application of a pesticide beneath the soil surface.

Special Application Methods

Some special application methods are used for forestry and roadside right-of-way weed control. They are described below.

With foliage stem sprays, the pesticide solution is sprayed on the leaves alone or leaves and stems. Foliage stem sprays can be applied from the time the leaves are fully expanded until they begin to turn color in the fall.
Some herbicides, however, should be applied only in late summer or early fall. Do not treat plants that are under moisture or heat stress. Take care to avoid drift to nearby sensitive vegetation.

**Basal sprays** are directed at the lower 18 inches of stems and trunks that are less than 6 inches in diameter. Thoroughly wet the basal area until runoff at the ground line is noticeable. A few herbicides are applied in a single, narrow band or stream to the basal region of brush. Basal treatments are usually effective on canes and thickets as well as trees. Applications to control brush can be made anytime, including the winter months, except when snow or water prevents spraying to the ground line. Basal treatments can be more labor intensive than foliar sprays but are useful in selectively removing undesirable species from stands of desirable trees.

**Cut-stump treatments** for brush control are made to the freshly cut stump surfaces. Treat stump surfaces within 2 or 3 hours after cutting—drying of the cut surface reduces control. Generally, the cut stump, trunk, and exposed roots are treated with the herbicide solution. Cut-surface treatments are recommended when trees are 4 inches or more in diameter and are usually more effective than basal bark sprays on plants this size or larger.

**Frill and hatchet injection methods** cut the bark around the base of the trunk; herbicide is either applied as a separate step or injected simultaneously into the cut area. The cut-stump, frill, and injection methods are very effective treatments on nearly all brush and tree species. However, *flashback* can be a problem with some herbicides applied directly into the tree—the injected herbicide moves through root grafts to other untreated adjacent plants.
trees and kills them. Read the pesticide label carefully before injecting or frilling trees. Treatment can be made at any time of the year. Deep snow may impede operations, however, and applications made during periods of heavy sap flow in the spring may not be effective. Hard to control thickets of brush or species with many stems have control problems with these methods.

The terms “foliage stem sprays,” “basal spray,” and “cut-stump treatment” are used above to define weed control application. However, the same terms may also be used for insecticide or fungicide application to Christmas trees. Always be aware of the intent and the type of pesticide being used before making an application.

COMPONENTS OF SPRAYERS

You must be thoroughly familiar with a sprayer’s components to properly select, maintain, and operate the sprayer. The major components of a sprayer are the tank, pump, flow control, and nozzles. Other important components are strainers, pressure gauges, hoses, and fittings.

Tanks

Suitable materials for spray tanks include stainless steel, polyethylene plastic, and fiberglass. Some pesticides corrode aluminum, galvanized, and steel tanks. The cover should form a watertight seal when closed to minimize spills. All tanks should have a drain plug at their lowest point and shut-off valves so that any liquid in the tank can be held without leaking if the pump, strainers, or other parts of the system need to be serviced.

Tank capacity markings must be accurate so that you can add the correct amount of water. A clear plastic tube (sight gauge) is mounted on metal tanks.

Agitators

Agitation is required to combine the components of the spray mixture uniformly and, for some formulations, to keep the material in suspension. If agitation is inadequate, the application rate of the pesticide may vary as the tank is emptied. The two common types of agitation are hydraulic and mechanical.

Hydraulic or jet agitation discharges the spray mixture at a high velocity into the tank. Liquid for agitation should come from the discharge side of the pump and not the bypass line of the pressure-regulating valve.

The quantity of flow required for agitation depends on the chemical used. Little agitation is needed for solutions and emulsions, but intense agitation is required for wettable powders. For jet agitators, a flow of 6 gallons per minute for each 100 gallons of tank capacity is adequate. The jet should be submerged to prevent foaming. Wettable powder suspensions can wear the inside of the tank if the jet stream passes through less than 12 inches of liquid before hitting the tank wall.

A mechanical agitator consists of a shaft with paddles and is located near the bottom of the tank. The shaft is driven by an electric motor or some other device powered by the tractor. This system is more costly than jet agitation. Mechanical agitators should operate at 100 to 200 rpm. Foaming will result at higher speeds.

Pumps

The heart of the spraying system is the pump. It must deliver the necessary flow to all nozzles at the desired pressure to ensure uniform distribution. Pump flow capacity should be 20 percent greater than the largest flow required by the nozzles and hydraulic agitation to compensate for pump wear.
When selecting a pump, consider resistance to corrosive damage from pesticides, ease of priming, and power source available. The materials in the pump housing and seals should be resistant to chemicals, including organic solvents.

Pesticide sprayers commonly use roller, piston, diaphragm, and centrifugal pumps. Each has unique characteristics that make it well adapted for particular situations. Choose a pump that best fits your pesticide application program.

Figure 3.8 Three types of pumps

Strainers

Proper filtering of the spray mixture not only protects the working parts of the spraying system but also avoids misapplication due to nozzle tip clogging. Three types of strainers commonly used on sprayers are tank filler strainers, line strainers, and nozzle strainers. As the mixture moves through the system, strainer openings should be progressively smaller. Strainer mesh is described by the number of openings per linear inch; a high number indicates small openings. Strainers need to be checked for clogs and rinsed frequently.

Figure 3.9. Strainers.

Hoses

Use synthetic rubber or plastic hoses that have burst strength greater than peak operating pressures, resist oil and solvents present in pesticides, and are weather-resistant.

Sprayer lines must be properly sized for the system. The suction line, often the cause of pressure problems, must be airtight, non-collapsible, as short as possible, and have an inside diameter as large as the pump intake.

Figure 3.10. Pressure regulator.

Pressure Regulators

A pressure regulator is one of the most important parts of a sprayer. It controls the pressure and therefore the quantity of spray material delivered by the nozzles. It protects pump seals, hoses, and other sprayer parts from damage due to excessive pressure, and it bypasses the excess spray material back to the tank.

There are two types of pressure regulators—simple relief valves and pressure unloaders. The relief valves are simple bypass valves that require the pump and engine to keep working just as though one were spraying. The unloaders maintain working pressure on the discharge.
end of the system but move the overflow back into the tank at lower pressure, thus reducing strain on the engine and the pump.

Be certain that the flow capacity of the pressure regulator matches that of the pump being used.

**Pressure Gauge**

A pressure gauge must be a part of every sprayer system to correctly indicate the pressure at the nozzle. Pressure directly affects the application rate and spray distribution. Pressure gauges often wear out because they become clogged with solid particles of spray material. A glycerin-loaded diaphragm gauge is more expensive but will last indefinitely.

![Figure 3.11. Pressure gauge.](image)

**Nozzles**

Nozzles are important in controlling the volume of pesticide applied, the uniformity of application, the completeness of coverage, and the degree of drift. Many types of nozzles are available, each one designed for specific applications. Regular flat-fan, flood, and whirl chamber nozzles are preferred for weed control. For minimum drift, flood, whirl chamber, and raindrop nozzles are preferable because they produce large droplets.

**SPRAYERS**

The primary function of any sprayer is to deliver the proper rate of chemical uniformly over the target area. When selecting a sprayer, be certain that its components will withstand the deteriorating effects, if any, of the chemical formulations you use. Also consider durability, cost, and convenience in filling, operating, and cleaning.

**Hydraulic Sprayers**

Water is most often used as the means of carrying pesticide to the target area with hydraulic spraying equipment. The pesticide is mixed with enough water to obtain the desired application rate at a specific pressure and travel speed. The spray mixture flows through the spraying system under pressure and is released through a nozzle onto the target area.

**Low-pressure Sprayers**

Low-pressure sprayers are normally designed to deliver low to moderate volumes at low pressure—15 to 100 pounds of pressure per square inch (psi). The spray mixture is applied through a boom equipped with nozzles. The boom usually mounted on a tractor, truck, or trailer or nozzle can be attached to a hand-held boom.

Roller-type pumps are often used on small tank sprayers (50 to 200 gallons), but sprayers with large tanks (200 to 1,000 gallons) usually have centrifugal pumps. Low-pressure sprayers do not deliver sufficient volume to penetrate dense foliage because of low operating pressure. They are most useful in distributing dilute pesticide over large areas.

**High-pressure Sprayers**

High-pressure sprayers are designed to deliver large volumes at high pressure. They are similar to low-pressure sprayers except that they have piston pumps that deliver up to 50 gallons of spray per minute at pressures up to 800 psi. A boom or handgun delivers 200 to 600 gallons per acre.

![Figure 3.12. High-volume foliage spray.](image)

High-pressure sprayers provide thorough coverage and can penetrate dense foliage; however, these sprayers produce large numbers of small spray droplets which can drift. These sprayers can provide low-pressure flow when the proper pressure regulators are used.

**Backpack Sprayers**

Backpack sprayers are useful in situations where small areas or widely dispersed individuals require treatment. They are well suited for treating individual brush plants and for basal and cut-surface applications. Tanks usually hold 3 to 5 gallons. The sprayers can be fitted with a single nozzle or with a boom with up to three nozzles. Some are filled to about three-quarters of the tank capacity with liquid and then air is pumped into the remaining space. Initial pressure is 30 to 60 psi, but it drops continuously as the spray is applied unless a special pressure regulator is used.

Other backpack sprayers have a lever that is pumped during the spraying operation to activate a plunger or diaphragm pump. They have a small air chamber to reduce the surging of the spray mixture as the lever is pumped. The boom can be equipped with a pressure gauge so that a nearly constant pressure can be maintained while spraying.
Figure 3.13. Backpack sprayer.

Miscellaneous Equipment

Tree injectors. Tree injectors offer a precise way of introducing a pesticide (most often an herbicide) into the trunks of well-developed brush or trees. The number of cuts and the amount of chemical solution delivered in each blow will depend on the species, trunk diameter, and product being used. Cuts are made at a 60 degree angle with the ground around the circumference of the tree. The cuts must penetrate the bark and reach the sapwood or inconsistent control will result. Tree injectors are feasible in areas where fewer than 500 trees per acre need to be removed or treated.

Figure 3.14. The tree injector offers a precise way of introducing pesticide into the trunks of well developed brush or trees.

Spot guns. Adjustable, industry-quality spot guns are recommended to apply several forestry herbicides to the soil at the base of undesired brush and small trees. Their capacity is adjustable from 2 to 20 milliliters per squeeze of the trigger. Frequently, undiluted pesticide is applied, so special care must be taken to assure operator safety.

Figure 3.15. Low-volume spot gun.

OPERATION AND MAINTENANCE OF SPRYERS

Proper operation and maintenance of spray equipment are essential for safe and effective pest control, will significantly reduce repair costs, and will prolong the life of the sprayer.

Before Spraying

At the beginning of each spraying season, fill the tank with water and pressurize the system to be sure all the parts are working and there are no drips or leaks. All nozzles should be of the same type, size, and fan angle. If using nozzle strainers, make sure the check valves are working properly. They function to prevent dripping when flow to the nozzle drops below a certain pressure. Measure the distance between the nozzle tip and the target and adjust the boom accordingly. Nozzle height is very important in broadcast application because it affects uniformity of the spray pattern.

Keep the tank level during filling so that the quantity in the tank is correctly indicated. The sprayer must now be calibrated. Calibration is described in the next chapter.

During Spraying

Frequently check the pressure gauge and tachometer while spraying. Make sure that the same pressure and speed used for calibration is used for sprayer operation. Speeds should be reasonable so that sprayer booms are not bouncing or swaying excessively. Periodically check hoses and fittings for leaks and nozzles for unusual patterns. If you must make emergency repairs or adjustments in the field, wear all protective clothing listed on the label as well as chemical-proof gloves.

After Spraying

Always flush the spray system with water after each use and apply this rinse water to sites for which the pesticide is labeled. Clean the inside and outside of the sprayer thoroughly before switching to another pesticide and before doing any maintenance or repair work. All parts exposed to a pesticide will normally have some residue, including sprayer pumps, tanks, hoses, and boom ends.
GRANULAR APPLICATORS

Granular applicators are designed primarily for soil applications and are available in various styles and sizes. Drop-through spreaders and rotary spreaders are the most common. Shaker cans and hand distribution of pellet or grid-ball formulations may also be used on occasion.

Granular applicators normally consist of a hopper for the pesticide, a mechanical-type agitator at the base of the hopper to provide efficient and continuous feeding, and some type of metering device, usually a slit-type gate, to regulate the flow of the granules.

Drop-through Spreaders

Drop-through spreaders are available in widths from 1½ to 3 feet or more. An adjustable sliding gate opens holes in the bottom of the hopper and the granules flow out by gravity feed. Normally, a revolving agitator is activated when the spreader is in motion to assure uniform dispensing.

Rotary Spreaders

Rotary spreaders distribute the granules to the front and sides of the spreader, usually by means of a spinning disc or fan. Heavy granules are thrown farther than lighter ones. A 6- to 8-foot swath width is common. Both power- and hand-driven rotary spreaders are available. The former are generally best suited for use in forests.

Figure 3.16. Granular spreaders are designed primarily for soil applications.
LEARNING OBJECTIVES

After completely studying this chapter, you should:

- Understand the purpose of calibration and why it is an essential process.
- Know the basic tools needed to calibrate sprayers and the variables that determine spray rate.
- Be able to check for and calculate nozzle output and know the guideline for determining when nozzles are worn out.
- Know what factors affect spray pattern uniformity and how to check for it.
- Understand how to calibrate a sprayer for broadcast application.
- Be able to calculate how much pesticide to add to the spray tank for broadcast application.
- Know how to properly calibrate a hand sprayer on a per acre basis and for a band application.
- Know how to calibrate granular applicators—both drop-through spreaders and rotary spreaders.

INTRODUCTION

The purpose of calibration is to ensure that your equipment delivers the correct amount of pesticide uniformly over the target area. Calibration is the step in pesticide application that is most often neglected and misunderstood. Because virtually every sprayer is a unique combination of pumps, nozzles, and other equipment, calibration is an essential process for an applicator to learn.

For proper calibration, you will need a few basic tools, including a stopwatch, a collection container graduated in ounces, a tape measure, and flags or stakes for marking. Unless your sprayer is new, it will contain a certain amount of pesticide residue; therefore, a pair of chemical-proof gloves is also recommended. Additionally, a pocket calculator will help with calculations.

In this chapter, we provide formulas that are designed to make calibration easier for you. In some of these formulas are numbers that are constants—that means the number remains in the formula whenever you use that formula. To make calibration easier for you, we provide
CALIBRATION OF SPRAYERS

Calibrating a sprayer will ensure that the sprayer is delivering the intended volume of spray mixture to the target area. You must determine each of the following:

- How much spray mixture the sprayer applies per acre.
- How many acres you can spray per tank.
- The recommended rate of pesticide application.
- The amount of pesticide to add to the spray tank.

Variables That Determine the Spray Rate

Two major variables affect the amount of spray mixture applied per acre (most commonly expressed in gallons per acre): the nozzle flow rate and the ground speed of the sprayer. You must understand the effect that each of these variables has on sprayer output to calibrate and operate your sprayer properly.

Nozzle Flow Rate

The flow rate through a nozzle varies with the nozzle pressure and the size of the nozzle tip. Increasing the pressure or using a nozzle tip with a larger opening will increase the flow rate (gallons per acre).

Increasing pressure will NOT give you a proportional increase in flow rate. For example, doubling the pressure will not double the flow rate—you must increase the pressure fourfold to double the flow rate.

<table>
<thead>
<tr>
<th>Sprayer pressure (psi)</th>
<th>Sprayer output (gallons per acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>40</td>
<td>20</td>
</tr>
<tr>
<td>160</td>
<td>40</td>
</tr>
</tbody>
</table>

Pressure cannot be used to make major changes in spray rate, but it can be used to make minor changes. Keep in mind that operating pressure must be maintained within the recommended range for each nozzle type to obtain a uniform spray pattern and minimize drift.

The easiest and most effective way to make a large change in flow rate is to change the size of the nozzle tips. Depending on operating pressure, the speed of the sprayer, and nozzle spacing, small changes in nozzle size can significantly change spray output per acre. Use nozzle manufacturers’ catalogs to select the proper tip size.

Ground Speed of the Sprayer

Provided the same throttle setting is used, as speed increases, the amount of spray applied per unit area decreases at an equivalent rate. For example, doubling the ground speed of a sprayer will reduce the amount of spray applied by one-half.

Some low-pressure sprayers are equipped with control systems that maintain a constant application rate over a range of travel speeds, provided the same gear setting is used. Pressure is automatically changed to vary the nozzle flow rate in proportion to changes in ground speed. Even so, do your calibration at a set ground speed. In the field, travel speed must be kept within certain limits to keep the nozzle pressure within the recommended range.

Precalibration Check of Nozzle Output

After making sure the system is clean, fill the tank approximately half full with water. Fasten a graduated container under each nozzle and operate the sprayer at a pressure within the recommended pressure range. Check to see that the flow rate from each nozzle is approximately the same; replace or clean any nozzle whose output differs by more than 5 percent from the average for all of the nozzles and again check the flow rates.

For example, if the following flow rates are obtained for six nozzles:

<table>
<thead>
<tr>
<th>Nozzle</th>
<th>Output (ounces per minute)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>40.0</td>
</tr>
<tr>
<td>2</td>
<td>43.0</td>
</tr>
<tr>
<td>3</td>
<td>39.5</td>
</tr>
<tr>
<td>4</td>
<td>40.5</td>
</tr>
<tr>
<td>5</td>
<td>37.5</td>
</tr>
<tr>
<td>6</td>
<td>39.5</td>
</tr>
</tbody>
</table>

The average nozzle output is 40 ounces.

Five percent of 40 ounces is (40 x 0.05) is 2 ounces. Any nozzle whose output differs from 40 ounces by more than 2 ounces should be cleaned or replaced; that is, any nozzle whose output is greater than 42 or less than 38. Therefore, nozzle #5 should be either cleaned or replaced. The flow rate of nozzle #2 is too high. This indicates that the nozzle is worn and should be replaced.

When the average nozzle output varies by more than 10 percent from the manufacturer’s specifications, the nozzles are worn enough to justify the purchase of a new set. This is particularly important when using flat-fan or flood nozzles because proper spray overlap becomes difficult to maintain with worn nozzles.
Spray Pattern Uniformity

A uniform spray pattern is crucial for an effective pesticide application. It’s not enough to apply a pesticide only in its correct amount—you also must apply it uniformly over the target area. The effects of non-uniform application are most obvious when herbicides are applied and streaking results. Spray pattern uniformity is affected by boom height, spacing and alignment of nozzles on the boom, condition of nozzles (worn, damaged), and operating pressure. Check that all nozzles are of the same type. Also, a frequent cause of poor spray patterns is using nozzles with different spray angles on the same boom.

To check the uniformity of the spray pattern, adjust the boom height for the spray angle and nozzle spacing being used. Align flat-fan nozzles at a slight angle to the boom. Using water, operate the sprayer at the desired speed and pressure on clean, dry pavement or on another smooth surface. Observe the spray pattern as the water evaporates. Clean or replace nozzle tips that produce a poor spray pattern; if necessary, readjust boom height and recheck the spray pattern. If you replace any nozzles, recheck the flow rates.

Broadcast Sprayer Calibration

There are a number of equally effective calibration methods that vary in their basic approach and degree of difficulty. For the purposes of this manual, we have chosen a simple method that will allow you to calibrate quickly.

1. Fill the sprayer tank approximately half full with water.

2. Determine the nozzle spacing or band width in inches and stake out the appropriate distance in the field according to the following table:

<table>
<thead>
<tr>
<th>Nozzle spacing or Band width (inches)</th>
<th>Travel distance (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>510</td>
</tr>
<tr>
<td>10</td>
<td>408</td>
</tr>
<tr>
<td>12</td>
<td>340</td>
</tr>
<tr>
<td>14</td>
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<td>204</td>
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<tr>
<td>22</td>
<td>185</td>
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<tr>
<td>24</td>
<td>170</td>
</tr>
<tr>
<td>26</td>
<td>157</td>
</tr>
</tbody>
</table>

For other nozzle spacings or band widths, determine the appropriate travel distance using the following formula:

\[
\text{Travel distance (feet)} = \frac{4080}{\text{Nozzle spacing or Band width (inches)}}
\]

In this formula, 4,080 is a constant.

For example, if your nozzle spacing is 38 inches:

\[
\text{Travel distance} = \frac{4,080}{38} = 107 \text{ feet}
\]

Measuring the appropriate travel distance is a critical step in calibration. To determine what volume your sprayer is delivering for some land area (i.e., gallons per acre), you must relate the average nozzle output to a unit area of land. You could determine the volume output by physically spraying an entire acre, but this would be very time consuming. Therefore, we use a fraction of an acre.

Figure 4.1. For calibration, drive the designated distance using the exact throttle setting and gear that are planned for the broadcast spray application.
3. In an appropriate site, drive the designated distance using the exact throttle setting and gear you plan to use during spraying. Be sure to note the throttle setting and gear: don’t rely on a speedometer. Start the spray rig (sprayer turned off) about 25 feet behind the starting point so that you will be at typical field speed at the beginning of the measured distance. Record your travel time in seconds.

4. Adjust the pressure to the desired setting. Use slightly higher pressure when you use nozzle check valves and nozzle strainers.

5. With the sprayer stationary, collect and record the output from any of several nozzles (e.g., four) in ounces for the recorded travel time. Because we already have determined that the output of all nozzles is within 5 percent of one another in the precalibration check, it is not necessary to collect again from each nozzle.

6. Determine the average nozzle output in ounces.

7. The spray rate in gallons per acre is equal to the average nozzle output in ounces. For example, if the average nozzle output for the recorded travel time is 20 ounces, the spray rate will be 20 gallons per acre.

8. If the spray rate is not reasonable for your particular spraying job, you can change output by one of three methods: adjust pressure, change speed, or replace nozzle tips. If only a minor change in output is needed, simply make an adjustment in pressure and determine the new average nozzle output. (Remember that operating pressure must be kept within the recommended range for the nozzle type you’re using so that he spray pattern is not distorted.) If a large change in output is necessary and you change travel speed, you will need to drive the designated field distance and determine the new travel time before calculating the average nozzle output. If it is impossible to obtain the desired output at an appropriate pressure and ground speed, you will need to change nozzle tips; in this case, you must repeat the precalibration check of nozzle output.

The sprayer is now calibrated. When operated at the designated speed and pressure, it will deliver the desired spray volume. You should occasionally remeasure output and determine if changes in flow rate have occurred as a result of nozzle wear or other variations. If you continue to use the same travel speed used during initial calibration, it will take only a few minutes to recheck your sprayer’s output.

Example: You want to make a postemergence broadcast application of a herbicide at a spray volume of 20 to 30 gallons per acre using regular flat-fan nozzles spaced 40 inches apart on the boom:

1. Fill the sprayer tank approximately half full with water.

2. The appropriate travel distance for 40-inch nozzle spacing is 102 feet; measure and mark this distance in the field.

3. Using the throttle setting and gear you plan to use during spraying, you find that it takes 14 seconds to drive 102 feet.

4. Adjust the pressure to the desired setting within the recommended pressure range of 15 to 30 psi for regular flat-fan nozzles; your chosen setting is 25 psi.

5. With the sprayer stationary, you collect the following outputs from four nozzles in 14 seconds:

<table>
<thead>
<tr>
<th>Nozzle</th>
<th>Output (ounces per 14 seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15.5</td>
</tr>
<tr>
<td>2</td>
<td>16</td>
</tr>
<tr>
<td>3</td>
<td>15.5</td>
</tr>
<tr>
<td>4</td>
<td>16</td>
</tr>
</tbody>
</table>

Total = 63 ounces

6. The average output of the nozzles for 14 seconds is

\[
\frac{63 \text{ ounces}}{4 \text{ nozzles}} = 16 \text{ ounces.}
\]

7. The spray rate, therefore, is equal to 16 gallons per acre.

8. The spray rate is lower than the recommended range of 20 to 30 gallons per acre stated on the label. The major change in output required should not be attempted by increasing pressure. You’ll need to either decrease travel speed, in which case you’ll also need to determine the new travel time, or increase nozzle tip size. Then determine the new average output.

Amount of Pesticide to Add to the Tank

Your next step is to determine the amount of pesticide to add to the spray tank. To do so, you need to know:

- The recommended rate of chemical application.
- The capacity of the spray tank.
- The calibrated output of the sprayer.

The rate of chemical to apply is determined from the label. Rates are expressed either as the amount of pesticide to be applied per acre (or area) or as the amount to mix with a certain volume of water (or other carrier).

Example: Broadcast Application. Pesticide A is recommended as a broadcast application of 2 quarts of product per acre for site preparation. Your sprayer has a 200-gallon tank and is calibrated to apply 20 gallons per acre. How much Pesticide A should you add to the spray tank?

1. Determine the number of acres you can spray with each tank, using the following formula:

\[
\text{Acres per tank} = \frac{\text{tank capacity (gallons per tank)}}{\text{spray rate (gallons per acre)}} \times \text{10 acres}
\]

\[
\frac{200}{20} \times 10 = 100 \text{ acres}
\]
2. Determine the amount of pesticide to add to each tank, using the following formula:
   
   \[
   \text{Amount per tank} = \text{acres per tank} \times \text{rate per acre}.
   \]

   With each tank, you will cover 10 acres and you want to apply 2 quarts of product per acre:
   
   \[
   \text{Amount per tank} = 10 \times 2 = 20 \text{ quarts}.
   \]

   You will need to add 20 quarts (5 gallons) of Pesticide A to each tank load.

   **Example: Broadcast Application.** Pesticide B is an 80 percent wettable powder formulation. After reading the label, you decide to apply 12 pounds per acre for perennial weed control. The area to treat is 150 feet wide and 180 feet long. Your backpack sprayer is equipped with a three-nozzle boom, has a 4-gallon tank, and is calibrated to apply 40 gallons per acre of spray solution. How much water and product do you add to the tank? (43,560 sq. ft. = 1 acre)

   1. Calculate the area to be treated as follows:
      
      \[
      150 \times 180 \text{ feet} = 27,000 \text{ square feet, which is equal to 0.62 acre (27,000-43,560)}
      \]

   2. Calculate the amount of water needed with this formula:
      
      \[
      40 \text{ gallons} = Y \text{ gallons} \frac{1 \text{ acre}}{0.62 \text{ acre}}
      \]

      Which is read as “40 gallons is to one acre as \(Y\) gallons is to 0.62 acre.”
      
      \[
      Y = (40 \times 0.62) = 24.8 \text{ gallons to treat 0.62 acre}
      \]

   3. With a 4-gallon tank, we will need more than 6 tanks full of solution; let’s plan to mix 7 loads.
      
      \[
      24.8 \text{ gallons} = 3.54 \text{ gallons per load} \frac{7 \text{ loads}}{}
      \]

   4. We need 12 pounds of Pesticide B to mix in each 40 gallons of water (the output of our sprayer); the formula to use is as follows:
      
      \[
      12 \text{ pounds} = Y \text{ pounds} \frac{40 \text{ gallons}}{3.54 \text{ gallons}}
      \]

      \[
      12 \times 3.54 = 1.06 \text{ pounds of Pesticide B} \frac{Y = 40}{\text{in each tank load of 3.54 gallons}}
      \]

   **Hand Sprayer Calibration**

   The calibration of a hand sprayer can be easily accomplished by following a few important steps.

   1. Measure a suitable test area (an area similar to that which you will be spraying). A minimum area of 10 feet by 25 feet (250 square feet) for the test area is suggested.

   2. Fill the sprayer with water and record the level.

   3. Spray the premeasured area using the same pressure and technique that you will use when applying the pesticide.

   4. Refill the tank to the original water level. Be sure to note the exact amount of liquid needed to refill the tank.

   5. Assuming a 250-square-foot area was sprayed; either multiply the volume used to refill the tank by 4 to get the volume per 1,000 square feet, or multiply the volume used to refill the tank by 175 to get the volume per acre.

   6. Check the label for the recommended volume to apply per 1,000 square feet or per acre. Adjust nozzles, speed, or pressure, and recalibrate if necessary.

   7. Determine the amount of pesticide needed for each gallon of water and the amount of spray mixture needed to cover the intended spray area.

   **Example: product rate and spray volume expressed per 1,000 square feet.** Your sprayer delivered 0.5 gallon of water over 250 square feet. The label recommends that 1.5 fluid ounces of herbicide be mixed in enough water to cover 1,000 square feet. The sprayer tank holds 3 gallons.

   1. What is the volume of application per 1,000 square feet based on the test area sprayed?
      
      \[
      \text{Volume per 1,000 square feet} = \text{Volume per 250 square feet} \times 4 = 0.5 \text{ gal} \times 4 = 2 \text{ gallons}
      \]

   2. How many fluid ounces of product are needed per gallon of water?
      
      \[
      \text{Amount needed} = \frac{\text{amount needed per 1,000 square feet}}{\text{volume sprayed per 1,000 square feet}} \frac{1.5 \text{ ounces}}{2 \text{ gallons}}
      \]

      \[
      = 0.75 \text{ ounces per gallon}
      \]

   3. How many fluid ounces of herbicide must be added to a full tank of water?
      
      \[
      \text{Amount per tank} = \text{tank capacity} \times \text{amount needed per gallon} \frac{3 \text{ gallons} \times 0.75 \text{ ounce}}{} = 2.25 \text{ ounces per tank}
      \]

   4. How much area will one tank (3 gallons) of spray cover? Remember, the sprayer was calibrated for 2 gallons of water per 1,000 square feet. In other words:
      
      \[
      \text{If 2 gallons covers 1,000 square feet, then 3 gallons will cover what fraction of 1,000 square feet?} \frac{2 \text{ gallons}}{1,000 \text{ square feet}} = Y \frac{3 \text{ gallons}}{}
      \]

      Solve for \(Y\) by cross multiplying:
      
      \[
      \frac{2Y = 1,000 \times 3}{Y = \frac{3,000}{2}}
      \]

      \[
      Y = 1,500 \text{ square feet}
      \]
Example: rate and volume expressed per acre.
Suppose your sprayer delivered 0.5 gallon of water over a 500-square-foot test area. The label recommends that 3 pints of herbicide be applied per acre. The sprayer capacity is 4 gallons.

1. What is the sprayer output per acre, based on the test area sprayed?

\[
\frac{0.5 \text{ gallon}}{500 \text{ square feet}} = \frac{Y \text{ gallons}}{43,560 \text{ square feet}}
\]

\[Y = 43.6 \text{ gallons per acre}\]

2. How many fluid ounces of herbicide are needed per gallon of water?

\[
\text{amount needed per acre} = \frac{\text{volume sprayed per acre}}{\text{amount per gallon}}
\]

\[
= \frac{43.6 \text{ gallons}}{1.1 \text{ ounces per gallon}}
\]

*3 pints = 48 ounces (3 pints x 16 ounces per pint)

3. How many fluid ounces of herbicide must be added to a full tank of water?

\[
\text{Amount per tank} = \text{tank capacity} \times \text{amount per gallon}
\]

\[
= 4 \text{ gallons} \times 1.1 \text{ ounce/gal}
\]

\[= 4.4 \text{ ounces per tank}\]

4. How much area will one tank (4 gallons) of spray cover? Remember, the sprayer was calibrated for 43.6 gallons of water per acre. In other words:

If 43.6 gallons cover 1 acre, then 4 gallons will cover what fraction of an acre?

\[\frac{43.6 \text{ gallons}}{1 \text{ acre}} = \frac{4 \text{ gallons}}{Y}
\]

By cross multiplying:

\[
\frac{43.6 \text{ gallons}}{1 \text{ acre}} = \frac{4 \text{ acres} \times Y}{43.6}
\]

\[= 0.092 \text{ acres (4,008 square feet)}\]

Example: Band Application for Hand Sprayers
You have a 3-gallon tank and want to band apply a product at the rate of 2 quarts per acre.

1. Measure and mark the calibration distance that coincides with your band width (see the table at bottom of page).

<table>
<thead>
<tr>
<th>Band width</th>
<th>Calibration distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 inches</td>
<td>408 feet</td>
</tr>
<tr>
<td>12 inches</td>
<td>340 feet</td>
</tr>
<tr>
<td>16 inches</td>
<td>255 feet</td>
</tr>
<tr>
<td>18 inches</td>
<td>227 feet</td>
</tr>
<tr>
<td>20 inches</td>
<td>204 feet</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Band width</th>
<th>Calibration distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>24 inches</td>
<td>170 feet</td>
</tr>
<tr>
<td>28 inches</td>
<td>146 feet</td>
</tr>
<tr>
<td>32 inches</td>
<td>127 feet</td>
</tr>
<tr>
<td>36 inches</td>
<td>113 feet</td>
</tr>
<tr>
<td>40 inches</td>
<td>102 feet</td>
</tr>
</tbody>
</table>

2. Fill the sprayer with water only and record the number of seconds required to walk the calibration distance at a comfortable, steady speed while spraying and pumping to maintain a uniform pressure.

3. While pumping to maintain the selected application pressure, collect the spray output from the nozzle for the same number of seconds needed to travel the calibration distance. The number of ounces collected equals the gallons per acre (GPA) applied. For example, if 16 ounces are collected from the nozzle, the gallons per acre equals 16.

4. To determine the amount of chemical to add to the spray tank, divide the capacity of the tank by the number of gallons per acre. This determines the fraction of an acre that can be covered with a tankful of spray. If your tank has a 3-gallon capacity:

\[
\frac{3 \text{ gal. tank}}{16 \text{ GPA}} = 0.188 \text{ acre covered per tank}
\]
5. Multiply the application rate of the product per acre times the fraction of the acre covered per tank and add that amount of chemical to the sprayer tank.

Application rate per acre = amount of chemical to add to the spray tank

\[ \text{Application rate per acre} = \frac{\text{amount of chemical}}{\text{acre(s) per tank}} \]

\[ 2 \text{ quarts per acre} \times 0.188 \text{ acre per tank} = 0.376 \text{ qts per tank} \]

\[ \text{multiply 0.376 qts x 32 ounces per qt to get 12 fluid ounces per tank} \]

**Liquid Application on a Percentage Basis**

Occasionally pesticide recommendations are expressed as a given amount of product in a specified volume of water. Such recommendations are expressed as “volume/volume” recommendations or as a percentage of product in the spray solution. The following example illustrates the method.

**Example: Rate expressed as volume per volume.**
Pesticide C is recommended as a cut-stump treatment to prevent sprouts from developing on tree trunks. Four gallons of product are recommended to be mixed with 100 gallons of diesel fuel or other oil carrier. You want to prepare 75 gallons of solution. How much Pesticide C do you mix with the 75 gallons of diesel fuel?

\[ 4 \text{ gallons Pesticide C} = \frac{Y \text{ gallons Pesticide C}}{75 \text{ gallons diesel}} \]

By cross multiplying:

\[ 100Y = 75 \times 4 \]
\[ 100Y = 300 \]
\[ Y = \frac{3 \text{ gallons of Pesticide C per 75 gallons of diesel fuel}}{} \]

**GRANULAR APPLICATOR CALIBRATION**

Occasionally, granular or pellet pesticides are used for weed control. The need for accurate calibration is just as great for granular applicators as for sprayers.

The application rate of granular applicators depends on the size of the metering opening, the speed of the agitator or rotor, travel speed, the roughness of the site, and the flowability of the granules. The flow rate of granules depends on particle size, density, type of granule, temperature, and humidity. Product manufacturers’ suggested setting should be used only as the initial setting for verification runs by the operator prior to use. A different applicator setting may be necessary for each pesticide applied; variations in flow rate also can occur with the same product from day to day or from site to site. It is, therefore, important to calibrate frequently to maintain the proper application rate.

Apart from the actual setting of the metering opening, ground speed is the most significant factor affecting the application rate. You must use the same ground speed during calibration that you intend to use during the application, and the speed must remain constant. Even though gravity-flow applicators use a rotating agitator whose speed varies with ground speed, the flow of granules through the opening is not necessarily proportional to speed. A speed change of 1 mile per hour may cause a significant variation in the application rate.

**Drop-through Spreaders**

Drop-through spreaders usually are calibrated using catch pans. Chain or wire catch pans beneath the spreader to collect granules as they are discharged. After traveling a distance based on the width of the spreader (swath width), weigh the granules collected in the catch pan to determine the application rate. Use the table listed below to select the appropriate distance to travel for your spreader. The entries in the table are based on the following computations:

\[ 1/50 \text{ acre} = 0.02 \times 43,560 \text{ square feet} = 871 \text{ square feet} \]

<table>
<thead>
<tr>
<th>Travel distance (feet)</th>
<th>1/50 acre (linear feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5</td>
<td>581</td>
</tr>
<tr>
<td>2</td>
<td>436</td>
</tr>
<tr>
<td>3</td>
<td>290</td>
</tr>
<tr>
<td>4</td>
<td>218</td>
</tr>
<tr>
<td>5</td>
<td>174</td>
</tr>
<tr>
<td>6</td>
<td>145</td>
</tr>
<tr>
<td>7</td>
<td>124</td>
</tr>
<tr>
<td>8</td>
<td>109</td>
</tr>
<tr>
<td>9</td>
<td>97</td>
</tr>
<tr>
<td>10</td>
<td>87</td>
</tr>
<tr>
<td>11</td>
<td>79</td>
</tr>
<tr>
<td>12</td>
<td>73</td>
</tr>
<tr>
<td>13</td>
<td>68</td>
</tr>
<tr>
<td>14</td>
<td>62</td>
</tr>
<tr>
<td>15</td>
<td>58</td>
</tr>
</tbody>
</table>

If your spreader has a different width, use this formula to calculate the distance to travel:

\[ \text{travel distance in feet} = \frac{871}{\text{Swath width in feet}} \]

For example, if you have a spreader that covers a 6.5-foot swath, the distance to travel is:

\[ 871 = 134 \text{ feet} \]

\[ 6.5 \]

The step-by-step procedure is:

1. Before starting, calculate how much material should be applied in the calibration area. You need to know only the recommended rate per acre and multiply this value by 1/50 (the area you will cover in the calibration exercise).

2. Measure out the distance to travel as determined by the swath width of the spreader.

3. Securely attach a collection pan to the spreader.

4. Set the feeder gate control to the setting recommended in the owner’s manual or on the product label.
5. Mark the hopper and fill it evenly with granules to this mark. Calibration must be done with the same granules you intend to use during application.

6. Operate the spreader in the premeasured calibration area at the speed you intend to use during application.

7. Weigh the amount of granules in ounces in the collection pan. Be sure to use a scale that can accurately measure to the nearest ounce.

8. Compare the amount of product collected in the calibration area with the amount calculated in Step 1 above. If they are within 5 percent of each other, the applicator is properly calibrated; if not, you need to adjust the feeder gate control and recalibrate.

Example: A broadcast application of Pesticide D is to be made at a rate of 60 pounds of product per acre. Your equipment broadcasts granules in a 15-foot swath width. After covering a distance of 58 feet, you collect 16 ounces of granules. Is your applicator properly calibrated?

1. Determine the amount of product in ounces that should be applied to the calibration area:

   \[(60 \text{ pounds}) \times (1/50) = 1.2 \text{ pound} \times 16 \text{ ounces per pound} = 19.2 \text{ ounces}\]

2. Determine if the amount actually applied (16 ounces) is within 5 percent of the recommended rate (19.2 ounces):

   \[19.2 \text{ ounces} \times 0.05 (5\%) = 0.96 \text{ ounces}\]

   If your applicator was properly calibrated, it should have applied between 18.2 and 20.2 ounces of product to the calibration area. It actually applied less. You will, therefore, need to adjust the feeder gate control to apply more material and then recalibrate.

Rotary Spreaders

Hand-pushed whirlwind spreaders are small, with swath widths ranging from 6 feet to 12 feet. The method of calibration is similar to the one described above, except catch pans are not used. To determine the output, first you must place 10 pounds of the product into the spreader. If your spreader has a swath of 6 feet, your travel distance would be 145 feet (871 square feet—6 feet).

To determine how much product was discharged, subtract the amount of product that remains in the spreader from the original load of 10 pounds. The difference should correspond to the target output. If it doesn’t, readjust the spreader and repeat the calibration procedure.

Rotary spreaders must not be used when non-selective herbicides are applied to sites adjacent to desirable plant species. In these situations, a drop applicator is preferred. It has more precision in pesticide placement and less chance for the pesticide to be distributed beyond the target boundaries.

---

**CONVERSION TABLES**

**Area**

- 144 square inches = 1 square foot
- 9 square feet = 1 square yard
- 43,560 square feet = 1 acre
- 4,840 square yards = 1 acre
- 160 square rods = 1 acre
- 640 acres = 1 square mile
- 2.5 acres = 1 hectare

**Length**

- 1 inch = 2.54 centimeters = 25.5 millimeters
- 1 foot = 12 inches
- 1 yard = 3 feet = 5.5 yards = 16.5 feet
- 1 rod = 5.5 yards = 16.5 feet
- 1 mile = 320 rods = 1,760 yards = 5,280 feet
- 1 meter = 39.4 inches = 1.09 yards = 1 kilometer = 1,000 meters = 0.62 miles

**Volume**

- 1 tablespoon (tbs or T) = 3 teaspoons (tsp or t)
- 1 fluid ounce = 2 tablespoons
- 8 fluid ounces = 16 tablespoons = 1 cup
- 16 fluid ounces = 2 cups = 1 pint
- 32 fluid ounces = 4 cups = 1 quart
- 128 fluid ounces = 4 quarts = 1 gallon
- 1 liter = 33.9 ounces = 1.06 quarts

**Weight**

- 1 ounce = 28.3 grams
- 1 pound = 16 ounces = 453.6 grams
- 2.2 pounds = 1 kilogram = 1,000 grams
- 1 ton = 2,000 pounds = 907 kilograms
- 1 metric ton = 1,000 kilograms = 2,205 pounds
After completely studying this chapter, you should:

- Understand the present state of Ohio forests.
- Know the major pest management tools on which forest managers rely.
- Know the common forest types in Ohio and the characteristics associated with each.
- Know what the term “tolerance” means when describing various tree species.
- Understand how tolerance relates to plant succession.
- Understand how forest type affects the type of pest management technique applied.

Many disease and insect pests of Ohio forests are restricted to certain tree species, distinct types of trees or specific tree associations. By knowing about Ohio forestry, its predominant forest types, and their growth and development, you will gain a better understanding of the tree/pest relationships to be found in your area. Following is a brief historical perspective of forest health and pest management in Ohio. (Note: Later chapters in this manual will discuss specific pest problems of trees and forests and their management.)

AN OVERVIEW OF OHIO FORESTY AND FOREST PEST MANAGEMENT

The history of Ohio’s State Forests is a long tale, one of vision, commitment, perseverance and accomplishment. It officially started in 1916 but took root long before. The previous century witnessed unprecedented loss and abuse of Ohio’s forests. A state that had been virtually all forest in pre-settlement times was reduced to 20% forest cover by the late 1800s. Ohio’s dwindling forests begged for help and the state responded.

America’s forestry movement actually started in Ohio with the creation of the American Forestry Association in Cincinnati in 1875. A bulging interest in the nation’s forests spawned the first American Forest Congress there in 1882. The passion brought forth and the momentum created at this national meeting sent citizens home to take action.
Ohio became one of the first states in the country to enact a formal forestry program. In addition to California, New York, and Colorado, Ohio created a state forestry agency in 1885.

**FOREST TYPES IN OHIO**

The soils, climate, and topography of Ohio are quite diverse. This diversity of site factors results in several types of forests (including exotics) that can grow in the state. A forest type is one or more species growing together because of similar environmental requirements and tolerance to light. Tolerance refers to the necessary amount of light reaching the forest floor for tree species to germinate or sprout, grow, and thrive. Shade-intolerant species such as aspen or jack pine require full sunlight to grow and survive; mid tolerant species such as many oaks and white pine require partial, lightly shaded conditions, while beech and hemlock can germinate and grow in very shaded conditions. Forest managers most often manage by forest type and not by individual species (except in those cases where a forest type is composed of only one species). Common Ohio forest types are Virginia-Pitch Pine, Oak Gum Oak-Hickory, Oak-Pine, Elm-Ash-Red and Sugar Maple.

Ohio is considered to be part of the Appalachian Hardwood Region based on the type of trees common in the state. There are more than 100 hardwood and 25 softwood tree species growing in Ohio. In addition to shrubs, there are more than 300 different woody species found in Ohio’s forests. Some of the most diverse temperate region forests in North America are found in Ohio. The survey estimated that there are more than 65 billion trees and shrubs on the 7.9 billion acres of forests, for an average of more than 8,000 woody stems per acre. There are more than 1 billion trees 5 inches dbh (diameter breast high) and larger. Though there are a great many species, between 10 and 20 tree species comprise the majority of all trees in Ohio forests. By volume, six species groups account for two-thirds of all trees. The most abundant species are the red and white oaks which make up almost 25 percent of total tree volume.

**Maple-beech**

Maple-beech forests (often called northern hardwoods) are those in which sugar maple and American beech predominate, but they usually contain a mixture of other species including yellow birch, basswood, white ash, northern red oak, white pine, hemlock, and others. This forest type makes its best growth and development on moist, well drained soils throughout the state. Historically, this forest type experiences regular, periodic outbreaks of forest tent caterpillar defoliation on about a 10-year cycle. Forest tent caterpillar feeds on a variety of hardwood tree species, and complete defoliation of maple-beech stands is possible. Other insect defoliators that feed on individual species within the type (e.g., linden looper or basswood thrips) are occasionally a problem but affect only the lindens or basswoods within a stand. Diseases such as *Nectria* canker (on many hardwood species); *Eutypella* canker and sapstreak disease can occasionally cause serious losses in timber value.

**Aspen-birch**

Aspen-birch forests are those in which a majority of the trees are quaking aspen, bigtooth aspen, and white birch. Common associates in this forest type include balsam poplar, balsam fir, red maple, white pine, and black and pin oaks. Aspen-birch forests can be found growing on a
wide range of sites, from wet clay loam to dry, sandy soils. This type is considered a short-lived forest type that is often replaced via succession with other tree species if the site is not harvested or disturbed in any way. **Plant succession** is the replacement of one plant community by another. It is closely linked with shade tolerance, which plays a role in species replacement during succession. Historically in Ohio, aspen-birch forests experienced periodic outbreaks of aspen tortrix and other similar defoliators as well as gypsy moth defoliation in more recent years. *Hypoxylon* canker is probably the most serious of the disease problems, especially in over-mature stands.

Figure 5.3. Yellow birch.

Figure 5.4. American basswood

Figure 5.5. Quaking aspen.

Figure 5.6. Bigtooth aspen.
Oak-hickory forests are those in which northern red oak, white oak, bur oak, and hickories (northern Ohio only) make up a majority of the trees. Common associates include yellow poplar, elm, maple, beech, and jack pine (especially in northern Ohio). In the southern Lower Peninsula, this forest type can be found growing on a variety of sites and is primarily composed of oak, hickory, and related species. In the northern Lower Peninsula and a few areas in the Upper Peninsula, it is found growing on very well drained, sandy soils, where pine species such as jack and red pine are major associates. Historically, this forest type has experienced a number of pest problems, singly or in combination, that have periodically (perhaps every 15 to 20 years) caused localized areas of mortality throughout the state. Leaf rollers, defoliating insects, drought, late spring frosts, and, more recently, gypsy moths are pest problems found within the oak-hickory forest type. When several pest problems occur within a few months of one another, the effects of the combination of stresses is generally referred to as oak decline. Other pests that can be found in the oak-hickory forest type include oak skeletonizer, orange-striped oak-worm, fall webworm, and several other leaf-feeding insects as well as anthracnose and oak wilt diseases.
Elm-ash-soft maple

Elm-ash-soft maple forests (also referred to as lowland hardwoods) are those in which a majority of the trees are elm, black and green ash, red and silver maple, and cottonwood. Lowland hardwoods are often found growing on wet, poorly drained sites such as river floodplains. These sites can be very productive for timber growth because of the consistent moisture and silt loads from periodic floods. However, wind throw and a high amount of defect in the wood quality can occasionally be problems because of shallow root systems and the fast growing, low density, easily rotted wood associated with tree species such as soft maples and cottonwoods. Pest problems such as Dutch elm disease have had a serious impact on this forest type and have virtually eliminated American elm from this type. Other pest problems include forest tent caterpillar, spring and fall cankerworms, and other defoliating insects as well as heartwood decay disease.
Figure 5.13. American elm.

Figure 5.14. Black ash.

Figure 5.15. Silver maple.

Figure 5.16. Eastern cottonwood.
Pine

The pine forest type is generally dominated by two of three native species of pine. Though all may be found primarily growing in forests, woodlands and landscapes throughout Ohio, there is some variability. Eastern Hemlock is generally found in cool moist ravines throughout Eastern Ohio. The Indians used the moist inner bark to make a poultice for wounds and sores. Even today hemlock oil, distilled from twigs, is used in liniments. The hemlock's small cones are among the smallest of the pine family.

When the first pioneers came to this country, the white pine was the monarch of the eastern forests. Trees with trunks six feet in diameter, soaring to a height of 250 ft. were reported. In those days of majestic sailing ships the long straight trunks of white pine were the preferred choice for ship's masts. This pine is distinguished from all other eastern pines by the fact that its soft bluish-green needles occur in bundles of five. The pollen-bearing flowers are clustered in small cones at the base of new growth. The bright red seed-producing flowers occur on twigs. The white pine is increasingly becoming a major understory species beneath aspen-birch or oak-hickory forests in some parts of the state. If left undisturbed, these sites may eventually convert entirely to white pine.

Historically, pine stands have periodically experienced a number of pest problems. White pine (especially overmature stands) is attacked by white pine budworm, which causes serious defoliation and mortality. Wildfire is also a major threat to this forest type. Several sawfly defoliators such as redheaded or introduced pine sawfly can occasionally attack red and white pine. Pine and Saratoga spittlebugs, pine root collar weevil, Zimmerman and European pine shoot moth, and other insects can occasionally cause significant damage and mortality to red and white pine stands. Several disease problems ranging from needle-cast foliage diseases and white pine blister rust to drought and other environmental problems have occasionally caused damage to red and white pine stands.

The remainder of the forest types that can be found growing in Ohio are balsam fir/white spruce, black spruce, northern white cedar, tamarack and exotic species such as the non-native Scotch pine. On occasion, all of these forest types can experience some type of major insect or disease problem. Some examples (in order of forest type listed above) include spruce budworm, arborvitae leaf miner, larch casebearer, and several needle-cast diseases of non-native species such as Scotch pine and Douglas-fir.
Figure 5.20. Balsam fir.

Figure 5.21. Black spruce.

Figure 5.22. White spruce.

Figure 5.23. Northern white cedar.
LEARNING OBJECTIVES

After completely studying this chapter, you should:

- Understand what causes tree disease.
- Know the major objective of tree disease management and how this objective might be achieved in an economically feasible manner.
- Understand how knowledge of the life cycle of disease organisms enables proper and timely management decisions.
- Know the silvi-cultural techniques available for preventing and managing disease.
- Know the important tree diseases in Ohio and the management strategies associated with each.
- Understand why and how disease control methods applied to forests will differ from disease control methods applied to Christmas tree plantations, forest nurseries, and seed orchards.
- Know the important diseases associated with Christmas tree plantations and management strategies for each.
- Know the chemical treatments available for controlling disease in forest nurseries.
- Know disease control methods applied to seed orchards.
- Understand methods for preventing pest resistance to fungicides.

WHAT CAUSES TREE DISEASE?

When a plant cannot function normally, it is diseased. The primary causes of disease in trees are pathogens and environmental factors. Trees have many disease pathogens: viruses, bacteria, fungi, nematodes, mycoplasma-like organisms, and parasitic higher plants. Fungal pathogens are the most prevalent. They cause seed rots, seedling damping-off, root rots, foliage diseases, cankers, vascular wilts, diebacks, galls and tumors, trunk rots, and decays of aging trees. Unfavorable weather and environmental factors such as temperature and moisture extremes, high winds, or ice can damage trees directly and predispose the trees to pest attack.

OBJECTIVES OF DISEASE MANAGEMENT

The major objective of disease management is to prevent or minimize losses while preserving tree quality. Absolute disease control is rarely achieved or even attempted. More often, management efforts are directed toward preventing disease or reducing it to the status of a tolerable nuisance. In most instances, forest disease management requires preventive methods over a long time and considers the stand as whole rather than specific diseased individuals. Christmas tree disease management, on the other hand, is more likely to consider the value of each tree.

Management measures must be economically feasible—expenditures must not exceed the expected benefits. Direct control of disease in the forest is limited by many factors, including:

- The vast areas involved.
- The inaccessibility of many stands.
- The long life cycle of trees.
- The relatively low per acre or per individual tree values.
Thus, spraying, dusting, or other direct control procedures commonly employed with high-value crops such as Christmas trees, forest nursery crops, and valuable seed orchards are rarely applicable in the forest. Occasionally, however, disease epidemics of introduced forest pests warrant drastic and costly direct control measures to meet the emergency.

TIMING OF DISEASE CONTROL MEASURES

When chemical disease control application is economically feasible, as in the case of Christmas trees or forest nursery stock, it is essential that the pest manager understand the life cycle of the disease to be controlled. For many diseases, only one short window of control may be available in a calendar year, or the control spray may have to be applied preventively—before any signs or symptoms of disease are present. Chemical control measures must be applied to the plant when infection is most likely to occur or it will be a waste of time, effort, and money. By understanding the life cycle of the disease organism, you will be able to make proper and timely management decisions.

FOREST DISEASE MANAGEMENT

The most important principle in forest protection is that preventing attack by an insect or disease pest and/or preventing further development of the pest problem is far more effective than attempting to stop the damage after it is underway. The wise application of forest management practices ultimately has more enduring and less expensive results than more direct methods of protection.

Most forest disease control is achieved through adjustments in forest management practices. General methods of silvicultural control may include:

- Decay reduction through rotation.
- Fire prevention and care when logging.
- Reductions of disease through timber stand improvement operations and the use of partial cutting methods.
- Use of prescribed burning.
- Maintenance of high stand densities where applicable.
- Salvage to reduce losses.

Planted stands are particularly liable to disease. The impact of disease will become increasingly important as more planting is done and as plantations become older. The critical period for most stands is from about 20 to 40 years of age, the period when the stands make the greatest demands on the site. Vigorous early growth is no assurance of satisfactory long-term development. The major effort toward disease control in plantations is through avoidance. Selecting a site with favorable growing conditions and then a species suited to that site is of primary importance. Planting stock must be free of disease. In choosing a species, consider the risks entailed by introducing exotics or extending the range of a species; also select a seed source that is adaptable to Ohio. Pure stands are at more risk than mixed stands, as are large areas of even-aged trees. Spacing, thinning, and weed control are also important for maintaining stand vigor.

DISEASE SURVEYS

Disease surveys are important and are the first step in application of control measures. Detection, appraisal, and control surveys are made for early recognition of disease; for information on scope of attack, extent of damage, possibilities for control, estimates of costs, and delimitation of control areas; and for assessing the effectiveness of control programs.

SOME IMPORTANT FOREST TREE DISEASES IN OHIO

Within the scope of this chapter, we cannot discuss all of the major forest tree diseases in Ohio. A few important and representative diseases have been chosen to serve as useful examples of diagnosis and control.

Canker Diseases—Various Fungi

"Canker" is a general term used to describe diseases of the bark and cambium. Canker diseases can occur on conifers, hardwoods, and softwood species, generally as a result of wounding. The fungi that cause cankers—Valsa (Cytospora) canker, Hypoxylon canker and Nectria canker, to name a few, often grow slowly in the living tissues of the cambium, eventually girdling branches or the trunk of the tree. Trees become disfigured, sometimes die, and are often left for cull. Cankers also create an entry point for decay organisms.

Figure 6.1. Nectria canker—one type of stem canker (R.L. Anderson, USDA Forest Service, Forest Pests of North America, Integrated Pest Management Photo CD Series, 1999, Bugwood and the University of Georgia, Tifton, Ga.).
**Table 6.1. Forest types and some important diseases.**

<table>
<thead>
<tr>
<th>Forest Type</th>
<th>Important Diseases</th>
<th>Affected Trees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maple-beech</td>
<td>Cankers (various)</td>
<td>Sugar maple, yellow birch</td>
</tr>
<tr>
<td></td>
<td>Wood decay</td>
<td>Sugar and red maple, paper and yellow birch</td>
</tr>
<tr>
<td>Aspen-birch</td>
<td>Hypoxylon canker</td>
<td>Aspen</td>
</tr>
<tr>
<td></td>
<td>Armillaria root rot</td>
<td>Aspen</td>
</tr>
<tr>
<td>Oak-hickory</td>
<td>Armillaria root rot</td>
<td>Oak</td>
</tr>
<tr>
<td></td>
<td>Oak wilt</td>
<td>Oak</td>
</tr>
<tr>
<td>Elm-ash-soft maple</td>
<td>Dutch elm disease</td>
<td>Elm</td>
</tr>
<tr>
<td></td>
<td>Decay</td>
<td>Ash, red maple</td>
</tr>
<tr>
<td>Pine</td>
<td>Armillaria root rot</td>
<td>Red pine</td>
</tr>
<tr>
<td></td>
<td>Scleroderris canker</td>
<td>Red, jack, and Scotch pine</td>
</tr>
<tr>
<td></td>
<td>White pine blister rust</td>
<td>White pine</td>
</tr>
</tbody>
</table>

**Management strategy:**
- Avoid wounds.
- Use resistant trees, if possible.
- Destroy infected trees.

**Decay in Northern Hardwoods**

Decay and discoloration associated with wounds are a major cause of loss in the quality of hardwood lumber and veneer. A number of fungi cause differing types of decay diseases, but the biology of infection is similar. Each tree type reacts to wounding by forming a barrier zone that discolors the cambium. As long as the wound remains open, it is subsequently colonized by a succession of microorganisms and, lastly, by wood decay fungi. There is no way to eliminate the fungi once they have colonized the tree. Visible wounds are a good indication of the presence of discoloration and decay in the standing tree. The decay fungi each produce unique fruiting bodies shaped variously like brackets, mushrooms, or hoofs on the branches or trunk of an infected tree. Spores are shed from the fruiting bodies at various times of the year but generally during moist, wet weather, and infection of other trees occurs at wound sites.

**Management strategy:**
- Avoid major wounds to tree stems and roots.
- Maintain stand vigor as high as possible.
- Harvest trees before discoloration and decay become economically important.
- Thin excessive stems in sprout stands as soon as possible.

![Hypoxylon Canker](image)

**Hypoxylon Canker**

Hypoxylon canker is the most destructive canker disease of aspen and one of the most important diseases in the Great Lakes states. The fungus enters the tree at branch stubs. The invaded tissue becomes yellow, and then the bark surface collapses irregularly after a few weeks. The trees may be killed as a result of girdling or by snapping off at the point of the canker. Alternating light and dark bands are apparent when the bark is sliced open.

**Management strategy:**
- High-density stands with a minimum of other tree species will have smaller losses to Hypoxylon canker.
Where disease incidence is high, other species should be grown, if possible.

Over-mature stands appear more susceptible to the disease, so shorter rotations can minimize losses.

Chemical control is not effective.

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**Armillaria** (Shoestring) Root Rot

*Armillaria* root rot is caused by several fungi in the genus *Armillaria*. The fruiting body is commonly known as the “honey mushroom” because of its golden color. Throughout the world, the fungus causes an economically important root and butt rot of forest, orchard, and ornamental trees and shrubs. Young trees, especially conifers, are often killed, either singly or in groups. This root rot is especially troublesome in plantations on cleared land where broadleaf trees have been recently felled.

General symptoms include reduced vigor, yellowing of foliage, and crown dieback, though trees may die abruptly without exhibiting decline symptoms. Fans or mats of white mycelium form under the bark of the lower stem and along roots, eventually girdling the tree. Flattened rhizomorphs (black or brown fungal “shoestrings”) may replace fans between bark and wood in advanced stages of the disease. Both the fans and the shoestrings are easily visible when present under the loosened bark just above the soil line or along the roots. Rhizomorphs grow out from decayed wood and roots and infect the roots of adjacent healthy trees. Old infected trees or stumps can act as reservoirs for the fungus. On conifers, especially pines, there is an abnormal flow of resin from the root collar of infected trees.
The disease is difficult to control, especially in forests. Preventive measures center around:

- Depriving the fungus of a food base by site selection, removing stumps and root systems from a planting site, rotating to annual crops for several years, poisoning stumps after felling, and increasing planting distance.
- Promoting conditions unfavorable for infection or growth of rhizomorphs by liming and aerating soil, planting less susceptible species, and maintaining high tree vigor.
- Fumigating the soil.

Oak Wilt

Oak wilt is a serious wilt disease that kills trees by plugging the water-conducting cells. All oak species are susceptible, but red and black oaks are much more susceptible than white or bur oaks.

![Figure 6.7. Oak wilt discoloration of water-conducting cells in white oak (F.A. Baker, Utah State University, Forest Pests of North America, Integrated Pest Management Photo CD Series, 1999, Bugwood and the University of Georgia, Tifton, Ga.).](image)

![Figure 6.8. Oak wilt foliar symptoms on northern red oak (F.A. Baker, Utah State University, Forest Pests of North America, Integrated Pest Management Photo CD Series, 1999, Bugwood and the University of Georgia, Tifton, Ga.).](image)

The fungus moves from infected oaks to healthy oaks in two ways—through root grafts and through fresh wounds via insect vectors. Spread by insects is most serious in late spring and early summer. The fungus invades the water-conducting vessels of the sapwood and stimulates the infected tree to plug the vessels. Sap flow is disrupted and the tree wilts.

There is no cure for infected trees; therefore, control depends on preventing the disease from spreading. Once established, the disease spreads quickly in an area via root grafts.

**Management strategy:**

- Prevent unnecessary wounding.
- Sever all grafted roots between diseased and healthy trees, either mechanically or chemically.
- Remove and destroy diseased trees; and in wood-lots, poison adjacent healthy oaks surrounding an oak wilt pocket.

Dutch Elm Disease

Like oak wilt, Dutch elm disease is a vascular wilt disease.

The fungus disease is transmitted by two insect vectors, the smaller European elm bark beetle and the native elm bark beetle, when they feed in the spring. Transmission also occurs underground through naturally grafted roots anytime during the growing season. The insects form egg galleries in dying or dead elms. New generations of emerging beetles carry fungus spores on their bodies. Spores are deposited in feeding wounds made by the beetles. Penetration by the fungus, infection, and disease development follow. The water-conducting cells plug up and the tree wilts in early summer—one branch at a time, or entirely. Diagnostic symptoms include wilting, yellowing, and then browning of leaves, and drying up of foliage on affected portions of the crown. Diseased branches develop brown streaking in the wood which is evident when the bark is peeled back. Vectors breed only in weakened, dying, or dead elms with tight bark.

![Figure 6.9. Oak wilt mortality center in oak stand (D.W. French, The University of Minnesota, Forest Pests of North America, Integrated Pest Management Photo CD Series, 1999, Bugwood and the University of Georgia, Tifton, Ga.).](image)
Scleroderris Canker

Scleroderris canker is primarily a problem of nurseries and young plantations, where it has occasionally caused extensive damage. Red, jack, and Scotch pines are the most important hosts.

Infected needles turn orange at the base during early May, approximately 9 months after infection. By midsummer, the needles are brown and can be easily pulled off. The fungus then grows along the branch until it reaches the main stem. Cankers form on infected twigs, branches, and trunks of young trees, killing them within a few months. In jack pine, girdling cankers form on the trunk near the soil line. An olive-green discoloration from the fungus occurs in infected wood. Infection typically occurs during moist weather from April to October.

Management strategy:

- In nurseries, Scleroderris canker is easily controlled with fungicide sprays.
- Frost injury favors infection in both nursery and forest sites. Therefore:
  - Avoid low sites with poor air drainage.
  - Plant under partial overstories (results in less disease than planting in completely open areas).
  - Burn or bury infected trees.

White Pine Blister Rust

The white pine blister rust fungus alternates between white pine and wild currant (Ribes spp.). Spores from white pine can infect only wild currant, and spores from wild currant can infect only white pine. Pine needles are infected in the fall from spores produced on the wild currant shrubs. The fungus moves into the branches and main stem, where swollen, spindle-shaped cankers eventually form. Resin flows from bark cracks on the canker and hardens in masses. Girdled branches will have brown and drooping dead needles called flags, which are easily spotted. In May and June, blisters filled with yellow-orange spores appear on the cankered areas of the pines. These spores will infect the wild
currant plants. The infection on currant causes spots that cover the underside of the leaves. Orange masses form on the leaf spots in early summer, followed by brownish, hair-like projections that produce spores to infect the pine in the fall.

**Management strategy**

- Eradicate Ribes (will work as a control measure only in areas where the disease is low to moderate).
- Prune branch galls from high-value trees.
- Seek disease-resistant trees if they are available.

**INTENSIVE DISEASE MANAGEMENT SITUATIONS**

Though chemical controls are used infrequently to control forest tree diseases, they provide important supplements to cultural practices in Christmas tree plantations, forest nurseries, and seed orchards.

**Christmas Tree Plantations**

Because of the high value of the crop, intensive disease control can be practiced in Christmas tree plantations. Foliage diseases can be a major problem with conifers grown for Christmas trees. Foliage diseases are destructive because:

- They can disfigure and cause severe needle loss, making the tree unmarketable.
They can easily spread from tree to tree and from plantation to plantation.

Major tree species grown for Christmas trees are:

- Scotch and white pine.
- Blue and white spruce.
- Balsam, Fraser, and concolor fir.
- Douglas-fir.

Each species has more than one disease that can ruin its value. Also, each disease has a specific life cycle, and control methods involving fungicide application will differ in timing, the number of applications required, and the choice of fungicide.

Cultural methods of management include planting disease-free nursery stock and growing varieties that are less susceptible to disease. For example, short-needled Spanish Scotch pine and French green varieties are particularly susceptible to Lophodermium needlecast. Additional cultural methods include proper site selection, good weed control practices, and shearing trees when the needles are dry.

**Lophodermium Needlecast**

Fungus spores are spread from diseased needles to healthy needles by rain and wind. In April and May, look for brown spots with yellow margins on the needles. The needles turn yellow and then brown by May/June. The dead needles fall off during June, July, and August, leaving tufts of green growth at the branch tips. In the fall, look for tiny, black, football-shaped fruiting bodies with a lengthwise slit down the middle, which form on the dead needles. Spores from these fruiting bodies infect new needles from late July through October.

**Management strategy:**

- Plant disease-resistant varieties.
- Do not leave live infected branches on stumps at harvest—they serve as reservoirs for disease.
- Fungicide applications should be made from late July through October, especially if rainy weather persists.

**Table 6.2. Christmas tree species and some important diseases.**

<table>
<thead>
<tr>
<th>Christmas Tree Species</th>
<th>Important Diseases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scotch pine</td>
<td><em>Lophodermium</em> needlecast</td>
</tr>
<tr>
<td></td>
<td><em>Sphaeropsis</em> (Diplodia) blight</td>
</tr>
<tr>
<td>Fraser fir</td>
<td><em>Phytophthora</em> root rot</td>
</tr>
<tr>
<td>Douglas-fir</td>
<td>Swiss needlecast, <em>Rhabdocline</em></td>
</tr>
<tr>
<td>White spruce, Blue spruce</td>
<td><em>Rhizosphaera</em> needlecast</td>
</tr>
</tbody>
</table>
Sphaeropsis (Diplodia) Blight

The fungus kills current-year shoots on Scotch pine, as well as Austrian and red pine trees of all ages. It overwinters in shoots, on cones, and in litter. Spores are released during wet weather from spring through fall. Trees stressed by poor site, poor weather, or insect problems are very susceptible. Once infection occurs, new shoots become stunted or curled. Small, black fruiting bodies erupt from the dead needles and shoot tissue. Sunken cankers may also form on the branches.

![Figure 6.18. Sphaeropsis blight](image1)

Management strategy:
- Plant clean stock.
- Be vigilant in inspecting trees for disease.
- Do not shear infected trees during wet weather to avoid spreading the disease.
- If there is disease pressure, treat trees with fungicide according to label directions during the spring.

Phytophthora Root Rot

Phytophthora root rot can be a severe problem on Fraser fir. The Phytophthora fungus is associated with wet soils and poor drainage. Such conditions not only promote reproduction and dispersal of the fungus but also promote the susceptibility of tree roots. Infection causes a reddish brown decay of rootlets and larger woody roots. Root death leads to cessation of growth and then chlorosis, drooping, and browning of foliage. Site is the most important consideration when planting Fraser fir. Plant trees only on sandy, well drained sites.

Management strategy:
- Buy Fraser fir seedlings only from reputable sources. Diseased seedlings may not show foliar symptoms until some time after planting.
- Avoid planting in compacted soils and soils with a high clay content.

![Figure 6.19. Phytophthora root disease on Fraser fir](image2)

Swiss Needlecast

This fungus causes needle browning and early needle loss on Douglas-fir. Wind-blown spores infect newly developing needles during rainy periods. One to three years later, the needles turn yellow-green mottled with brown or entirely brown before falling. By the time the disease becomes noticeable, much green foliage is already infected. The black, fuzzy fruiting bodies of the fungus are visible in the rows of pore like openings (stomata) on the undersides of the needles.

![Figure 6.20. Swiss needlecast—close-up view of infected needle](image3)

Management strategy:
- Plant clean stock.
- Avoid shearing during wet weather to prevent spreading infection from tree to tree.
- Use several applications of preventive fungicide beginning at shoot elongation in the spring.
Rhabdocline Needlecast

This fungus disease causes browning and early needle loss of Douglas-fir, especially the Rocky Mountain variety. Disease symptoms become evident in the fall, when yellow spots appear on infected needles. In spring, the spotted needles turn yellowish brown to reddish brown. The brown needles begin to fall off in early summer. Fruiting bodies that develop on the brown needles release spores during moist weather from May to July. Wind-borne spores infect only the young needles.

Figure 6.21. Rhabdocline needlecast symptoms on blue spruce (R.L. Anderson, USDA Forest Service, Forest Pests of North America, Integrated Pest Management Photo CD Series, 1999, Bugwood and the University of Georgia, Tifton, Ga.).

Management strategy:
- Plant disease-free stock and disease-resistant varieties.
- If the disease is present, shear healthy trees first.
- Apply appropriate fungicides according to label directions if disease pressure warrants it.

Rhizosphaera Needlecast

This fungus causes needles of spruce to turn purplish brown and fall prematurely. The fruiting bodies are fuzzy and black and protrude through the breathing pores (stomata) along the length of the needles. Spores from these fruiting bodies cause the initial infection. Infection is possible from mid-April to October but usually occurs during wet weather right after spruce buds break. Infected needles turn yellow, then purplish-brown by July/August. The lower portions of the tree generally show the most brown needles, which drop off by late fall.

Figure 6.22. Rhizosphaera needlecast symptoms showing typical pattern/color (Minnesota Dept. of Natural Resources—FIA, Forest Pests of North America, Integrated Pest Management Photo CD Series, 1999, Bugwood and the University of Georgia, Tifton, Ga.).

Management strategy:
- Plant disease-free stock.
- Do not shear infected foliage during wet weather.
- Do not leave infected branches on stumps of harvested trees.
- Fungicide sprays are effective if applied in spring as new growth is emerging.

Forest Nurseries

Chemical control methods in nurseries rely primarily on treatment before the disease becomes established. This may be done by fumigating the soil to eradicate the pathogen or by protecting the plant with foliage, seed treatment, or root drench fungicide applications.

Soil fumigation. A common method of disease control is soil fumigation. Because soil fumigation requires a separate pesticide certification standard, we will not discuss it here.

Seed treatment. Seed treatments are used in nurseries to control seed- and soil borne fungal pathogens that cause seed rots, damping-off, and seedling root rots. Fungicides are applied as dusts, slurries, or pellets.

Soil drenches. Soil drenches are used in forest nurseries to suppress soil borne plant pathogens in seed and transplant beds. They also may be used as treatments in greenhouses and shade houses. They are most effective as preventive treatments.

Foliar applications. Protection of foliage with fungicide sprays is a common practice in nurseries. Foliage diseases frequently become epidemic under nursery conditions. Crop rotation, plowing to turn under crop refuse, and disease resistance, if available, can help control leaf spots and blights, but, close spacing, overhead irrigation, and other factors contribute to frequent and severe foliar disease outbreaks unless treated. The high value of nursery crops justifies foliar treatments.

Effective treatment depends on the right selection of pesticides. Read the labels carefully. Timing and thoroughness of application also are important. Many fungicides are effective only when applied before infection occurs. This frequently requires application when stage of plant growth or weather conditions dictate it, rather than waiting for symptoms to begin to develop.
Seed Orchards

Several diseases already covered in this chapter have the potential for significant impact on seed production.

Hardwood seed orchards are subject to canker diseases and defoliation by leaf-spotting fungi. Management consists of pruning cankered branches or applying an appropriate fungicide to protect the foliage.

PEST RESISTANCE TO FUNGICIDES

Pesticide resistance of fungal diseases is related to the specificity of the fungicide. The more specific the site and mode of fungicidal action within the fungus, the greater the likelihood for the pathogen to develop a tolerance to that pesticide. Most of the newer fungicides are very specific in their mode of action. Therefore, resistance in plant pathogens has increased substantially in recent years. Cross-resistance has also been observed in some pathogen populations, but not with the frequency found in insect populations.

Resistance to fungicides can be prevented or postponed indefinitely by following label directions and these guidelines:

- Use integrated control strategies.
- Limit the use of pesticides as much as possible.
- Rotate different brands and classes of fungicides.
LEARNING OBJECTIVES

After completely studying this chapter, you should:

- Understand the concept of economic thresholds and know what factors need to be considered to determine them.
- Know the difference between natural (non-chemical) and applied (chemical and non-chemical) controls.
- Know the common forest insect pests in Ohio, their habits and habitat, the type of damage they cause, and management strategies for each.
- Know which forest pest management situations require intensive insect management.
- Know important insect and mite pests of Christmas trees, their habits and habitat, the type of damage they cause, and management strategies for each.
- Know how resistance to insecticides might be prevented or postponed.

All species of trees are affected by a complex of insect pests. Every part of a tree—its roots, trunk, branches, twigs, buds, leaves, needles, cones, and seeds—may be fed upon by insects. Insects may attack trees of any age. The types of insect pests affecting a specific tree will depend on the age, vigor, location, and susceptibility of the tree.

Stressed trees are often more susceptible to insect attack than healthy trees. Stunting, distortion, weakening, or death of a tree is frequently caused by some combination of adverse environmental factors and insect attack. For example, severe drought stress followed by two-lined chestnut borer infestation may eventually kill an oak tree. In a few cases, insects such as white pine weevil prefer to attack healthy trees.

It is important to realize that not all insects are pests; in fact, only a small percentage cause damage to trees. Most forest insects play important roles in forest ecosystems.

ECONOMIC THRESHOLDS

The decision to control an insect pest lies with the forest owner or manager. Proper decisions can be made only after the trees have been monitored for the level of pest activity, injury potential has been evaluated, and a cost-benefit analysis has been made. By comparing the cost of applying controls to the projected market value of the stand at maturity, we can then know the pest population level at which it becomes economically beneficial to apply control measures. This population level is referred to as the economic threshold.
Generally, insecticide use in a forest is not justified because of the expense of chemical treatment, the low value of individual trees, and environmental considerations.

With Christmas trees and other specialty forest crops, the economic thresholds may be different and the use of insecticides is more often justified.

NON-CHEMICAL MANAGEMENT

Because of environmental issues and the relatively high costs of chemical controls, we can often rely on some non-chemical alternatives to manage insect pests.

Natural Controls

The term “natural control” implies that we are not directly involved in the regulation of insect numbers. The environment applies many pressures that usually keep insect populations from reaching damaging levels. Such environmental factors that limit the abundance or distribution of pest species include biotic (living) and abiotic (non-living) factors.

Biotic factors

- Insectivorous vertebrates such as rodents, skunks, and birds.
- Predaceous insects such as ladybird beetles, ground beetles, ants, and lacewings.
- Parasitic wasps and flies.
- Insect diseases caused by microorganisms such as viruses, bacteria, and fungi.

Abiotic factors

- Climatic factors, including heat, cold, and too much or too little moisture.
- Topographic barriers such as mountain ranges and bodies of water.
- Soil conditions, such as compaction, physical make-up, and moisture content.
- Disturbances such as wildfire.

Applied Controls

Any method, chemical or non-chemical, used by managers to reduce insect numbers is considered to be applied control. The most important types of non-chemical applied control are discussed in the following sections.

- Regulatory controls are utilized by governmental agencies to keep pest problems from spreading. Objectives include preventing foreign pest species from entering this country, eradicating newly introduced pests, and containing pest species within defined boundaries. Specific actions include inspecting plant materials, monitoring survey and detection traps, destroying or fumigating infested materials, and establishing and enforcing quarantines. More information on this topic is available in Chapter 10.

Mechanical controls include devices to trap, kill, or prevent free movement of insects. An example is placing sticky bands on trees to trap gypsy moth larvae.

Cultural controls make the environment less favorable for pest activity by modifying cultural practices. Proper site selection results in a favorable habitat for the tree, more vigorous growth, and fewer insect problems from secondary pests such as bronze birch borer that attack only stressed trees. Stand management, including proper species selection, proper thinning, and adjustment of harvest age, can reduce problems caused by some insects such as jack pine budworm. Sanitation is the removal of breeding material, a practice used in control of some bark beetle species.

Biological controls use living organisms or their products to achieve pest control. The results are similar to biotic natural controls, but here we are directly involved in the application of the controls. The major groups of beneficial organisms involved are predaceous and parasitic insects and insect disease organisms. Methods include introduction of new natural enemies from the original home of a foreign pest species; rearing and releasing beneficial predator and parasitoid species; and conservation of natural enemy populations by providing food, overwintering habitat, alternative prey, or other resources for beneficial species, or by minimizing the use of broad-spectrum insecticides that would kill beneficial insects.

CHEMICAL MANAGEMENT

- Chemical controls are also considered applied controls. However, their application is limited in forest situations because of the relatively high cost of application compared with the market value and long rotation age of trees. Chemical controls are used more commonly for Christmas trees because of the high value and the short rotation age of the crop. Chemical control is used for several reasons: it is often effective, its effects are immediate and predictable, it can rapidly reduce damaging populations, and it can be used where needed. However, chemical controls may have negative impacts on non-target organisms, including natural enemies, and may lead to contamination of soil or water.
Table 7.1. Forest types and some common insect pests.

<table>
<thead>
<tr>
<th>Forest Type</th>
<th>Some Important Insect Pests</th>
<th>Affected Trees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maple-beech</td>
<td>Forest tent caterpillar</td>
<td>Maple, birch, oak</td>
</tr>
<tr>
<td>Aspen-birch</td>
<td>Forest tent caterpillar</td>
<td>Aspen-birch</td>
</tr>
<tr>
<td></td>
<td>Gypsy moth</td>
<td></td>
</tr>
<tr>
<td>Oak-hickory</td>
<td>Two-lined chestnut borer</td>
<td>Oak</td>
</tr>
<tr>
<td></td>
<td>Gypsy moth</td>
<td>Oak and other hardwoods</td>
</tr>
<tr>
<td>Elm-ash-soft maple</td>
<td>European elm bark beetle</td>
<td>Elm</td>
</tr>
<tr>
<td></td>
<td>Native elm bark beetle</td>
<td></td>
</tr>
<tr>
<td>Pine</td>
<td>White pine weevil</td>
<td>White pine</td>
</tr>
<tr>
<td></td>
<td>Jack pine budworm</td>
<td>Jack and red pines</td>
</tr>
</tbody>
</table>

SOME COMMON FOREST INSECT PESTS IN OHIO

Within the scope of this chapter, we cannot discuss all of the major insect forest pests in Ohio. A few important and representative pests have been chosen to serve as useful examples of diagnosis and management.

Forest Tent Caterpillar

Forest tent caterpillars are important defoliators of aspens but also damage maple, birch, oak, ash, and willow. Larvae emerge from overwintering egg masses on branches in late April to late May. Larvae often feed, molt, and rest in groups, massing on trunks during non-feeding periods. Despite the name, no tents are constructed. Defoliation occurs in June. Heavily defoliated trees re-fooliate by late July. Larval development takes 5 to 8 weeks. Mature larvae spin cocoons for pupation and emerge as adults after 2 to 3 weeks. Mating and egg laying usually occur from early to mid-July. Trees are rarely killed, but growth loss can be significant.

Management strategy:
- Chemical controls are seldom required in the forest.
- When chemical control is needed, use a microbial insecticide in May when feeding begins.

Gypsy Moth

Gypsy moth larvae eat the leaves of many hardwoods such as oak, birch, and aspen, as well as the needles of some conifers. Complete defoliation of hardwoods is common but seldom kills the trees. Conifers, however, die if the trees are completely stripped. Gypsy moth infestations cause growth loss and detract from tree appearance. Egg masses overwinter and hatch begins in mid-April or May, depending on temperature. Larvae feed on foliage for 1 to 2 months while they complete development. When nearing maturity, they feed only at night and rest under bark, rocks, or litter during the day where they are protected from predators. Pupation occurs on or near tree bases, in litter, or in the tree canopy. Adults emerge in 10 to 14 days, then mate and lay eggs.

Figure 7.1. Larva of forest tent caterpillar (K.E. Gibson, USDA Forest Service, Forest Pests of North America, Integrated Pest Management Photo CD Series, 1999, Bugwood and the University of Georgia, Tifton, Ga.).

Figure 7.2. Gypsy moth larva on leaf (J.H. Ghent, USDA Forest Service, Forest Pests of North America, Integrated Pest Management Photo CD Series, 1999, Bugwood and the University of Georgia, Tifton, Ga.).
Chapter 7

Forest Pest Management

Management strategy:

- Stand age, condition, and value; severity of the gypsy moth threat; and management objectives must all be carefully considered to determine if a pesticide spray program is warranted.

- Microbial pesticides are effective and have low environmental impact. Spray when insects are in the first to the third instars, usually mid-May to early June.

Two-lined Chestnut Borer

Two-lined chestnut borer infests low-vigor oak trees that have been stressed by drought or other factors. Branch dieback occurs from the crown downward, and tree death is possible within 2 to 4 years. Healthy trees are seldom affected. Adult beetles emerge through D-shaped holes in the bark from late May to mid-September, peaking in mid-June. Adults feed on foliage, then mate and lay eggs within a month of emergence. Eggs hatch in 7 to 14 days, and larvae tunnel around in the sapwood. This tunneling eventually girdles and kills branches. The larvae then overwinter in the pupal stage and pupate the following summer.

Management strategy:

- Manage oak stands to optimize tree vigor.

- When two-lined chestnut borer outbreaks occur options include sanitation harvests, salvage, or delay of any activity in the stand that may further reduce vigor or wound trees.

European Elm Bark Beetle

Elm bark beetles are primarily responsible for the long-distance spread of Dutch elm disease (see Chapter 6). The European elm bark beetle is more important than the native elm bark beetle as a vector of Dutch elm disease because of its breeding dominance over the native species. The European species overwinters as a full-grown larva in the inner bark of elm trees. Pupal development is completed in the spring. Adults emerge through small holes chewed in the bark. Emergence continues for several weeks beginning in the middle of May. Adult beetles feed on young bark, usually in twig crotches, where they inoculate elms with the spores of Dutch elm disease. The spores are present in their brood galleries and on their body parts. Unhealthy or recently killed elm trees are chosen for egg laying. The egg-laying gallery is oriented parallel to the wood grain. As the eggs hatch, each larva chews a short tunnel (feeding gallery) radiating away from the egg-laying gallery. Pupation occurs at the end of the feeding gallery when the larva is mature.
Management strategy:
- Salvage recently killed or dying trees. Remove bark from infested trees or logs, or destroy infested material by burning or chipping to prevent egg laying.

Native Elm Bark Beetle

The native elm bark beetle overwinters either as a fully grown larva or as an adult. The life cycle is very similar to that of the European elm bark beetle. However, the egg-laying galleries and the subsequent feeding galleries run perpendicular to the wood grain.

Management strategy:
- The same as for European elm bark beetle.

White Pine Weevil

White pine weevil is an important pest of white and jack pine as well as some spruces. Damage results in growth and productivity loss and distortion of tree form. Adult weevils overwinter in duff below host trees until April, when they begin feeding on the terminal leader. Stout, vigorous tree leaders with thick bark are selected for feeding and egg laying. Egg laying begins a week after feeding starts. Eggs hatch in 2 weeks, and larvae form feeding rings around the leader and feed downward, consuming inner bark. Larvae complete development in 5 to 6 weeks. Pupation occurs in the pith or wood of dead leaders, usually 1 to 3 years below the current growth. Adult weevils emerge in August or September, feed on upper lateral shoots, terminals, and other areas of the crown; then move down to the duff to overwinter.

Management strategy:
- Plant densely so that damaged trees quickly reestablish dominance.
- Plant below an over-story so that trees are less suitable for weevils.
- If an insecticide is needed, spray only the leader of the tree in the spring to kill feeding adults.
- Corrective pruning may be needed to establish a dominant leader.

Jack Pine Budworm

Jack pine budworm defoliates jack, white, and red pines in spring and early summer. Severe or repeated defoliation may kill trees, especially over-mature or low-vigor trees. Significant growth loss and top-kill also occur.
Adult moths lay eggs on 1-year-old needles in midsummer, and hatch occurs in 10 to 14 days.

Larvae overwinter in silk shelters on the bark. Larvae emerge from the overwintering sites in late May or early June and usually begin feeding in pollen cones until current-year needles expand. They clip off and web needles together with silk. Drying out of the clipped and webbed foliage gives the trees a reddish appearance that is characteristic of jack pine budworm damage. The larvae can also damage female cones, and this may reduce the trees' ability to regenerate naturally. Larvae mature and pupate in early summer. Adult moths emerge from pupae in 6 to 10 days and complete egg laying in 3 to 5 days.

**Management strategy:**

- Maintain stand stocking at 70 to 110 square feet per acre.
- Optimal rotation age is 40 to 45 years.
- Chemical control can rarely be economically justified.

## INTENSIVE INSECT MANAGEMENT SITUATIONS

Chemical controls are used infrequently to control forest tree insects, but they provide important supplements to cultural practices in Christmas tree plantations and are used occasionally in forest nurseries and seed orchards.

### Christmas Tree Plantations

Christmas tree plantations are areas where intensive insect control is often practiced because of the high value of the crop and relatively low tolerance for damage. Insects and their close relatives, mites, are the most common pests of Christmas trees.

Cultural methods of insect management include proper site selection, planting pest-free stock, shearing and pruning damaged or infested shoots, and good sanitation. Knowing the life cycle and needs of each pest will help you modify and time cultural practices to manipulate pest habitat and possibly reduce the need for pesticides.

### Pine Needle Scale

Pine needle scale affects all pines and some spruces. The insects suck sap from the needles, thereby weakening the tree and reducing its vigor. The small, white, oyster-shaped scale bodies also cover the needles and detract from the appearance of the tree. Small, reddish eggs overwinter on the needles beneath dead female scales. Crawlers hatch in May, settle on the needles to feed and grow the white, waxy coating that is nearly impenetrable to pesticides. The scales quickly mature and produce a second generation of crawlers by mid- to late July.

![Figure 7.10. Pine needle scale infestation (J.B. Hanson, USDA Forest Service, Forest Pests of North America, Integrated Pest Management Photo CD Series, 1999, Bugwood and the University of Georgia, Tifton, Ga.).](image)

**Management strategy:**

- When monitoring, be sure to check lower branches, where many infestations begin.
- Cut, remove, and destroy severely infested trees.

### Table 7.2. Christmas tree species and some important insect and mite pests.

<table>
<thead>
<tr>
<th>Christmas Tree Species</th>
<th>Some Common Insect and Mite Pests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pines</td>
<td>Pine needle scale</td>
</tr>
<tr>
<td></td>
<td>Pine root collar weevil</td>
</tr>
<tr>
<td></td>
<td>Zimmerman pine moth</td>
</tr>
<tr>
<td>Balsam, concolor, Fraser fir</td>
<td>Balsam gall midge</td>
</tr>
<tr>
<td>Douglas-fir</td>
<td>Cooley spruce gall adelgid</td>
</tr>
<tr>
<td>White spruce, blue spruce</td>
<td>Cooley spruce gall adelgid (blue spruce)</td>
</tr>
<tr>
<td></td>
<td>Eastern spruce gall adelgid (white spruce)</td>
</tr>
<tr>
<td></td>
<td>Spruce spider mites</td>
</tr>
</tbody>
</table>

- Insecticides or horticultural oil sprays to control crawlers are effective in mid- to late May and again in late July or early August for control of the second generation.

### Pine Root Collar Weevil
Grub-like pine root collar weevil larvae girdle the root collar (where stem and roots meet below the soil surface) of Scotch, red, and, occasionally, white pine. The root collar may be surrounded by pitch-soaked, blackened soil. Trees fade to yellow, then red, and may topple over or break off at the root collar. Adult weevils lay eggs at the bases of pines in the spring and summer. The larvae hatch and feed on the inner bark of the root collar, then pupate in the nearby soil. Adults emerge in late summer and feed on trees for a short time before overwintering in the litter. The larvae are the most destructive stage of this insect.

Figure 7.11. Damage by pine root collar weevil on Scotch pine. (Manfred Mieike, Bugwood.org)

Management strategy:
- Avoid mixing pine species if pine root collar weevil is a frequent problem in the area.
- Scout trees 1 inch in diameter or larger before mid-May and again before mid-August.
- Remove lower two to three whorls of branches to allow sunlight to reach the root collar. This makes conditions unfavorable to weevils.
- Rake away needle accumulation from root collar area to increase soil temperature and reduce weevil survival.
- Treat root collar and surrounding soil of infested trees with insecticide to kill adults.

Zimmerman Pine Moth

Zimmerman pine moth attacks all pines, especially Scotch and Austrian. Branches may be killed and the top may break off above the point of attack. The caterpillar larvae overwinter in bark crevices. They become active in early April to early May and bore under the bark and into the stem at branch whorls. Pitch masses form on the stem at the entrance to the feeding tunnel. Adults emerge between mid-July and late August, and then lay eggs on the bark. After hatching, the caterpillars spin silken cases and overwinter.

7.12. Pitch mass and frass of Zimmerman pine moth at the branch whorl on a young Scotch pine (Whitney Cranshaw, Colorado State Univ., The Bugwood Network)

Management strategy:
- Scout for pitch masses throughout the year, especially as trees reach 5 to 8 years of age.
- Cut and burn infested trees in winter.
- Apply insecticides to the stem and bark of large branches in early to mid-April.
- Northern European Scotch pine varieties are often more susceptible than southern European varieties.

Balsam Gall Midge

The larvae of the tiny balsam gall midge feed on new needles of balsam and Fraser firs, causing small galls to form on the needles. Galled needles drop in October or November, leaving bare spots on branches. Mature larvae overwinter in the soil beneath the tree. Pupation occurs in spring, and flying adults emerge from the soil in late May to early June. Mating occurs and eggs are laid on newly emerging foliage. Developing larvae feed on needles, causing galls to form.

Figure 7.13. Needle galls caused by balsam gall midge on fir. (Steven Katovich, USDA Forest Service, Bugwood.org)

Management strategy:
- Scout for galls between June and October starting 3 to 4 years before harvest. Consider treating trees if 5 to 10 percent of the needles are galled.
- Natural predators and a competing midge species
will take care of light infestations.
- Insecticide is effective between late May and mid-June, just as galls begin to form.

Cooley Spruce Gall Adelgid

This insect is a pest of Colorado blue spruce and Douglas-fir, often moving from spruce to Douglas-fir in the same season. Symptoms are quite different on the two trees. On spruce, overwintered females lay eggs in masses of white, cottony wax near the buds in spring. Feeding by young nymphs causes the new needle growth to form a gall that surrounds the adelgids. The galls are initially green, pineapple-shaped, and 2 to 3 inches long; they are located at the ends of the shoots. The galls turn red and then brown before they open in mid-July. The nymphs leave the galls and either continue their life cycle on spruce or fly to Douglas fir. On Douglas-fir, adelgids lay eggs on the needles. The young winter on the needles, looking like bits of white cotton. Nymph feeding causes yellow spots on needles, and needles may bend or curl. Galls are not formed on Douglas-fir. Eventually a winged stage takes the adelgid back to spruce, but the cycles can continue on either host.

Management strategy:
- Keep Colorado blue spruce and Douglas-fir plantings separated to limit damage.

Blue spruce
- Scout in April for nymphs.
- If insecticide is needed, spray trees just before buds break in April or early May. A fall application may be needed as well.
- Cut off and burn or bury galls before they open in July.

Douglas-fir
- Monitor trees of all ages throughout the season.
- If it is necessary to control overwintering insects, apply insecticide in fall or before buds break in spring.
- Another application may be needed in late June to mid-July.

Eastern Spruce Gall Adelgid

White, Black Hills and Norway spruce are hosts to eastern spruce gall adelgid. The galls from Cooley adelgid form at the tips of branches, while the smaller galls from the eastern adelgid form along the twigs at the base of new growth. The biology of the insect is similar to that of the Cooley adelgid except that galls caused by eastern spruce gall adelgid are smaller and located behind current-year shoots.

Management strategy:
- Cut and destroy severely infested trees.
- If insecticide treatment is needed, treat in April as buds begin to swell or in the fall after galls have opened.

Spruce Spider Mites

Spruce spider mites can affect all Christmas tree species. Spider mites suck the juices from needles, cause bronzing or grayish discoloration of needles. Fine web-
bings may also be present. Injury can become severe, especially after hot, dry weather or where overuse of pesticides has killed the natural enemies of the mites. Spruce spider mites are tiny and difficult to see. Spherical eggs overwinter at the bases of needles. Hatch occurs in early summer. In favorable weather, it may take only 2 to 5 weeks to complete a life cycle. Several generations can occur in one summer. Eggs are laid in fall and overwinter.

**Management strategy:**

- Scout last year’s damage in early June, checking older needles near the main stem. Abundance of eggs, webbing, or live mites will determine if a miticide application is necessary.
- Selective products that control spider mites but do not harm predatory mites are available.

**Forest Nurseries**

Insects are rarely important as pests in forest nurseries. White grubs, the larvae of June beetles, will occasionally cause damage by feeding on roots of tree seedlings. Death or stunting may result. If grubs are identified, apply an appropriate insecticide to the affected block according to label directions.

**Seed Orchards**

Cone and seed insects can be problems in conifer seed orchards. The extent of damage depends on whether the insect damages entire cones or individual seeds, and on the density of the insect population in relation to cone abundance. In some years when insect density is high and cone production is relatively low, a major portion of the seed crop can be lost.

Important seed and cone insects include seed bugs, coneworms, cone beetles, and, occasionally, tip moths. Seedbugs have piercing/sucking mouthparts and feed on seeds within developing cones. They leave few external signs of damage. It is difficult to distinguish between viable seed and damaged seed without running extracted seeds through an X-ray machine. Coneworms and cone beetles bore into cones and may destroy the entire cone or a portion of it. These insects usually leave frass, webbing, and other obvious signs of damage, especially when cones are split open.

Management of seed and cone insects may include cultural strategies and insecticides. Prescribed fire can be used to control insects that overwinter in litter. Insects that overwinter in cones can be controlled by removing or destroying cones on the trees and on the ground. In some high-value seed orchards, registered insecticides may be applied at regular intervals to protect seed trees from a complex of seed and cone insects. If a specific insect pest is causing damage, however, it is best to apply insecticides only during the vulnerable stage of that pest’s life cycle. This strategy, along with an emphasis on cultural controls, helps conserve natural insect predators and parasitoids.

**PEST RESISTANCE TO INSECTICIDES**

The insects left alive after a pesticide application may be more tolerant to a pesticide, and, over time, the insect population can evolve genetic resistance to the pesticide. Insects can also develop cross-resistance. Cross-resistance occurs when an insect population that has developed resistance to a certain pesticide also develops resistance to other related or unrelated pesticide compounds to which it has never been exposed.

Resistance to insecticides can be prevented or postponed indefinitely by following label directions and these guidelines:

- Use integrated control strategies.
- Limit the use of pesticides as much as possible.
- Rotate different brands and classes of insecticides.
LEARNING OBJECTIVES

After completely studying this chapter, you should be able to:

- Know the goals and objectives of vegetation management in forestry.
- Understand cultural, mechanical, and chemical weed control and how they are integrated for successful vegetation management.
- Know how to evaluate the results of a vegetation management program or practice.
- Know the objectives of weed management in Christmas tree plantations.
- Understand the basic characteristics of herbicides and how they are used to choose an herbicide for a particular weed management situation.
- Understand the factors that influence herbicide effectiveness.
- Understand the importance of weed resistance to herbicides, the practices that lead to it, and the steps that help to prevent it.

FOREST WEED CONTROL

Weed control practices in forests are designed to favor the growth of the desired tree species, improve visibility along forest roads, control noxious weeds, and improve wildlife habitats. The goal is to manage timber species, ground vegetation, and wildlife so that each component is maximized yet balanced. Vegetation management is a primary means to achieve a productive forest.

Managers need to integrate the best cultural, mechanical, and chemical practices into appropriate and cost-effective management systems to minimize losses and detrimental effects due to weeds.

Objectives of Forest Weed Management

A forester might undertake a weed management program with one or more of the following objectives in mind:

- Removing unwanted vegetation from planting sites to favor the planted trees.
- Releasing more desirable species from less desirable overtopping species.
- Thinning excess plants from a stand.
- Preventing disease movement through root grafts.
- Preventing invasion of herbaceous and/or woody vegetation into recreational areas and wildlife openings.
- Controlling vegetation along forest roads and around buildings and facilities.
- Eliminating poisonous plants from recreational areas.
- Controlling production-limiting weeds in a seed orchard or tree nursery.

When establishing a forest, relatively few seeds or seedlings are introduced into an environment in which an almost unlimited number of other plants exist or have the potential to become established. The immediate goal of the forest manager is species survival, which is achieved by reducing the competition from weeds. Site preparation and tree release are the procedures that minimize the density and reduce the vigor of the competing vegetation in the year of and in the years immediately following.
after planting. The type and intensity of management practices depend on the vigor of the desired (planted) species and the indigenous species.

**INTEGRATED CONTROL**

Successful vegetation management plans incorporate the right package of practices into well planned programs that are executed on a timely basis. No single plan is best suited for each site, so careful analysis of each site is necessary. Routinely review the results obtained and modify the plans as needed to ensure satisfactory control.

**Cultural Control**

Cultural weed control is simply carrying out those practices that favor the desired tree species and make them more competitive with weeds. Examples include the following:

- Select the best adapted species and varieties.
- Practice thorough site preparation.
- Plant vigorous, large, healthy seedlings.
- Plant seedlings at the appropriate spacing and replace those that die.
- Apply necessary insect, disease, and rodent control measures.
- Maintain optimum stocking levels for the site at each stage of stand development.

**Mechanical Control**

Many specialized machines and attachments are used in forest vegetation management, including brush rakes, angle blades, shearing blades, rolling brush cutters, and shredders. Large offset disks and integral plows are sometimes used. In addition, chain saws, axes, brush hooks, powered brush cutters, hatches, and other hand tools can be used in weeding operations.

On gentle slopes, mechanical means of site preparation and rehabilitation are generally sufficient to remove debris, control weeds, prepare seedbeds, reduce soil compaction caused by logging, and carry out minor land leveling operations.

Mechanical thinning is sometimes practiced, especially in very dense stands where clearing in regularly spaced strips is desired and no selection of individual trees is necessary. Mechanical thinning is not acceptable for release when desired small trees are hidden by taller, brushy trees or where individual tree selection is desired.

Mechanical control is not suited to all sites. The major obstacles to the use of mechanical vegetation management are unsuitable terrain, the likelihood of soil erosion, and relatively high operating costs.

Manual vegetation removal can be done in areas inaccessible to machines or to complement or replace the use of large equipment. Manual cutting is most effective when species to be cut are not too dense and do not resprout. Because conifers do not resprout, they are easily controlled by cutting. Many brush species, however, resprout readily from the trunk or established roots, and this reduces the effectiveness of cutting. Manual cutting may not always be appropriate for site preparation or release, but it can be effectively combined with herbicide treatment of stumps to remove selected trees and prevent regrowth.

![Figure 8.1. Woody plants may sprout from the base or roots.](image)

**Chemical Control**

Chemical control of weed species is normally practical only once or twice in the life of a forest stand. The benefits of herbicides applied during site preparation and release may be evident through the life of the stand if their use is supplemented by all the other principles of good forest management. Use of herbicides is only one step in a long-term production plan. Application of herbicides must be both necessary and compatible with all other phases of the plan.

Once the weed species to be controlled have been identified, the correct herbicide, formulation, rate, water volume, method of application, and time of treatment must be determined. Before using any pesticide, read the entire label.

**Evaluating the Results**

After using any vegetation management practice, inspect the area to evaluate the results. Keep in mind the type and species of vegetation treated, the soil type, and weather conditions during and after application. Know the objectives of the control program when evaluating the results. In some cases, suppression of treated vegetation is sufficient; in others, selective control is desired. Initial herbicide activity and possible injury to adjacent desirable vegetation can be determined 2 to 4 weeks after application. The results of vegetation control treatments should be evaluated after about 2 months, at the end of the season, and then for several years. The effectiveness of brush and perennial weed control measures cannot be fully evaluated for at least 12 and sometimes 24 months after treatment.

Evaluation must be an on-going activity. It allows you to make adjustments in rates, products, and timing of herbicide applications, and to plan any additional control measures that may be needed.
CHRISTMAS TREE PLANTATION
WEED CONTROL

Christmas tree production has developed into an intensive agricultural operation designed to maximize the quantity and quality of trees per acre and minimize the number of years to harvest. An intensive management program focusing on the factors affecting tree growth, foliage quality, and general appearance is necessary. The effective use of herbicides is an essential part of this management program.

Objectives of Weed Control

A Christmas tree plantation manager might undertake a weed management program with one or more of the following objectives in mind:

- Preparing the planting site.
- Increasing survival, nutrition, and growth of newly planted trees by eliminating competition.
- Reducing rodent damage.
- Developing better quality foliage on the lower parts of the trees by eliminating the shading effect of weed growth.
- Permitting easier and higher quality shearing.
- Reducing the probability of foliage diseases.

The Christmas tree plantation manager must also consider the impression that a clean, well managed plantation makes on potential buyers and on cut-your-own customers.

HERBICIDE CHARACTERISTICS

Herbicides are chemicals that affect the germination, growth, and behavior of plants. To choose the appropriate herbicide for a particular situation, you need to understand some basic herbicide characteristics.

Selectivity or Specificity

Herbicides are not equally effective on all types of vegetation. Selective herbicides are available that control grasses only, broadleaf plants only, or certain grasses and broadleaf plants. There are also non-selective herbicides that kill all vegetation that they come in contact with. Some herbicides are selective in Christmas tree plantations when applied during certain periods of the year, such as before the trees begin growing in the spring, after they have hardened off in the late summer, or when they are dormant.

Mode of Action

Herbicides affect plants in different ways. Some are absorbed through the foliage; others are applied to the soil and are absorbed though the root systems of actively growing plants. A few herbicides kill only the portion of the plant to which they are applied. Other herbicides are applied to or incorporated in the soil to prevent the germination of weed and grass seeds.

Residual Nature

Herbicide effects vary, in part because of their residual characteristics. An herbicide is considered to have residual effect if it prevents the regrowth of vegetation for a period of time after application. This time period varies from a few months to more than a year. Several residual herbicides exert preemergent control by continuing to kill weeds as their seeds germinate.

Application rate, soil texture (particularly clay content), soil organic matter content, soil moisture level and herbicide solubility affect an herbicide's residual properties. Many herbicides that are absorbed through foliage have little or no residual effect (postemergent), whereas those applied to the soil before plant growth usually have residual effect.

Formulation

Herbicides are available in several formulations:

- Solutions, which are completely soluble in water or other solvents, such as fuel oil.
- Emulsions, which are two unlike liquids mixed together.
- Wettable powders, which consist of finely divided solid particles that can be dispersed in a liquid.
- Granules, which contain crystals of the effective chemical bound together with an inert carrier.

Each formulation has advantages related to its manner of application and the targeted plants' susceptibility to the formulation used.

An herbicide mixture's effectiveness depends on the user's knowledge of the formulation characteristics. For example, soluble herbicides must be mixed with clean water because dirt will inactivate them. Combinations of emulsifiable compounds or wettable powders and water require spray tank agitation to maintain a uniform

Figure 8.2. (a) Germinating weeds require preemergence herbicide; (b) postemergence herbicide is applied after weeds emerge.
suspension. Failure to agitate may result in erratic application rates.

**FACTORS INFLUENCING HERBICIDE EFFECTIVENESS**

To successfully control vegetation, the manager must understand the factors that influence herbicide effectiveness. Effective control is related to:

**Application Rate**

The amount of herbicide required per acre to obtain effective control depends on several variables, including herbicide formulation, soil type, and targeted vegetation. Specific application rates for various conditions are listed on the herbicide label. Follow these recommendations to obtain safe, economical, and effective results.

**Equipment Calibration**

*Calibration* is the process of measuring and adjusting the amount of pesticide your equipment will apply to a specific area. Proper calibration of equipment is required to obtain good results when using herbicides. Calibrate equipment at least once each year. Once equipment is calibrated, it is essential that the same ground speed, pump pressure, and nozzle size are maintained during actual application.

**Application Method**

For successful results, it is essential that coverage is uniform, regardless of method used for application. The equipment must be maintained and cleaned so that the herbicides will flow correctly. For herbicides that do not form true solutions, especially wettable powders, maintain agitation throughout the spray application. Failure to agitate can cause erratic application rates.

**Targeted Vegetation**

Because of differences in anatomy and physiology, some plants are more affected by herbicides than others. Annual weeds and grasses are easily controlled with pre-emergent products, while perennial grasses and weeds, particularly those with deep root systems, are more difficult to control chemically. Some plants, such as horsetails and sedges, are very difficult to control. Because of such differences, two or more herbicides are often combined in the spray tank. Determine the compatibility of various herbicides before preparing tank mixes to avoid interactions that may make each compound less effective. There is also a danger that an improper tank mix could damage the plants you are trying to protect. Pesticide dealers provide charts that outline the compatibility of many herbicides.

**Soil-site Characteristics**

Soils with high clay or organic matter contents require a heavier application rate of residual herbicide than coarse-textured sands or gravelly soils. If the amount of herbicide necessary for effective control on heavy soil is applied to a lighter textured soil, the herbicide may injure non-target plants. Further, residual herbicides persist longer on heavier soils because clay and organic particles adsorb more of the material.

**Weather Conditions**

Weather factors at the time of and following application can heavily influence herbicide effectiveness. Cool and cloudy weather following application of foliar herbicides will reduce their effectiveness. Lack of rain following soil application of herbicides may allow weeds to grow and germinate before the herbicide moves into the soil solution. Heavy rain, however, may leach the herbicide from the upper soil or wash it to low-lying areas. In both cases, the herbicide is less effective and may damage non-target plants. Weather conditions are one of the most common reasons why herbicide applications fail to control weeds.

**RESISTANCE TO HERBICIDES**

Weed resistance to herbicides is being discovered in the major agricultural areas of the United States. It is important to monitor the results of weed control applications carefully and follow guidelines to avoid resistance.
Figure 8.4. Quackgrass is a perennial grass that reproduces by seed and rhizomes.

Triazine-resistant common lamb’s-quarters have been confirmed in sites throughout most of the corn production regions of Ohio. In addition, resistance has been confirmed in pigweed species, common ragweed, common groundsel, and mare’s tail (horseweed). The occurrence of triazine resistance is generally associated with cropping systems where triazine (i.e., atrazine, simazine, and others) herbicides have been frequently used for weed control. Triazine-resistant biotypes of several other species have been identified in other states and countries.

Concern is growing about resistance to other classes of herbicides. Resistance to other types of herbicides has not yet been observed in Ohio but has become a serious problem in western U.S. crop growing regions and has been recently confirmed in many sites throughout the north central region of the United States.

An understanding of the practices that lead to herbicide resistance is important because prevention is the best approach. Use weed control practices that delay or prevent the development of herbicide resistance. The following practices were modified from a list developed by the North Central Weed Science Society Herbicide Resistance Committee:

- Scout regularly and identify weeds present.
- Combine mechanical control practices such as cultivation with herbicide treatments.
- Rotate herbicides using herbicides with differing modes of action. Do not make more than two consecutive applications of herbicides with the same mode of action against the same weed unless other effective control practices are also included in the management system.
- Apply herbicides in tank-mixed, prepackaged, or sequential mixtures that include multiple modes of action. Combining herbicides with different modes of action and similar persistence in soil will help prevent herbicide resistance.
LEARNING OBJECTIVES

After completely studying this chapter, you should:

- Know the types of damage caused by various vertebrate pests and when it is necessary to apply control techniques.
- Understand the various control techniques available to control vertebrate pest damage.
- Know what six questions need to be considered to apply the appropriate control technique.

WILD VERTEBRATE POPULATIONS AND PROBLEMS

Wild vertebrates—mammals, birds, reptiles, amphibians, and fish—are an important part of a healthy forest. Most oak trees, for example, are planted as acorns by squirrels and birds. At times, however, an increase in animal numbers or a change in their behavior can damage commercially valuable trees. When this occurs, the damage they cause may require control. Most often, damage by wild animals to naturally occurring forests is not severe enough to be of concern, but occasionally damage control efforts are economically and ecologically worthwhile. For example, abundant rodents, rabbits, or deer can totally prevent forest regeneration or severely damage entire stands of seedlings and saplings.

The table on the following page lists kinds of damage, species involved, and current damage control techniques.

DAMAGE CONTROL TECHNIQUES

Repellents

Repellents are devices or chemicals that irritate one or more of the senses of an animal and cause it to change its behavior. Repellents are usually cost effective only in nurseries and Christmas tree plantations. Even then, durability is limited (i.e., many repellents wash off in the rain), and the cost of repeated application usually makes other methods preferable. Seed treatments, chemical sprays, and auditory repellents for short-term problems are examples of efficient repellents.
Table 9.1. Vertebrate damage and control techniques.

<table>
<thead>
<tr>
<th>Damage</th>
<th>Species</th>
<th>Control Technique</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumption of seed in tree nurseries</td>
<td>rodents, birds</td>
<td>repellents, toxic baits</td>
</tr>
<tr>
<td>Consumption of seedlings and saplings in tree nurseries and naturally occurring stands; consumption of bark or branches; deformation of trees</td>
<td>rodents, deer, rabbits, porcupines, bears, and elk</td>
<td>repellents, toxic baits, physical barriers, biological controls, cultural techniques</td>
</tr>
<tr>
<td>Consumption of buds</td>
<td>squirrels, birds, deer</td>
<td>physical barriers, repellents</td>
</tr>
<tr>
<td>Flooding of trees; consumption of bark or branches; deformation of trees</td>
<td>beavers</td>
<td>destruction or modification of dam, trapping, shooting</td>
</tr>
</tbody>
</table>

Figure 9.2. Repellents will help prevent consumption of buds by tree squirrels.

Physical Barriers

A physical barrier is a device used to exclude animals to prevent damage. Examples of physical barriers to individual trees are sheet metal, wire mesh, or plastic around the trunk of seed orchard trees to exclude squirrels or around the bases of Christmas trees to exclude mice. Permanent 8- to 10-foot-high woven wire fences and seven- or eight-wire high tensile strength steel electric fences are examples of area barriers.

Cultural and Silvicultural Practices

Damage can be prevented by forest management techniques. Increasing the size of irregularly shaped clearcuts can produce more seedlings than a deer herd can consume, leaving enough for adequate regeneration. Growing species or varieties of trees less palatable to wild animals, especially in areas most subject to damage, also helps reduce or control damage. Elimination of vole habitat in nurseries and plantations is most helpful.
Figure 9.6. Meadow vole damage can be prevented by eliminating habitat (i.e., weeds, ground cover, litter) around plantation trees (Mike Ostry, USDA Forest Service – North Central Research Station Archive, USDA Forest Service, Bugwood.org).

Toxic Baits

Mixed grains or food pellets treated with poison can be used to reduce rodent populations that would consume seeds or seedlings. Correct application—such as using PVC tubes to hold the bait—is essential to successfully reduce damage and avoid killing non-target animals.

Figure 9.7. Various types of bait packs containing rodenticides are commercially available. Placing the bait packs inside PVC tubes will avoid killing non-target animals.

Figure 9.8. Two types of traps—body-gripping (top) and leghold (below).

Biological Controls

Encouraging predatory birds (raptors) and snakes to use tree nurseries and plantations facilitates damage control. Raptors can be encouraged to hunt nurseries and plantations by placing nesting boxes for kestrels and perches for other hawks and owls in or near the area. Large numbers of harmless vole-eating snakes can be attracted to tree areas in spring and fall by creating a snake hibernaculum (overwintering shelter).

Dog Restraint Systems

Dogs confined to a tree area by electric shock collars and a perimeter antenna wire will greatly limit deer and rabbit damage. Dogs, preferably two males, must be housed, watered, and fed within the perimeter wire and must be trained not to cross the wire.

Beaver Dam Modification

If the presence of beaver in an area is acceptable or desirable but the beaver pond floods the wrong place, the dam can be modified to permanently reduce or eliminate the beaver pond by properly using and installing perforated plastic pipe.

Figure 9.9. Use of PVC pipe to prevent flooding by beaver ponds—the Clemson beaver pond leveler.
DESIRABILITY OF A SPECIFIC CONTROL PRESCRIPTION

Before applying pest damage control techniques, one must answer six questions.

1. **What is the problem?** Sapsucker damage to trees, for example, occurs in trees weakened by some other cause, such as insects, disease, mechanical injury, site conditions, etc. Solving the problem involves treating the tree, not the sapsuckers. Another example is damage to bark caused by weather or insects, not vertebrates.

2. **Will the technique(s) work?** Effective taste repellents, for example, may be applied to young trees in the spring, but subsequent untreated new growth over the summer is then browsed by deer or rabbits. In this case the repellent did not fail—the applicator failed to match application to damage. As another example, ultrasonic repellent devices have little effect on most vertebrates.

3. **Are the techniques efficient?** Will the cost of the technique be less than the cost of the damage? Benefits should be greater than costs.

4. **Which combinations of techniques are most efficient?** Integrated damage control is not only always more efficient—it is often the only effective strategy.

5. **Will non-target species be affected?** If so, how seriously? Applications of any lethal control that seriously reduce numbers of non-target species should not even be considered except when the alternative loss is great. No lethal control should ever be applied if its use or repeated use causes long-term reductions of non-target species.

6. **Will the reduction of damage-causing animal numbers be effective or create additional or more serious problems?** In some cases, large numbers of the damage-causing animal are not the main reason for the damage.

Reducing the number of animals, except for total elimination, may not limit damage. An example is flooding caused by beaver activity. An annual killing of beavers will not result in the elimination of the dam that is the cause of the flooding, but modification of the dam may permanently solve the problem. Also, a change in the numbers of one animal could produce changes in numbers or behavior of another animal so that one problem is traded for another. For example, shrews may damage a seed or seedling bed, but choosing a control strategy that eliminates shrews may result in an increase in their prey—mice and voles—which can be far more destructive.

The concepts of integrated pest management apply to vertebrate populations in the same way they apply to disease, insects, and weed pests of forests and Christmas tree plantations.
APPENDIX A
GLOSSARY
Glossary of Terms for Forest Pest Management

ABSORPTION—The movement of a chemical into plants, animals (including humans), and/or microorganisms.

ACARICIDE—A pesticide used to control mites and ticks. A miticide is an acaricide.

ACTIVE INGREDIENT—The chemical or chemicals in a pesticide responsible for killing, poisoning, or repelling the pest. Listed separately in the ingredient statement.

ACUTE TOXICITY—The capacity of a pesticide to cause injury within 24 hours following exposure. LD₅₀ and LC₅₀ are common indicators of the degree of acute toxicity. (See also chronic toxicity.)

ADJUVANT—A substance added to a pesticide to improve its effectiveness or safety. Same as additive. Examples: penetrants, spreader-stickers, and wetting agents.

ADSORPTION—The process by which chemicals are held or bound to a surface by physical or chemical attraction. Clay and high organic soils tend to adsorb pesticides.

AGGREGATION PHEROMONE—See pheromone.

AEROSOL—A material stored in a container under pressure. Fine droplets are produced when the material dissolved in a liquid carrier is released into the air from the pressurized container.

ANTI-SIPHONING DEVICE—A device attached to the filling hose that prevents backflow or back-siphoning from a spray tank into a water source.

ANTICOAGULANT—A chemical that prevents normal blood clotting—the active ingredient in some rodenticides.

ANTIDOTE—A treatment used to counteract the effects of pesticide poisoning or some other poison in the body.

AQUIFER—A natural water-bearing stratum of permeable rock, sand, or gravel in which groundwater is stored.

ARACHNID—A wingless arthropod with two body regions and four pairs of jointed legs. Spiders, ticks, and mites are in the class Arachnida.

ARTHROPOD—An invertebrate animal characterized by a jointed body and limbs and usually a hard body covering that is molted at intervals. For example, insects, mites, and crayfish are in the phylum Arthropoda.

ATTRACTANT—A substance or device that will lure pests to a trap or poison bait.

AVICIDE—A pesticide used to kill or repel birds. Birds are in the class Aves.

BACTERIA—Microscopic organisms, some of which are capable of producing diseases in plants and animals. Others are beneficial.

BACTERICIDE—Chemical used to control bacteria.

BAIT—A food or other substance used to attract a pest to a pesticide or to a trap.

BAND APPLICATION—The application of a pesticide in a strip or band of a certain width, usually done in row crops.

BROADCAST APPLICATION—The uniform application of a pesticide to an entire area.

BENEFICIAL INSECT—An insect that is useful or helpful to humans; usually insect parasites, predators, pollinators, etc.

BIOLOGICAL CONTROL—Control of pests using predators, parasites, and disease-causing organisms. May be naturally occurring or introduced.

BIOMAGNIFICATION—The process whereby one organism accumulates chemical residues in higher concentrations from organisms it consumes.

BOTANICAL PESTICIDE—A pesticide produced from chemicals found in plants. Examples are nicotine, pyrethrins, and strychnine.

BRAND NAME—The name or designation of a specific pesticide product or device made by a manufacturer or formulator; a marketing name.

CALIBRATE, CALIBRATION OF EQUIPMENT—The measurement of dispersal or output and adjustments made to control the rate of dispersal of pesticides.

CARBAMATES (N-methyl carbamates)—A group of pesticides containing nitrogen, formulated as insecticides, fungicides, and herbicides. The N-methyl carbamates are insecticides and inhibit cholinesterase in animals.

CARCINOGENIC—The ability of a substance or agent to induce malignant tumors (cancer).

CARRIER—An inert liquid, solid, or gas added to an active ingredient to make a pesticide dispense effectively. A carrier is also the material, usually water or oil, used to dilute the formulated product for application.
CERTIFIED APPLICATORS—Individuals who are certified to use or supervise the use of any restricted-use pesticide covered by their certification.

CHEMICAL NAME—The scientific name of the active ingredient(s) found in the formulated product. This complex name is derived from the chemical structure of the active ingredient.

CHEMICAL CONTROL—Pesticide application to kill pests.

CHEMOSTERILANT—A chemical compound capable of preventing animal reproduction.

CHEMTREC—The Chemical Transportation Emergency Center has a toll-free number (800-424-9300) that provides 24-hour information for chemical emergencies such as a spill, leak, fire, or accident.

CHLORINATED HYDROCARBON—A pesticide containing chlorine, carbon, and hydrogen. Many are persistent in the environment. Examples: chlordane, DDT, methoxychlor.

CHOLINESTERASE, ACETYLCHOLINESTERASE—An enzyme in animals that helps regulate nerve impulses. This enzyme is depressed by N-methyl carbamate and organophosphate pesticides.

CHRONIC TOXICITY—The ability of a material to cause injury or illness (beyond 24 hours following exposure) from repeated, prolonged exposure to small amounts. (See also acute toxicity.)

COMMON NAME—A name given to a pesticide’s active ingredient by a recognized committee on pesticide nomenclature. Many pesticides are known by a number of trade or brand names, but each active ingredient has only one recognized common name.

COMMUNITY—The various populations of animal species (or plants) that exist together in an ecosystem. (See also population and ecosystem.)

CONCENTRATION—Refers to the amount of active ingredient in a given volume or weight of formulated product.

CONTACT PESTICIDE—A compound that causes death or injury to insects when it contacts them. It does not have to be ingested. Often used in reference to a spray applied directly on a pest.

CONTAMINATION—The presence of an unwanted substance (sometimes pesticides) in or on plants, animals, soil, water, air, or structures.

CULTURAL CONTROL—A pest control method that involves manipulating the environment to make it more favorable for the plant and less favorable for the pest, such as good site selection, planting resistant varieties, and selective pruning.

CROSS-RESISTANCE—Cross-resistance occurs when pest populations that have become resistant to one pesticide also become resistant to other chemically related pesticides. (See also resistance.)

DECONTAMINATE—To remove or break down a pesticidal chemical from a surface or substance.

DEGRADATION—The process by which a chemical compound or pesticide is reduced to simpler compounds by the action of microorganisms, water, air, sunlight, or other agents. Degradation products are usually but not always less toxic than the original compound.

DEPOSIT—The amount of pesticide on treated surfaces after application.

DERMAL TOXICITY—The ability of a pesticide to cause acute illness or injury to a human or animal when absorbed through the skin. (See exposure route.)

DESICCANT—A type of pesticide that draws moisture or fluids from a pest, causing it to die. Certain desiccant dusts destroy the waxy outer coating that holds moisture within an insect’s body.

DETOXIFY—To render a pesticide's active ingredient or other poisonous chemical harmless.

DIAGNOSIS—The positive identification of a problem and its cause.

DILUENT—Any liquid, gas, or solid material used to dilute or weaken a concentrated pesticide.

DOSE, DOSAGE—Quantity, amount, or rate of pesticide applied to a given area or target.

DRIFT—The airborne movement of a pesticide spray or dust beyond the intended target area.

DRIFT MANAGEMENT PLAN—A written plan required of commercial and private applicators by Ohio Regulation 637 whenever there is a chance of a spray application drifting from the target onto non-target and off-site sensitive areas.

DUST—A finely ground, dry pesticide formulation containing a small amount of active ingredient and a large amount of inert carrier or diluent such as clay or talc.

ECOSYSTEM—A system made up of communities of plants, animals and microorganisms and their interrelated physical environments. It includes both the organic and inorganic aspects involved in the cyclic processes of life. An ecosystem includes communities (of populations) with the necessary physical (habitat, moisture, temperature) and biotic (food, hosts) supporting factors.

EMULSIFIABLE CONCENTRATE—A pesticide formulation produced by mixing or suspending the active ingredient (the concentrate) and an emulsifying agent in a suitable carrier. Adding it to water forms a milky emulsion.

EMULSIFYING AGENT (EMULSIFIER)—A chemical that aids in the suspension of one liquid in another that normally would not mix together.

EMULSION—A mixture of two liquids that are not soluble in each other. One is suspended as very small droplets in the other with the aid of an emulsifying agent.

ENCAPSULATED FORMULATION—A pesticide formulation with the active ingredient enclosed in capsules of polyvinyl or other materials; principally used for slow release.
ENDANGERED SPECIES—A plant or animal species whose population is reduced to the extent that it is near extinction and that a federal agency has designated as being in danger of becoming extinct.

ENTRY INTERVAL—See reentry interval.

ENVIRONMENT—All of our physical, chemical, and biological surroundings, such as climate, soil, water, and air, and all species of plants, animals, and microorganisms.

ENVIRONMENTAL PROTECTION AGENCY OR EPA—The federal agency responsible for ensuring the protection of humans and the environment from potentially adverse effects of pesticides.

EPA ESTABLISHMENT NUMBER—A number assigned to each pesticide production plant by the EPA. The number indicates the plant at which the pesticide product was produced and must appear on all labels of that product.

EPA REGISTRATION NUMBER—An identification number assigned to a pesticide product when the product is registered by the EPA for use. The number must appear on all labels for a particular product.

ERADICATION—The complete elimination of a (pest) population from a designated area.

EXOSKELETON—The external hardened covering or skeleton of an insect to which muscles are attached internally; periodically shed.

EXPOSURE ROUTE OR COMMON EXPOSURE ROUTE—The manner—dermal, oral, or inhalation/respiratory—by which a pesticide may enter an organism.

FIFRA—The Federal Insecticide, Fungicide, and Rodenticide Act—the federal law and its amendments that control pesticide registration and use.

FLASHBACK—When a herbicide injected directly into a tree moves through root grafts to other untreated adjacent trees and kills them.

FLOWABLE—A pesticide formulation in which very finely ground solid particles are suspended (not dissolved) in a liquid carrier.

FOG TREATMENT—A fine mist of pesticide in aerosol-sized droplets (under 40 microns). Not a mist or gas. After propulsion, fog droplets fall to horizontal surfaces.

FOREST TYPE—One or more tree species growing together because of similar environmental requirements and tolerance to light (examples: maple-beech, aspen-birch, oak-hickory, elm-ash-soft maple, and pine).

FORMULATION—The pesticide product as purchased, containing a mixture of one or more active ingredients, carriers (inert ingredients), and other additives making it easy to store, dilute, and apply.

FRASS—Solid larval insect excrement; mixed with wood fragments in wood-boring and bark-boring insects.

FUMIGANT—A pesticide formulation that volatilizes, forming a toxic vapor or gas that kills in the gaseous state. Usually, it penetrates voids to kill pests.

FUNGICIDE—A chemical used to control fungi.

FUNGUS (plural, fungi)—A group of small, often microscopic, organisms in the plant kingdom that cause rot, mold, and disease. Fungi need moisture or a damp environment (wood rots require at least 19 percent moisture). Fungi are extremely important in the diet of many insects.

GALL—A swelling or outgrowth of tissue induced by a pathogen or insect on a plant.

GENERAL-USE (UNCLASSIFIED) PESTICIDE—A pesticide that can be purchased and used by the general public. (See also restricted-use pesticide.)

GRANULE—A dry pesticide formulation. The active ingredient is either mixed with or coated onto an inert carrier to form a small, ready-to-use, low-concentrate particle that normally does not present a drift hazard. Pellets differ from granules only in their precise uniformity, larger size, and shape.

GROUNDWATER—Water sources located beneath the soil surface from which spring water, well water, etc., are obtained. (See also surface water.)

HAZARD—see risk.

HERBICIDE—A pesticide used to kill plants or inhibit plant growth.

HOST—Any animal or plant on or in which another lives for nourishment, development, or protection.

IGR, INSECT GROWTH REGULATOR JUVENOID—A pesticide constructed to mimic insect hormones that control molting and the development of some insect systems affecting the change from immature to adult. (See juvenile hormone.)

INERT INGREDIENT—In a pesticide formulation, an inactive material without pesticidal activity.

INGREDIENT STATEMENT—The portion of the label on a pesticide container that gives the name and amount of each active ingredient and the total amount of inert ingredients in the formulation.

INHALATION—Taking a substance in through the lungs; breathing in. (See exposure route.)

INSECT GROWTH REGULATOR—see IGR.

INSECTICIDE—A pesticide used to manage or prevent damage caused by insects. Sometimes generalized to be synonymous with pesticide.

INSECTS, INSECTA—A class in the phylum Arthropoda characterized by a body composed of three segments (head, thorax, and abdomen) and three pairs of legs.

INSPECTION—To examine for pests, pest damage, other pest evidence, etc. (See monitoring.)

INTEGRATED PEST MANAGEMENT (IPM)—A planned pest control program in which various methods are integrated and used to keep pests from causing economic, health-related, or aesthetic injury. IPM includes reducing pests to a tolerable level. Pesticide application is not the primary control method but is an element of IPM— as are cultural, mechanical, and biological methods. IPM
programs emphasize communication, monitoring, inspection, and evaluation (keeping and using records).

JUVENILE HORMONE—A hormone produced by an insect that inhibits change or molting. As long as juvenile hormone is present, the insect does not develop into an adult but remains immature.

LABEL—All printed material attached to or on a pesticide container.

LABELING—The pesticide product label and other accompanying materials that contain directions that pesticide users are legally required to follow.

LARVA (plural larvae)—An early developmental stage of insects with complete metamorphosis. Insects hatch out of the egg as larvae before becoming pupae (resting stage) and then adults.

LC₅₀—Lethal concentration. The concentration of a pesticide, usually in air or water, that kills 50 percent of a test population of animals. LC₅₀ is usually expressed in parts per million (ppm). The lower the LC₅₀ value, the more acutely toxic the chemical.

LD₅₀—Lethal dose. The dose or amount of a pesticide that can kill 50 percent of the test animals when eaten or absorbed through the skin. LD₅₀ is expressed in milligrams of chemical per kilogram of body weight of the test animal (mg/kg). The lower the LD₅₀, the more acutely toxic the pesticide.

LEACHING—The movement of a substance with water downward through soil.

MESOTHORAX—The second segment of an insect’s thorax. One pair of legs and usually one pair of wings are attached.

METAMORPHOSIS—A change in the shape or form of an animal. Usually used when referring to insect development.

METATHORAX—The third segment of an insect’s thorax. One pair of legs and often one pair of wings are attached.

MICROBIAL DEGRADATION—Breakdown of a chemical by microorganisms.

MICROBIAL PESTICIDE—Bacteria, viruses, fungi, and other microorganisms used to control pests. Also called biorationals.

MICROORGANISM—An organism so small it can be seen only with the aid of a microscope.

MITICIDE—A pesticide used to control mites. (See acaricide.)

MODE OF ACTION—The way in which a pesticide exerts a toxic effect on the target plant or animal.

MOLT—Periodic shedding of the outer layer (e.g., an insect’s exoskeleton is shed periodically).

MONITORING—On-going surveillance. Monitoring includes inspection and record keeping. Record keeping during monitoring allows evaluation of pest population suppression, identification of pest infestations, prediction of pest outbreaks from weather data, and management of the progress of the control program.

NECROSIS—Death of plant or animal tissues that results in the formation of discolored, sunken, or necrotic (dead) areas.

NON-POINT SOURCE POLLUTION—Pollution from a generalized area or weather event, such as land runoff, precipitation, acid rain, or percolation rather than from discharge at a single location. (See point source pollution.)

NON-RESIDUAL PESTICIDE—Pesticides applied to obtain effects only during the time of treatment.

NON-TARGET ORGANISM—Any plant or animal other than the intended target(s) of a pesticide application.

NYMPH—The developmental stage of insects with gradual metamorphosis that hatches from the egg. Nymphs become adults.

ORAL TOXICITY—The ability of a pesticide to cause injury or acute illness when taken by mouth, one of the common exposure routes.

ORGANOPHOSPHATES—A large group of pesticides that contain the element phosphorus and inhibit cholinesterase in animals.

PARASITE—A plant, animal, or microorganism living in or on, or with another living organism for the purpose of obtaining all or part of its food.

PARASITOID—An organism that lives during its development in or on the body of a single host organism, eventually killing it.

PATHOGEN —A disease-causing organism.

PERSONAL PROTECTIVE EQUIPMENT (PPE)—Devices and clothing intended to protect a person from exposure to pesticides. Includes such items as long-sleeved shirts, long trousers, coveralls, suitable hats, gloves, shoes, respirators, and other safety items as needed.

PEST—An undesirable organism (plant, animal, bacterium, etc.); any organism that competes with people for food, feed, or fiber, causes economic damage, is a public health concern, reduces aesthetic qualities, or impedes industrial or recreational activities.

PESTICIDE—A chemical or other agent used to kill, repel, or otherwise control pests or to protect from a pest.

pH—A measure of the acidity/alkalinity of a liquid—acid below pH 7; basic or alkaline above pH 7 (up to 14).

PHEROMONE—A substance emitted by an animal to influence the behavior of other animals of the same species. Examples are sex pheromones (to attract mates) and aggregation pheromones (to keep members of the same species together in a group). Some pheromones are synthetically produced for use in insect traps.

PHOTODEGRADATION—Breakdown of chemicals by the action of light.

PHYTOTOXICITY—Injury to plants caused by a chemical or other agent.
PLANT SUCCESSION—The replacement of one plant community by another.

POINT SOURCE POLLUTION—Pollution from a specific site that contaminates water. (See non-point source pollution.)

POISON CONTROL CENTER—A local agency, generally a hospital, that has current information on the proper first aid techniques and antidotes for poisoning emergencies. Centers are listed in telephone directories.

POPULATION—Individuals of the same species. The populations in an area make up a community. (See ecosystem.)

POSTEMERGENT HERBICIDE—Applied after weeds have emerged to kill them by contact with the foliage. (See preemergent herbicide.)

PRECIPITATE—A solid substance that forms in a liquid and settles to the bottom of a container; a material that no longer remains in suspension.

PREDATOR—An animal that attacks, kills, and feeds on other animals. Examples of predaceous animals are hawks, owls, snakes, many insects, etc.

PREEMERGENT HERBICIDE—Applied before emergence of weeds to kill them as they sprout. (See postemergent herbicide.)

PROPELLANT—The inert ingredient in pressurized products that forces the active ingredient from the container.

PROTHORAX—The first segment of an insect’s thorax. One pair of legs is attached.

PUPA (plural: pupae)—The developmental (resting) stage of insects with complete metamorphosis where major changes from the larval to the adult form occur.

RATE OF APPLICATION—The amount of pesticide applied to a plant, animal, unit area, or surface; usually measured as per acre, per 1,000 square feet, per linear foot, or per cubic foot.

RECHARGE WATER—Water that seeps through the soil from rain, melting snow, or irrigation and adds to the amount of water in the ground.

REGULATORY PEST—Plant-feeding exotic insects that have become established in some states or regions and are, therefore, subject to regulatory controls.

REENTRY INTERVAL—The length of time following an application of a pesticide when entry into the treated area is restricted.

REGISTERED PESTICIDES—Pesticide products that have been registered by the Environmental Protection Agency for the uses listed on the label.

REPELLENT—A compound that keeps insects, rodents, birds, or other pests away from humans, plants, domestic animals, buildings, or other treated areas.

RESIDUAL PESTICIDE—A pesticide that continues to remain effective on a treated surface or area for an extended period following application.

RESIDUE—The pesticide active ingredient or its break-down product(s) that remain in or on the target after treatment.

RESTRICTED-USE PESTICIDE—A pesticide that can be purchased and used only by certified applicators or persons under their direct supervision. A pesticide classified for restricted use under FIFRA, Section 3(d)(1)(C).

RESISTANCE—The inherited ability of a pest to tolerate the toxic effects of a particular pesticide.

RISK—A probability that a given pesticide will have an adverse effect on humans or the environment in a given situation.

RODENTICIDE—A pesticide used to control rodents.

RUNOFF—The movement of water and associated materials on the soil surface. Runoff usually proceeds to bodies of surface water.

SHADE-INTOLERANT—Tree species that require full sunlight to grow and survive (examples: aspen and jack pine). (See tolerance.)

SHADE-TOLERANT—Tree species that grow best under low-light conditions (examples: beech and hemlock). (See tolerance.)

SIGNAL WORDS—Required word(s) that appear on every pesticide label to denote the relative toxicity of the product. Signal words are DANGER-POISON, DANGER, WARNING, and CAUTION.

SITE—Areas of pest infestation. Each site should be treated specifically or individually.

SOIL INJECTION—The placement of a pesticide below the surface of the soil.

SOIL DRENCH—To soak or wet the ground surface with a pesticide. Large volumes of the pesticide mixture are usually needed to saturate the soil to any depth.

SOIL INCORPORATION—The mechanical mixing of a pesticide product with soil.

SOLUTION—A mixture of one or more substances in another substance (usually a liquid) in which all the ingredients are completely dissolved. Example: sugar in water.

SOLVENT—A liquid that will dissolve another substance (solid, liquid, or gas) to form a solution.

STOMACH POISON—A pesticide that must be eaten by an animal to be effective; it will not kill on contact.

SUPPLEMENTAL LABELING—Pesticide label information that appears on a separate piece of paper and contains information regarding the site, pest, rate, etc. Supplemental labeling may be supplied at the time of purchase or requested from the dealer.

SURFACE WATER—Water on the earth’s surface: rivers, lakes, ponds, streams, etc. (See also groundwater.)

SUSPENSION—Pesticide mixtures consisting of fine particles dispersed or floating in a liquid, usually water or oil. Example: wettable powders in water.
TARGET—The plants, animals, areas, or pests at which the pesticide or other control method is directed.

TECHNICAL MATERIAL—The pesticide active ingredient in pure form as it is manufactured by a chemical company. It is combined with inert ingredients or additives in formulations such as wettable powders, dusts, emulsifiable concentrates, or granules.

THORAX—The middle part of an insect’s body between the head and the abdomen. It is divided into three segments—the prothorax, mesothorax, and metathorax. A pair of legs is attached to each thoracic region.

THRESHOLD LEVEL—The level of pest density at which the pest or its damage becomes unacceptable and control measures are required.

TOLERANCE—The necessary amount of light cast onto the forest floor for tree species to germinate or sprout, grow, and thrive. Tree species range from shade-intolerant (e.g., aspen, jack pine) to shade-tolerant (e.g., beech and hemlock). Midtolerant species include many oaks and white pine.

TOXIC—Poisonous to living organisms.

TOXICANT—A poisonous substance such as the active ingredient in a pesticide formulation.

TOXICITY—The ability of a pesticide to cause harmful, acute, delayed, or allergic effects. The degree or extent to which a chemical or substance is poisonous.

USE—The performance of pesticide-related activities requiring certification include application, mixing, loading, transport, storage, or handling after the manufacturing seal is broken; care and maintenance of application and handling equipment; and disposal of pesticides and their containers in accordance with label requirements. Uses not needing certification are long-distance transport, long-term storage, and ultimate disposal.

VAPOR PRESSURE—The property that causes a chemical to evaporate. The higher the vapor pressure, the more volatile the chemical—the easier it will evaporate.

VECTOR—A carrier, an animal (e.g., insect, nematode, mite) that can carry and transmit a pathogen from one host to another.

VERTEBRATE—Animal characterized by a segmented backbone or spinal column.

VIRUS—Ultramicroscopic parasites composed of proteins. Viruses can multiply only in living tissues and cause many animal and plant diseases.

VOLATILITY—The degree to which a substance changes from a liquid or solid state to a gas at ordinary temperatures when exposed to air.

WATER TABLE—The upper level of the water-saturated zone in the ground.

WETTABLE POWDER—A dry pesticide formulation in powder form that forms a suspension when added to water.

For further definition of terms consult:

- Region V Office of the EPA, Chicago, Ill.
- Ohio Department of Agriculture State Plan for Commercial and Private Applicators.
- Federal Agency Secretary’s Office (for federal employees using restricted pesticides in performance of official duties).
- Local, state, and national pest control associations.
APPENDIX B

BIBLIOGRAPHY


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