Forest Pest Management A Guide for Commercial Applicators Category 2
Michigan State University
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Forest Pest Management

A Guide for Commercial Applicators
Category 2

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Forest Environment Pesticide Study Manual. 1996. Donald P. Hanely, David M. Baumgartner, Gary L. Thomasson. Pullman: Washington State University Cooperative Extension (Figures 3.3, 8.1).

Forest and Right-of-Way Pest Control. 1995. Patrick J. Marer, Mark Grimes, Richard Cromwell. Davis: University of California (Figures 2.3, 3.2, 3.4, 3.5, 3.6, 3.14).

Herbicides and Forest Vegetation Management: Controlling Unwanted Trees, Brush, and Herbaceous Weeds in Pennsylvania. Extension Circular 369. 1994. James Finley, Helene Harvey, and Robert Shipman. University Park: Pennsylvania State University (Figures 3.1, 3.12, 3.15).

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).

Prevention and Control of Wildlife Damage. 1994. Hygnstrom, S.E., R.M. Timm, and G.E. Larson (eds.). Lincoln: University of Nebraska Cooperative Extension Service, USDA-APHIS, Great Plains Agricultural Council Wildlife Committee (Figures 9.3, 9.4, 9.5, 9.7, 9.8, 9.9).

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

FRONT COVER PHOTO CREDIT: *Ganoderma applanatum* wood decay fungi (top left), T. Laurent, USDA Forest Service, *Forest Pests of North America, Integrated Pest Management Photo CD Series*, 1999, Bugwood and the University of Georgia, Tifton, Ga.; Gypsy moth larva (top right), 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.; Leaffooted pine seed bug (bottom left), L.R. Barber, USDA Forest Service, Parks & Recreation, *Forest Pests of North America, Integrated Pest Management Photo CD Series*, 1999, Bugwood and the University of Georgia, Tifton, Ga.; White-tailed deer (bottom right), C.J. Randall, Michigan State University. These same photographs appear in color on the cover page for Appendix E.

FOREST PEST MANAGEMENT
A Guide for Commercial Applicators

INTRODUCTION

How to Use This Manual

This manual contains the information needed to become a certified commercial applicator in Category 2, Forest Pest Management. This manual is intended for use in combination with the Pesticide Applicator Core Training Manual (Extension Bulletin E-2195), available through the Michigan State University Bulletin Office. However, this manual would also be useful to anyone interested in learning more about forest pest management.

Category 2, 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 2 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. For more specific information on how to become a certified applicator in Michigan, refer to the beginning of the core manual (E-2195) or to the Michigan Department of Agriculture's Web site: <http:\\www.mda.state.mi.us>

CHAPTER 1

PRINCIPLES OF PEST MANAGEMENT

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)

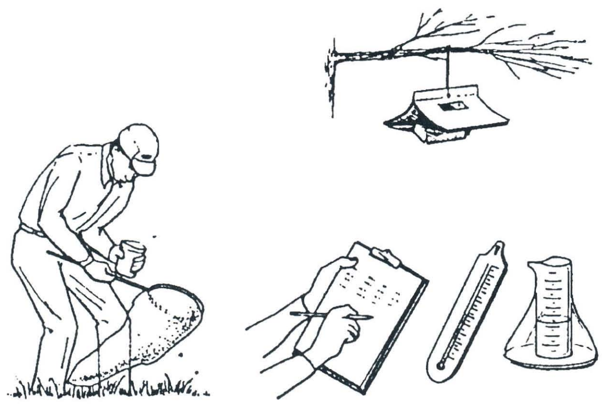
The goal of IPM is to use all appropriate tools and tactics to prevent economically important pest damage without disrupting the environment. Information gathering and decision making are used to design and carry out a combination of measures for managing pest problems. IPM is the best approach to manage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

What are these IPM tools and how are they used?

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.

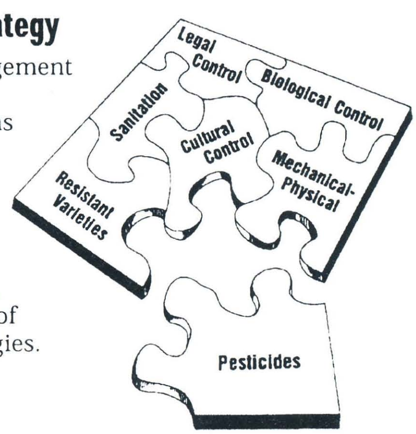
It is important to know where to find help in diagnosing pest problems. The local county Extension office can provide you with forms and instructions for sending samples to Michigan State University for diagnosis.

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

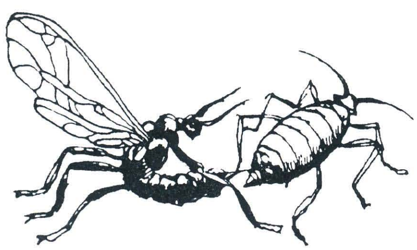
Cultural management manipulates the environment to make it more favorable for the plant and less favorable for the pest. Cultural controls such as good site selection, planting resistant varieties, or selective pruning make it less likely that the pest will survive, colonize, grow, or reproduce. Cultural 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 biocontrol 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 posttreatment 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.

CHAPTER 1

Review Questions

Chapter 1: Principles of Pest Management

Write the answers to the following questions and then check your answers with those in the back of the manual.

1. Why is a good pest control decision usually a compromise?

2. Which of the following is NOT a component of scouting trees?
   A. Record observations.
   B. Examine a representative sample of trees from the site.
   C. Search for a single pest at each inspection.
   D. Examine each tree from top to bottom and from outer edges to center.

3. What is the first thing you should do when you detect the presence of a pest?
   A. Select a control tactic.
   B. Identify the organism.
   C. Determine the threshold level for control.
   D. Notify the Department of Agriculture.

4. How would you go about identifying an insect pest found on a tree?

5. What is the threshold level?

6. Describe a situation in which you would not recommend a control procedure for a severe pest infestation.

7. Name an unwanted side effect when pesticides are used to control a pest population.

8. What IPM practice manipulates the environment to make it more favorable for plants and less favorable for pests?
   A. Biological management
   B. Mechanical management
   C. Pesticide use
   D. Cultural management

9. A net is an example of what type of IPM practice?
   A. Biological management
   B. Mechanical management
   C. Pesticide use
   D. Cultural management

10. What IPM practice depends on natural enemies of pests?

A. Biological management
B. Mechanical management
C. Pesticide use
D. Cultural management

11. Pesticides are an important tool in the practice of IPM.

A. True
B. False

12. Biological control organisms are not affected by pesticides.

A. True
B. False

13. The effectiveness of a pesticide application is related to:

A. Choosing the right pesticide
B. Proper timing
C. Good coverage
D. All of the above

14. Why is it important to evaluate the results of IPM management strategies?

15. Another term for evaluating pest management strategies is:

A. Biocontrol
B. Site-specific
C. Diagnosis
D. Record keeping

16. After pest management tactics are applied:

A. Don't return to the site until pests are a problem again.
B. Don't return to the site until the biocontrol organisms are active.
C. Return to the site and harvest the crop.
D. Return to the site and evaluate the degree of pest control.

17. What type of information should be recorded when evaluating the effectiveness of an IPM program?

18. Sound IPM practices have both economic and environmental benefits.

A. True
B. False

CHAPTER 2

MINIMIZING PESTICIDE IMPACT

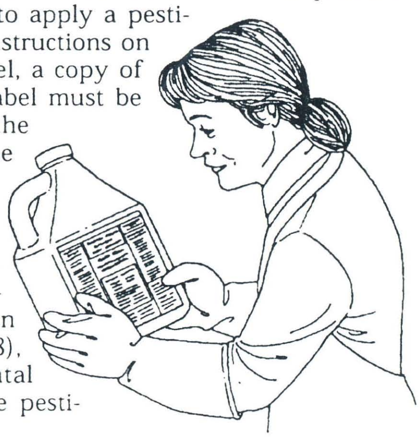
LEARNING OBJECTIVES

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 needs 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) and in Michigan by the Michigan Department of Agriculture (MDA). 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 preharvest 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 MSU Extension or the Michigan Department of Agriculture.

PROTECTING OUR GROUNDWATER

Many people who live in rural Michigan 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.

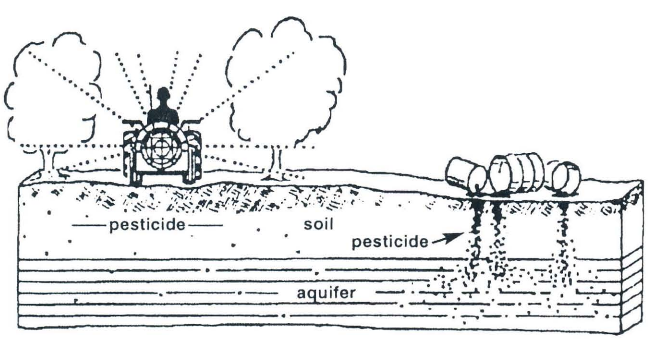


Figure 2.1. Point and non-point source pollution (Texas Agricultural Extension Service).

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.

Keeping Pesticides Out of Groundwater and Surface Water

A pesticide that is not volatilized (becomes 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 underapplication.

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.

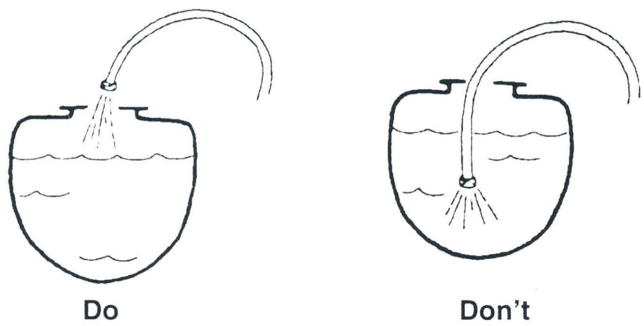


Figure 2.2. Keep hoses out of contaminated water.

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

Mix on an impervious pad. Mix and load pesticides on an impervious pad, if possible, 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.

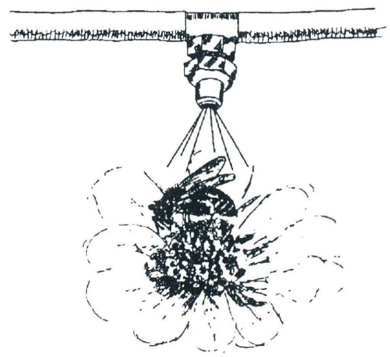
Dispose of wastes and containers properly. All pesticide wastes must be disposed of in accordance with local, state, and federal laws. Triple rinse containers. Pour the rinse water into the spray tank for use in treating the site or the crop on the label. After triple rinsing, perforate the container 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 MDA 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.

PROTECTING NON-TARGET ORGANISMS

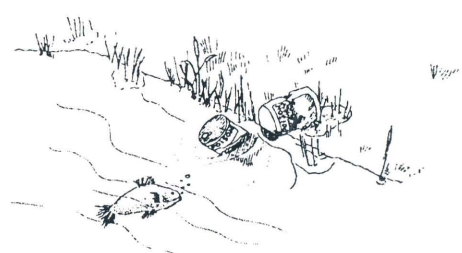
Bees and other pollinating insects can be killed by insecticides. Take the following precautions to reduce the chance of bee poisoning:

- 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.



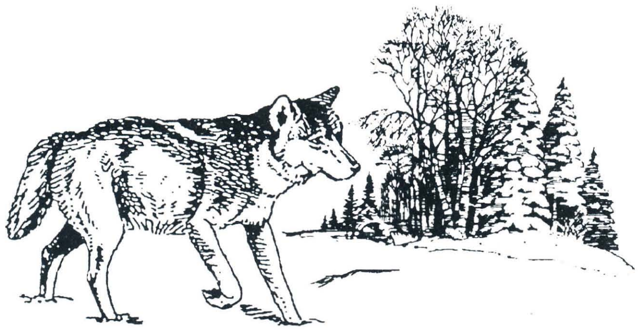
The best way to avoid injury of **beneficial insects and microorganisms** is to minimize the use of pesticides. Use selective pesticides whenever possible, and apply only when necessary as part of a total integrated pest management program.

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.



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.

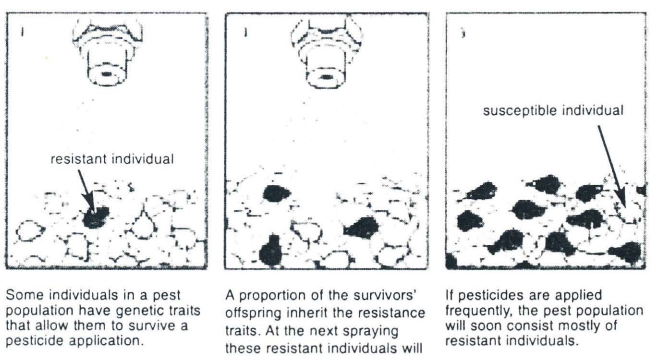


Figure 2.3. Resistance involves a change in the genetic characteristics of pest populations and is inherited from one generation to the next (David Kidd, Univ. of Calif., Davis).

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 pesticide off-target drift is anticipated, a ***drift management plan*** must be used by private and commercial applicators to minimize the occurrence and adverse effects of off-target drift. For more information on the Michigan regulation (Reg. 637) that requires a drift management plan, contact the Michigan 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.

CHAPTER 2

Review Questions

Chapter 2: Mimimizing Pesticide Impact

Write the answers to the following questions and then check your answers with those in the back of the manual.

1. If an applicator applies a pesticide according to the instructions on the supplemental label, he/she must:
   A. Notify the Michigan Department of Agriculture.
   B. Notify the pesticide dealer before the application.
   C. Notify the pesticide dealer after the application.
   D. Have the supplemental label in his/her possession at the time of the application.

2. The pesticide label contains information on:
   A. Ways to protect the applicator.
   B. Ways to protect the environment.
   C. Ways to protect the crop.
   D. All of the above

3. You should always select pesticides for the crop that you wish to use them on and the pest(s) that you wish to control.
   A. True
   B. False.

4. FIFRA is:
   A. A federal law.
   B. A law only in the state of Michigan.
   C. The law that regulates fertilizers.
   D. Administered by the Michigan Department of Natural Resources.

5. FIFRA regulates the registration and use but not the distribution and sale of pesticides.
   A. True
   B. False

6. Another term for water obtained from a well is:
   A. Surface water.
   B. Groundwater.
   C. Potential water.
   D. Runoff water.

7. If an aquifer is polluted, one or more wells drilled into the aquifer may also be polluted.
   A. True
   B. False

8. The water table fluctuates:
   A. Only in the summer.
   B. Only in the winter.
   C. Never.
   D. Throughout the year.

9. Recharge water that seeps through the soil from rain, melting snow, and irrigation:
   A. Raises the water table.
   B. Lowers the water table.
   C. Has no effect on the water table.
   D. None of the above

10. Non-point source pollution is generally easier to trace back to the origin than point source pollution.
    A. True
    B. False

11. Keeping pesticides from polluting groundwater is harder than cleaning up polluted water.
    A. True
    B. False

12. By using an integrated pest management program, you can always avoid using pesticides to control pests.
    A. True
    B. False

13. Back-siphoning can occur if there is no air gap between the water level and the hose.
    A. True
    B. False.

14. Mixing/loading a spray tank on an impervious pad and proper disposal of pesticide containers are two practices that can reduce the potential for:

    A. Pest resistance.
    B. Surface and groundwater contamination.
    C. Back-siphoning.
    D. Drift.

15. Which pesticide form is the most hazardous to bees?

    A. Dust
    B. Granules
    C. Emulsifiable concentrates
    D. Sprays

16. Which pesticide form is the least hazardous to bees?

    A. Dust
    B. Granules
    C. Microencapsulation
    D. Sprays

17. If weeds are in bloom near plants that must be sprayed with insecticide, which is the best practice to avoid killing pollinators?

    A. Wait for the weeds to finish blooming.
    B. Spray without regarding the weeds.
    C. Mow the weeds and then spray.
    D. None of the above.

18. If bees are in an area to be sprayed, what is the best time of the day to spray?

    A. Early morning
    B. Midday
    C. Evening
    D. None of the above

19. Pesticide use poses a threat to fish, wildlife, and birds.

    A. True
    B. False

20. The inherited ability of a pest to tolerate the toxic effects of a pesticide is called:

    A. Pesticide resistance.
    B. Pesticide toxicity.
    C. Pesticide use.
    D. Pesticide management.

21. If a pest can resist the toxic action of one pesticide, it can usually resist other pesticides that act in the same way.

    A. True
    B. False

22. The ability of a pest to develop resistance to pesticides it has never encountered is called:

    A. Mechanical control.
    B. Cross-resistance.
    C. Toxic action.
    D. Microencapsulation.

23. There is no way to delay the onset of pesticide resistance.

    A. True
    B. False

24. Rotating pesticides from different chemical families to kill a particular pest is one way to:

    A. Manage pesticide resistance.
    B. Calibrate spray equipment.
    C. Encourage pest buildup.
    D. Minimize drift.

25. Why is it important to maintain good public relations when applying pesticides?

26. If the applicator is asked a question about the pesticide application that he/she can't answer, he/she should:

    A. Refuse to respond to the question.
    B. Be polite and give your best guess.
    C. Leave the site and not return.
    D. Find out the answer and get back to the person.

CHAPTER 3

APPLICATION METHODS AND EQUIPMENT

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.

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.

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.

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.

Figure 3.2. Foliage stem sprays can be applied from the time the leaves are fully expanded until they begin to turn color in the fall (David Kidd, Univ. of Calif., Davis).

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.

Figure 3.3. Basal sprays are directed at the lower 18 inches of stems and trunks that are less than 6 inches in diameter.

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.

Figure 3.4. Cut-stump 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 (David Kidd, Univ. of Calif., Davis).

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

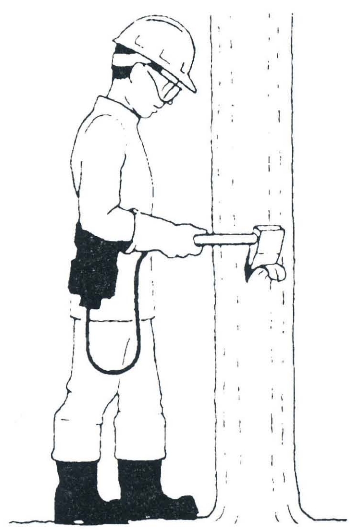


Figure 3.5. The hatchet injector allows the herbicide to be simultaneously injected into the cut area (David Kidd, Univ. of Calif., Davis).

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. Thickets of brush or species with many stems cannot be easily controlled with these methods.

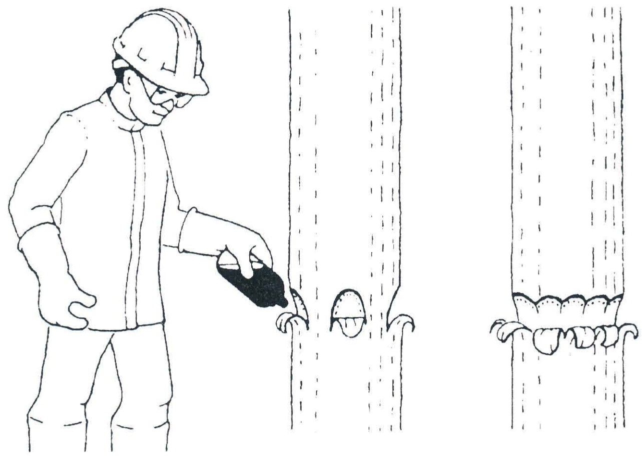


Figure 3.6. Frill cuts involve making downward angled ax or hatchet cuts in a continuous single line of overlapping cuts completely around the tree trunk. The chips are left in place to form a catch basin for the herbicide squirted into the wounds (David Kidd, Univ. of Calif., Davis).

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.

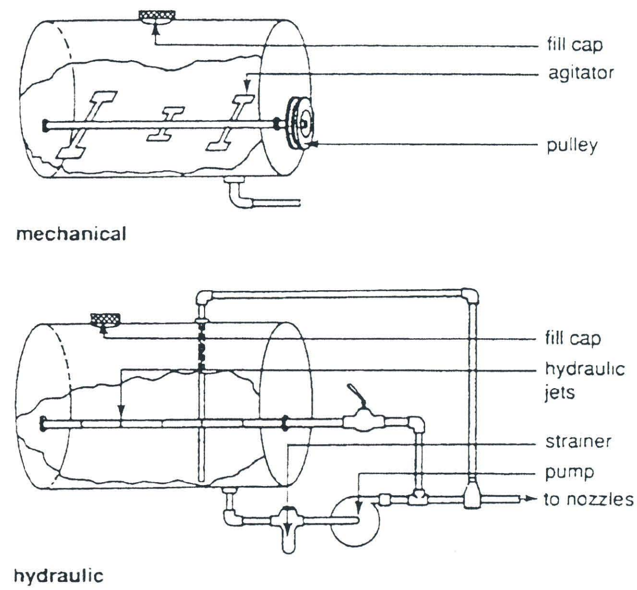


Figure 3.7. Two types of agitators in sprayer tanks (mechanical and hydraulic).

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.

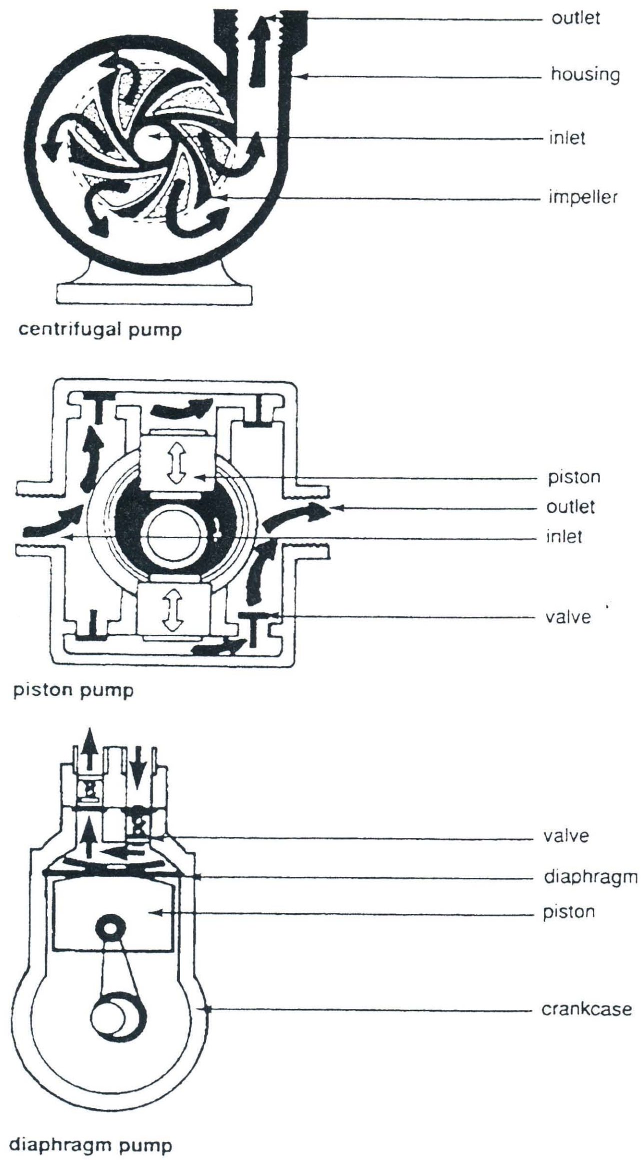


Figure 3.8. Three types of pumps.

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.

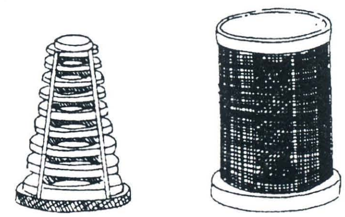


Figure 3.9. Strainers.

Hoses

Use synthetic rubber or plastic hoses that have a 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.

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.

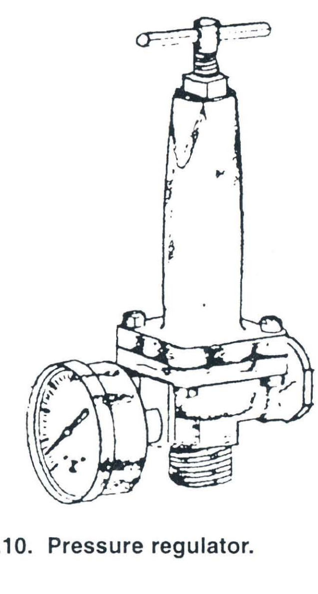


Figure 3.10. Pressure regulator.

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 glycerine-loaded diaphragm gauge is more expensive but will last indefinitely.

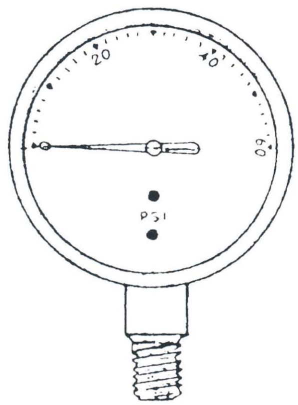


Figure 3.11. Pressure gauge.

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 is mounted on a tractor, truck, or trailer, or the nozzle(s) 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.

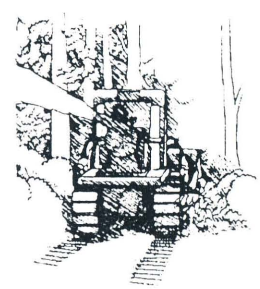


Figure 3.12. High-volume foliage spray.

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 a 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.

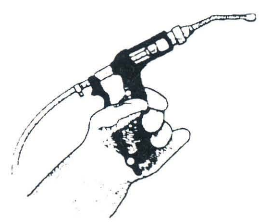


Figure 3.15. Low-volume spot gun.

OPERATION AND MAINTENANCE OF SPRAYERS

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, making sure that the sprayer is operating at the same pressure and speed used when it was calibrated. 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 gridball formulations may also be used on occasion.

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

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.

CHAPTER 3

Review Questions

Chapter 3: Application Methods and Equipment

Write the answers to the following questions and then check your answers with those in the back of the manual.

1. Which of the following methods of application mixes the pesticide into the soil using tillage equipment?
   A. Soil treatment
   B. Soil application
   C. Soil fumigation
   D. Soil incorporation

2. What are some of the factors that influence the choice of pesticide application method?

3. Flashback can occur with which of the following pesticide application methods?
   A. Directed spray
   B. Foliar application
   C. Hatchet injection
   D. Soil incorporation

4. What is one reason to use a directed-spray pesticide application?
   A. To minimize contact with beneficial insects.
   B. To get an evenly distributed application.
   C. To avoid flashback.
   D. All of the above.

5. Cut-stump pesticide treatments are most effective when applied:
   A. Within hours after cutting.
   B. Within days after cutting.
   C. Within weeks after cutting.
   D. Within months after cutting.

6. Pesticides can corrode certain materials from which spray tanks are made.
   A. True
   B. False

7. A spray tank should have:
   A. An opening for filling.
   B. A shut-off before the pump.
   C. A drain plug at the lowest point.
   D. All of the above.

8. To compensate for pump wear, pump flow capacity should ______________ the largest flow required by the nozzles and hydraulic agitation.
   A. Be less than
   B. Be equal to
   C. Be greater than
   D. Not affect

9. All spray pumps are resistant to the corrosive effects of pesticides.
   A. True
   B. False

10. Which of the following formulations requires the most agitation?
    A. Wettable powders
    B. Solutions
    C. Emulsions
    D. Liquids

11. Hydraulic agitation is accomplished by a shaft with paddles in the spray tank.
    A. True
    B. False

12. With paddle agitation, foaming can result if the shaft motor is operated:
    A. Too slow.
    B. Too fast.
    C. Too long.
    D. Too little.

13. With hydraulic agitation, foaming can result if the jet is:
    A. Not operating.
    B. Above the liquid level in the tank.
    C. Below the liquid level in the tank.
    D. All of the above.

14. As liquid moves from the spray tank to the nozzle, the strainer mesh should:
    A. Remain the same.
    B. Become larger.
    C. Become smaller.
    D. Not matter.

15. Strainers within the spray system are cleaned automatically by the movement of the spray solution.
    A. True
    B. False

16. The burst strength of spray system hoses should be greater than the:
    A. Peak operating pressure.
    B. Volume of spray delivered.
    C. Length of the hose.
    D. Temperature during the application.

17. What does the pressure regulator do?

18. Relief valves and pressure unloaders are two types of:
    A. Pressure gauges.
    B. Nozzles.
    C. Pressure regulators.
    D. Hose fittings.

19. Nozzle types are specific to the types of applications.
    A. True
    B. False

20. Low-pressure sprayers and high-pressure sprayers are most efficient if they have the same type of pump.
    A. True
    B. False

21. Low-pressure sprayers are very useful for:

A. Penetrating dense foliage.
B. Delivering dilute pesticide over large areas.
C. Spot treatment.
D. All of the above.

22. High-pressure sprayers can:

A. Provide high volume at high pressure.
B. Penetrate dense foliage.
C. Increase spray drift.
D. All of the above.

23. It is hardest to maintain uniform pressure when using a:

A. Backpack sprayer.
B. High-pressure sprayer.
C. Low-pressure sprayer.
D. Hydraulic sprayer.

24. Tree injectors are most often used with:

A. Insecticides.
B. Fungicides.
C. Herbicides.
D. Rodenticides.

25. Tree injectors treat several trees at the same time.

A. True
B. False

26. Spotguns are used to spray herbicide on the soil at the base of undesirable brush .

A. True
B. False

27. What are the first two tasks when readying sprayers for the new season?

28. If a sprayer breaks down, it is not necessary to wear personal protective equipment while doing repairs.

A. True
B. False

29. After the inside of the spray tank has been rinsed with water, the water should be:

A. Sprayed on any site as long as it has plant material growing on it.
B. Sprayed on any bare soil.
C. Sprayed on a site that appears on the pesticide label.
D. Stored.

30. Granular applicators are designed primarily for:

A. Foliar application.
B. Soil application.
C. Spot application.
D. Basal application.

CHAPTER 4

CALIBRATION

LEARNING OBJECTIVES

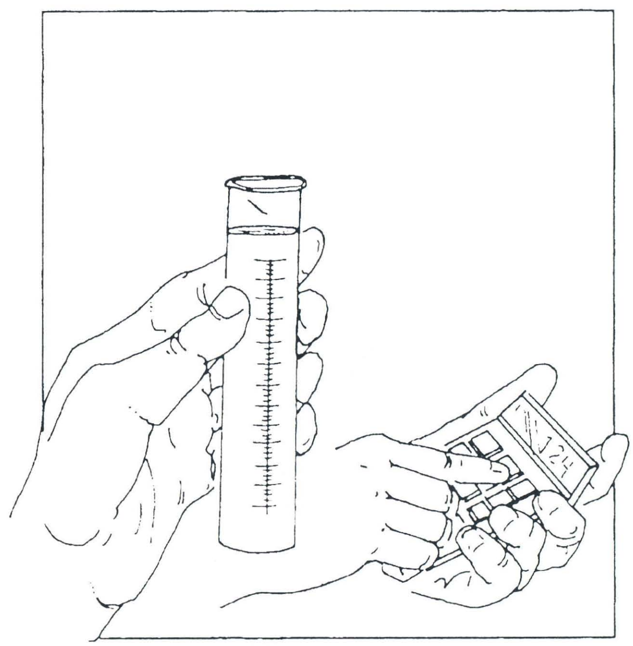
After completely studying this chapter, you should:

- 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 you with the constants rather than go through the complicated calculations from which the constants are derived.

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.

Sprayer pressure (speed constant)	Sprayer output (gallons per acre)
10 psi	10
40 psi	20
160 psi	40

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 sprayer 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.

Sprayer speed (pressure constant)	Sprayer output (gallons per acre)
1 mph	40
2 mph	20
3 mph	13.3
4 mph	10

To determine the new output after changing speed:

$$\text{New output} = \frac{\text{old output x old speed}}{\text{new speed}}$$

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:

Nozzle	Output (ounces per minute)
1	40.0
2	43.0
3	39.5
4	40.5
5	37.5
6	39.5
	Total 240.0 ounces

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:

Broadcast nozzle spacing or band width (inches)	Travel distance (feet)
8	510
10	408
12	340
14	291
16	255
18	227
20	204
22	185
24	170
26	157

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

$$\text{Travel distance (feet)} = \frac{4{,}080}{\text{Nozzle spacing or band width (inches)}}$$

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.

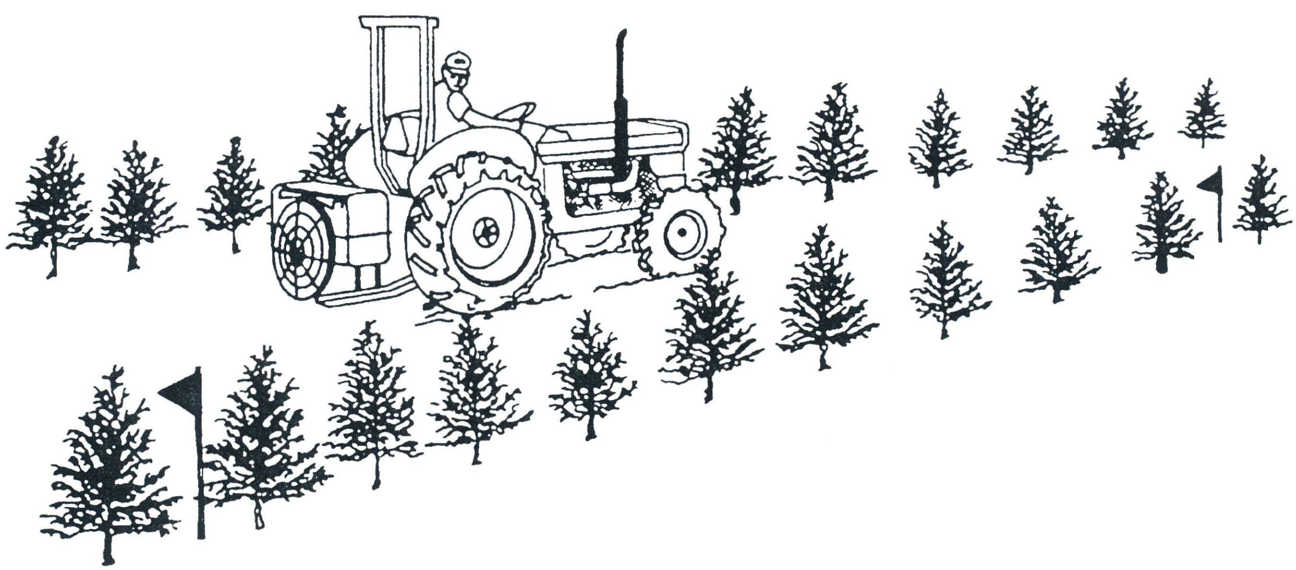


Figure 4.1. For calibration, drive the designated distance using the exact throttle setting and gear that are planned for the broadcast spray application.

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:

Nozzle	Output (ounces per 14 seconds)
1	15.5
2	16
3	15.5
4	16
	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 product 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:

$$\text{Acres per tank} = \frac{\text{tank capacity (gallons per tank)}}{\text{spray rate (gallons per acre)}} = \frac{200}{20} = 10 \text{ acres}$$

2. Determine the amount of pesticide to add to each tank, using the following formula:

   Amount per tank = acres per tank x rate per acre.

   With each tank, you will cover 10 acres and you want to apply 2 quarts of product per acre:

   Amount per tank = 10 x 2 = 20 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 x 180 feet = 27,000 square feet, which is equal to 0.62 acre (27,000 ÷ 43,560)

2. Calculate the amount of water needed with this formula:

   $$\frac{40 \text{ gallons}}{1 \text{ acre}} = \frac{Y \text{ gallons}}{0.62 \text{ acre}}$$

   which is read as "40 gallons is to one acre as Y gallons is to 0.62 acre."

   Y = (40 x 0.62) = 24.8 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.

   $$\frac{24.8 \text{ gallons}}{7 \text{ loads}} = 3.54 \text{ gallons per load}$$

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:

   $$\frac{12 \text{ pounds}}{40 \text{ gallons}} = \frac{Y \text{ pounds}}{3.54 \text{ gallons}} =$$

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

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?

   Volume per 1,000 square feet = volume per 250 square feet x 4 = 0.5 gal x 4 = 2 gallons

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

   $$\text{Amount needed per gallon} = \frac{\text{amount needed per 1,000 square feet}}{\text{volume sprayed per 1,000 square feet}}$$

   $$= \frac{1.5 \text{ ounces}}{2 \text{ gallons}}$$

   = 0.75 ounces per gallon

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

   Amount per tank = tank capacity x amount needed per gallon

   $$= 3 \text{ gallons} \times \frac{0.75 \text{ ounce}}{\text{gallon}}$$

   = 2.25 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:

   If 2 gallons covers 1,000 square feet, then 3 gallons will cover what fraction of 1,000 square feet?

   $$\frac{2 \text{ gallons}}{1{,}000 \text{ square feet}} = \frac{3 \text{ gallons}}{Y}$$

   Solve for Y by cross multiplying:

   2Y = 1,000 x 3

   $$Y = \frac{3{,}000}{2}$$

   Y = 1,500 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?

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

$Y = 43.6$ gallons per acre

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

$$\text{Amount per gallon} = \frac{\text{amount needed per acre}}{\text{volume sprayed per acre}}$$

$$= \frac{48 \text{ ounces*}}{43.6 \text{ gallons}}$$

$= 1.1$ 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?

Amount per tank = tank capacity x amount per gallon
= 4 gallons x 1.1 ounce/gal
= 4.4 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:

43.6 gallons Y = 1 acre x 4 gallons

$$Y = \frac{4 \text{ acres}}{43.6}$$

= 0.092 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*).

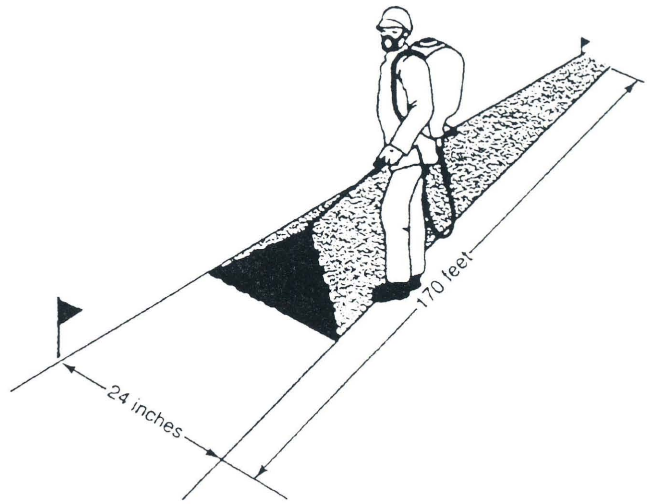


Figure 4.2. Calibration course of a 24-inch band application.

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:

$$\frac{3 \text{ gal. tank}}{16 \text{ GPA (gallons per acre)}} = 0.188 \text{ acre covered per tank}$$

Select the calibration distance to be used on band width			
Band width	Calibration distance	Band width	Calibration distance
10 inches	408 feet	24 inches	170 feet
12 inches	340 feet	28 inches	146 feet
16 inches	255 feet	32 inches	127 feet
18 inches	227 feet	36 inches	113 feet
20 inches	204 feet	40 inches	102 feet

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.

   $$\text{Application rate per acre x acre(s) per tank} = \text{amount of chemical to add to the spray tank}$$

   2 quarts per acre x 0.188 acre per tank = 0.376 qts per tank (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?

$$\frac{\text{4 gallons Pesticide C}}{\text{100 gallons diesel}} = \frac{\text{Y gallons Pesticide C}}{\text{75 gallons diesel}}$$

By cross multiplying:

$$100Y = 75 \times 4$$

$$100Y = 300$$

$$Y = \text{3 gallons of Pesticide C per 75 gallons of diesel fuel}$$

GRANULAR APPLICATOR CALIBRATION

Occasionally, granular or pelleted 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 acre = 0.02 x 43,560 square feet = 871 square feet

$$\text{Travel distance} = \frac{\text{871 square feet}}{\text{Swath width}}$$

Swath width (feet)	Travel distance to cover 1/50 acre (linear feet)
1.5	581
2	436
3	290
4	218
5	174
6	145
7	124
8	109
9	97
10	87
11	79
12	73
15	58

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:

$$\frac{871}{6.5} = 134 \text{ feet}$$

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 pounds) x (1/50) = 1.2 pound x 16 ounces per pound = 19.2 ounces

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

   19.2 ounces x 0.05 (5%) = .96 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
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	1000 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

Review Questions

CHAPTER 4

Chapter 4: Calibration

Write the answers to the following questions and then check your answers with those in the back of the manual.

1. Why is calibration of various spray systems essential?

2. Calibration ensures that the correct amount of pesticide is delivered uniformly over the target area.

   A. True

   B. False

3. What happens to the flow rate if you increase the nozzle pressure or use a larger nozzle tip opening?

   A. Has no effect of the flow rate.

   B. Increases the flow rate.

   C. Decreases the flow rate.

4. To double the flow rate, you must increase the pressure:

   A. Twofold.

   B. Threefold.

   C. Fourfold.

   D. Fivefold.

5. If the throttle setting remains constant, and the speed doubles, the amount of spray per acre:

   A. Remains constant.

   B. Doubles.

   C. Is reduced by half.

   D. Is reduced by one quarter.

6. Measuring and comparing the output of each nozzle to the average output of all the nozzles allows you to determine if:

   A. The pump is functioning properly.

   B. Any nozzle is worn or clogged.

   C. It is the right nozzle for the job.

   D. The pressure is accurate.

7. If the spray pattern is not uniform, you should:

   A. Check the boom height.

   B. Check the spacing and alignment of the nozzles on the boom.

   C. Check the operating pressure.

   D. Do all of the above.

8. You determine the distance to travel for calibration by:

   A. Using a formula with a constant and the nozzle spacing.

   B. Reading it from the pesticide label.

   C. Reading it from the tractor handbook.

   D. Setting an arbitrary distance based on the type of pesticide.

9. Why is there an operating pressure range for each type of nozzle?

   A. To prevent nozzle clogging.

   B. To relieve strain on the pump.

   C. To keep the spray pattern from distorting.

   D. To calculate the travel distance.

10. In a broadcast sprayer calibration, if the nozzle spacing is 30 inches, what is an appropriate distance to stake out in the field?

    A. 101 feet

    B. 136 feet

    C. 256 feet

    D. 1 acre

11. In Question 10, it took 20 seconds to travel the appropriate distance. What does this travel time tell you?

    A. How long you should measure the output from nozzles.

    B. How long it will take to spray the entire field.

    C. How long it will take to empty the tank.

    D. Whether the sprayer is properly calibrated.

12. When calibrating a broadcast sprayer, you find that the average nozzle output is 25 ounces. What is the spray rate in gallons per acre?

    A. 25 gallons per acre
    B. 30 gallons per acre
    C. 35 gallons per acre
    D. 40 gallons per acre

13. What can you do if your calibrated spray rate is less than the recommended rate stated on the label?

    A. Increase the pressure
    B. Decrease travel speed
    C. Increase nozzle tip size
    D. B and/or C

14. In a broadcast sprayer application, if the spray tank capacity is 150 gallons and the spray rate is 30 gallons per acre, how many acres can be sprayed per tank?

    A. 0.2 acres
    B. 0.5 acres
    C. 3 acres
    D. 5 acres

15. In Question 14, how much pesticide will you need to add per tank if the label recommends 4 quarts of product per acre?

    A. 10 quarts
    B. 20 quarts
    C. 30 quarts
    D. 40 quarts

16. Using a 3-gallon backpack sprayer, you decide to apply 9 pounds of herbicide per acre. Your sprayer is calibrated to apply 30 gallons of spray solution per acre. How many tank loads are needed to treat 1 acre, and how many pounds of herbicide are needed in each tank load?

    A. 5 tank loads with 0.3 pounds of herbicide per load
    B. 5 tank loads with 0.9 pounds of herbicide per load
    C. 10 tank loads with 0.3 pounds of herbicide per load
    D. 10 tank loads with 0.9 pounds of herbicide per load

17. How do you determine what rate of pesticide to apply?

    A. Use a formula.
    B. Read it off the spray tank.
    C. Read the pesticide label.
    D. All of the above.

18. When using a hand sprayer:

    A. Maintain the pressure as evenly as possible.
    B. It's not necessary to calibrate.
    C. The speed at which you walk should vary.
    D. It is not possible to do band applications.

19. When calibrating your hand-held single-nozzle sprayer, you found that it delivered 1 gallon of water per 250 square feet. The label recommends that 2 fluid ounces of herbicide be mixed in enough water to cover 1,000 square feet. The spray tank holds 3 gallons. How many fluid ounces of herbicide must be added to a full tank of water, and how much area will one tank of spray cover?

    A. 1 ounce of herbicide and 500 square feet per tank
    B. 1.5 ounce of herbicide and 500 square feet per tank
    C. 1.5 ounce of herbicide and 750 square feet per tank
    D. 2 ounces of herbicide and 1,000 square feet per tank

20. You calibrated your handheld single-nozzle sprayer to spray 0.5 gallon of water over a 300-square-foot test area. What is the sprayer output per acre based on the test area sprayed?

    A. 32.3 gallons per acre
    B. 72.6 gallons per acre.
    C. 108.3 gallons per acre
    D. 123 gallons per acre

21. In Question 20, how many ounces of herbicide are needed per gallon of water if the label recommends 4 pints of herbicide be applied per acre?

    A. 0.88 ounce per gallon
    B. 1.08 ounce per gallon
    C. 1.23 ounce per gallon
    D. 2.1 ounce per gallon

22. If you are using a hand sprayer to apply pesticide in a band 20 inches wide, how far should you walk to calibrate your sprayer and record the number of seconds?

    A. 170 feet
    B. 204 feet
    C. 255 feet
    D. 408 feet

23. In calibrating a hand-held sprayer for a band application, you collected 15 ounces from the nozzle in the time it took to travel the calibration distance. Your spray tank holds 3 gallons. How much chemical should be added to the tank at an application rate of 3 quarts per acre?

A. 3 fluid ounces per tank

B. 6.3 fluid ounces per tank

C. 12.8 fluid ounces per tank

D. 19.2 fluid ounces per tank

24. The flow rate of dry granular pesticide products:

A. Varies because of many factors such as particle size and humidity.

B. Remains constant from product to product.

C. Prevents accurate calibration.

D. Allows for less frequent calibration than liquid products.

25. Which is NOT the same between drop-through spreaders and rotary spreaders?

A. They are used in granular applications.

B. Their calibration depends on factors such as travel speed and particle size.

C. They can be used in weed control.

D. They use catch pans.

26. A broadcast application of granular pesticide is to be made at the rate of 30 pounds of product per acre. Your equipment broadcasts granules in a 10-foot swath. How many feet do you travel to calibrate your spreader?

A. 218 feet

B. 145 feet

C. 87 feet

D. 58 feet

27. In Question 26, a pesticide application is to be made at the rate of 30 pounds of product per acre. What amount of product should be applied to the calibration area?

A. 9.6 ounces

B. 12 ounces

C. 15.3 ounces

D. 19.2 ounces

28. You collected 12 ounces of granules when calibrating the spreader in Question 26. This means that your spreader is properly calibrated.

A. True

B. False

29. Rotary spreaders are more precise than drop-through spreaders in placing pesticides.

A. True

B. False

CHAPTER 5

FOREST TYPES IN MICHIGAN

LEARNING OBJECTIVES

After completely studying this chapter, you should:

- Understand the present state of Michigan forests.
- Know the major pest management tools on which forest managers rely.
- Know the common forest types in Michigan 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 Michigan forests are restricted to certain tree species, distinct types of trees or specific tree associations. By knowing about Michigan 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 Michigan. (Note: Later chapters in this manual will discuss specific pest problems of trees and forests and their management.)

AN OVERVIEW OF MICHIGAN FORESTRY AND FOREST PEST MANAGEMENT

Michigan is a state blessed with an abundance of healthy, productive forestlands. Half of Michigan is forested. As of 1993, there were 18.6 million acres of commercial timberland in the state. Surprisingly, the 1993 Forest Inventory of Michigan revealed that the state had gained 1.1 million acres of timberland since 1980. The survey also revealed that Michigan's forests are generally getting older (the majority of trees are now small sawlog size) and are increasing in volume at a very productive rate. Economically, Michigan forests support 150,000 jobs and add $9 billion to the state's economy.

In addition, Michigan's forests are growing 2.5 times more wood than is being harvested each year. This means that, despite all the timber harvesting that occurs to support Michigan's forest industry, the forests of Michigan are still growing more wood than can theoretically be harvested without damaging the resource. Consequently, because of this excessive growth, a significant number of trees are lost each year to insects, disease and other natural causes. The 1993 Forest Inventory revealed that each year in Michigan approximately 202 million cubic feet of wood are lost to mortality.

Some mortality is natural and to be expected, but forest managers are concerned about insect, disease, and other pest problems that might produce significant growth loss and/or mortality. Because it is rarely economically feasible or environmentally favorable to apply pesticides to large acreage of forestland, forest managers instead concentrate on keeping forests healthy and productive. Healthy and productive trees and forests are much better at withstanding the stress of any pest problems that may occur on a periodic basis. The major pest management tools on which forest managers rely are matching tree species to the site at planting, thinning younger stands of trees to reduce competition, and harvesting overmature forests, which are more susceptible to pests.

FOREST TYPES IN MICHIGAN

The soils, climate, and topography of Michigan are quite diverse. This diversity of site factors results in 10 types of forests (including exotics) that can be found growing in the state. A ***forest type*** is one or more tree 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; midtolerant 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 Michigan forest types are: **maple-beech, aspen-birch, oak-hickory, elm-ash-soft maple,** and **pine.**

The maple-beech forest type is by far the largest forest type in Michigan, covering more than 7 million acres (approximately 38 percent) of land area. The aspen-birch forest type is the next largest and covers more than 2.5 million acres (or approximately 17 percent) of land in the state. The oak-hickory forest type covers about 1.9 million acres, and the elm-ash-soft maple forest type covers another 1.7 million acres of land in Michigan. Jack, red, and white pine are the most common softwood types and together make up more than 10 percent of the timberland (approximately 1.9 million acres). Together, these five forest types account for about 85 percent of the forest cover in Michigan. The remaining 15 percent of timberland is in one of several other forest types—balsam fir/white spruce, black spruce, northern white cedar, tamarack, or exotics such as non-native Scotch pine plantations—or in timberland area without trees.

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

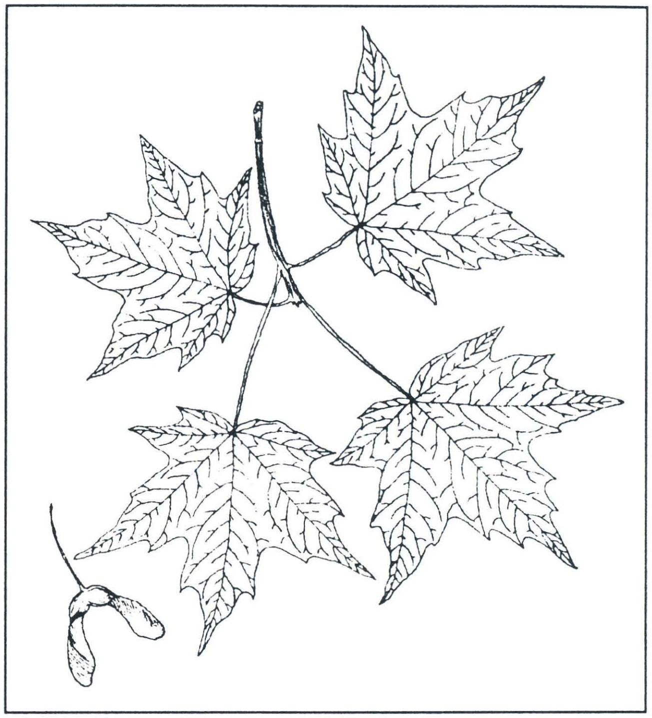


Figure 5.1. Sugar maple.

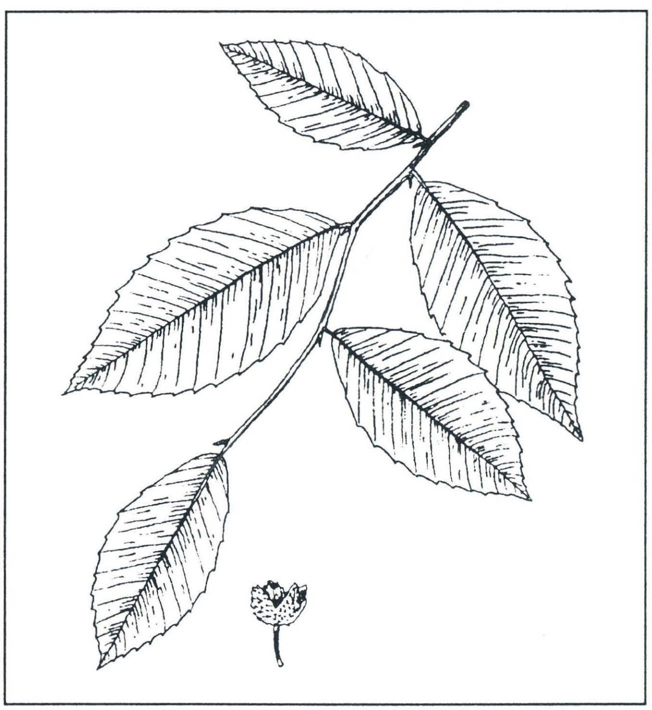


Figure 5.2. Beech.

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 Michigan, 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 overmature stands.

Figure 5.3. Yellow birch.

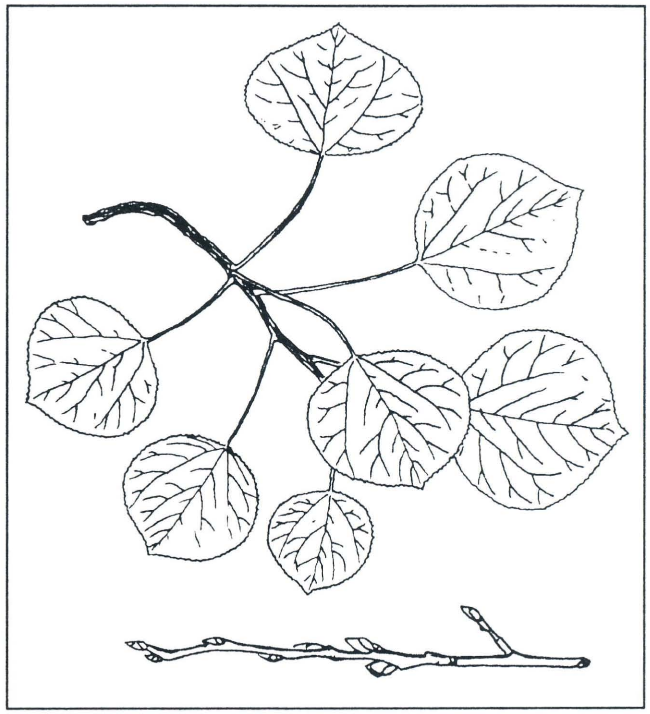


Figure 5.5. Quaking aspen.

Figure 5.4. American basswood.

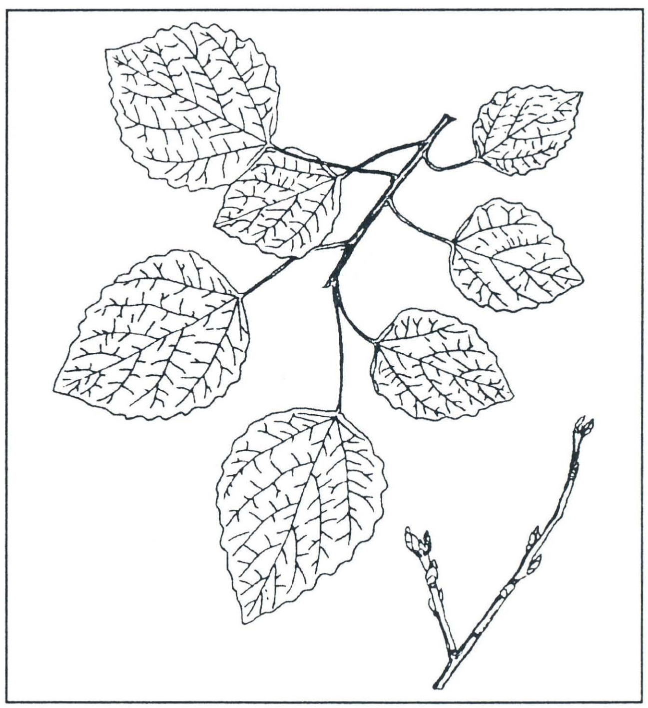


Figure 5.6. Bigtooth aspen.

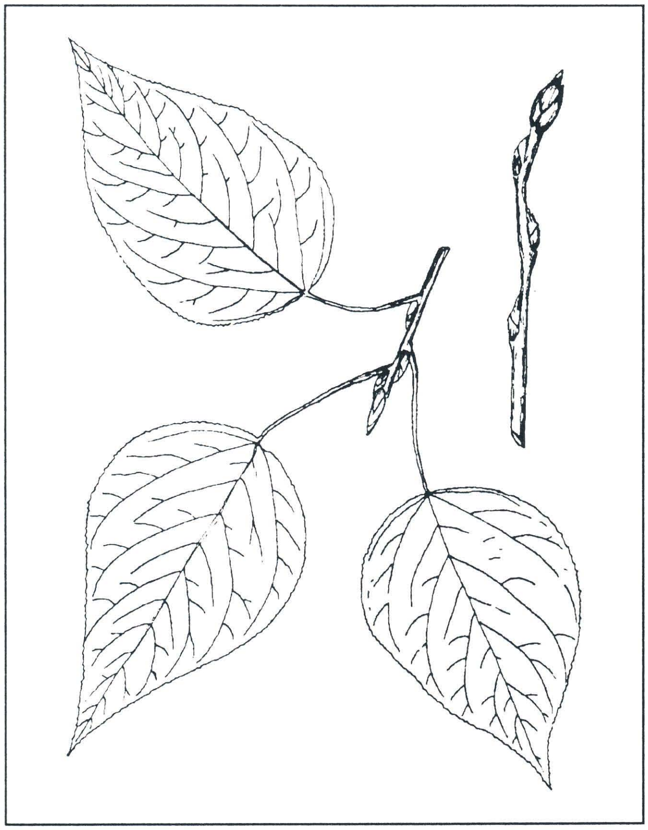


Figure 5.7. Balsam poplar.

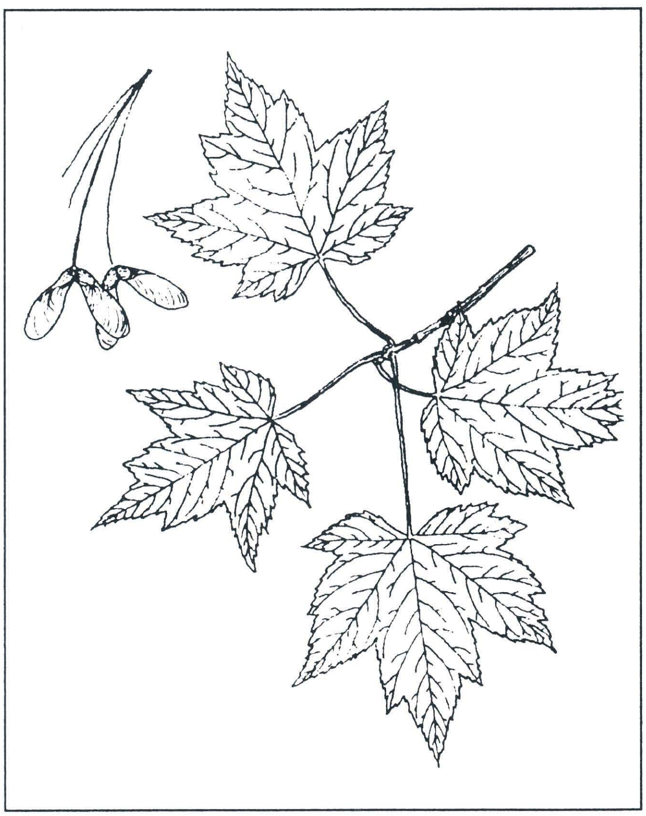


Figure 5.8. Red maple.

Oak-hickory

Oak-hickory forests are those in which northern red oak, white oak, bur oak, and hickories (southern Michigan only) make up a majority of the trees. Common associates include yellow poplar, elm, maple, beech, and jack pine (especially in northern Michigan). 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. Leafrollers, defoliating insects, drought, late spring frosts, and, more recently, gypsy moth 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 oakworm, fall webworm, and several other leaf-feeding insects as well as anthracnose and oak wilt diseases.

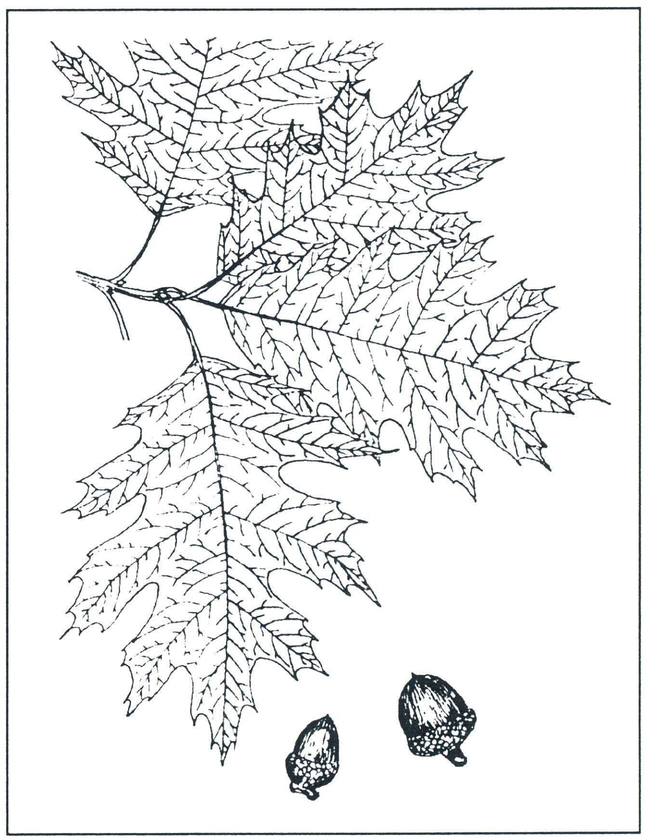


Figure 5.9. Northern red oak.

Figure 5.10. White oak.

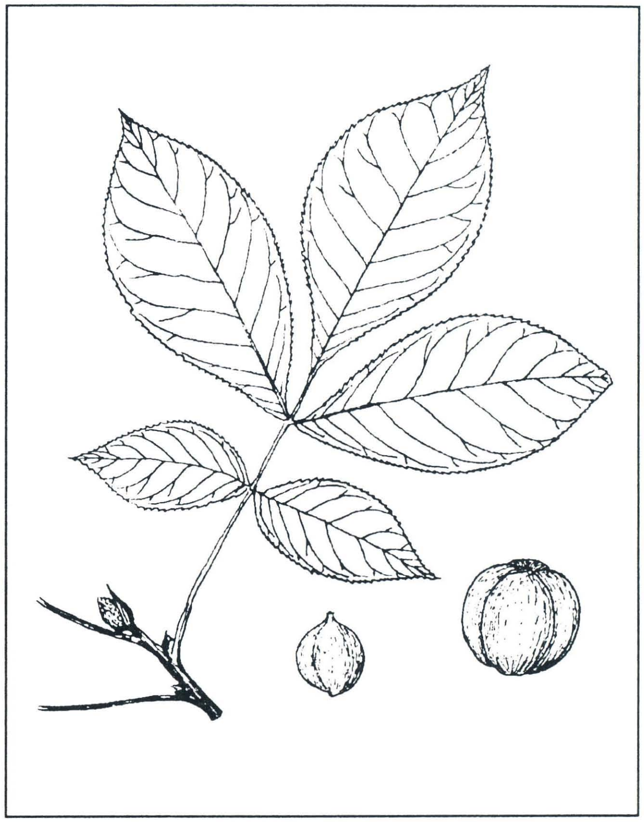


Figure 5.12. Shagbark hickory.

Figure 5.11. Yellow poplar.

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, windthrow 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.

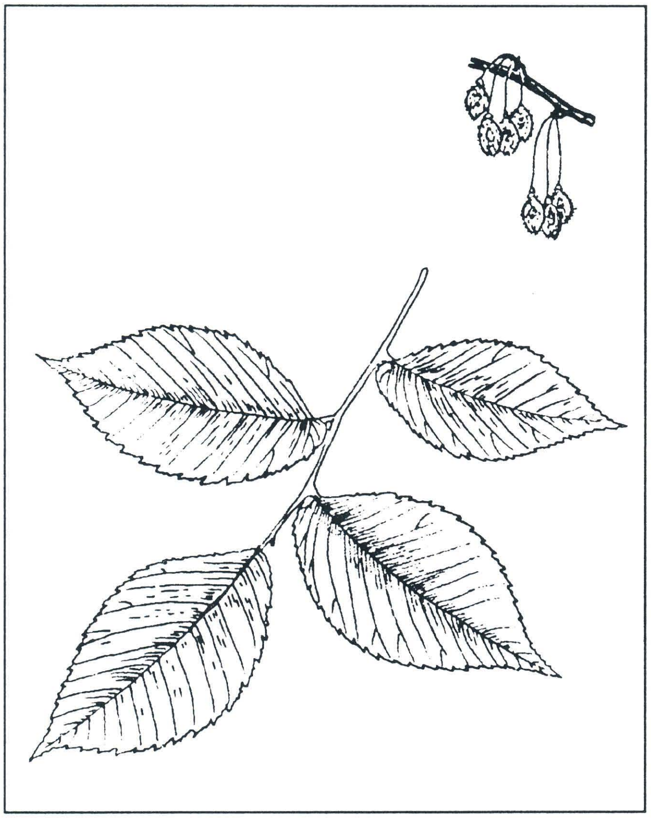


Figure 5.13. American elm.

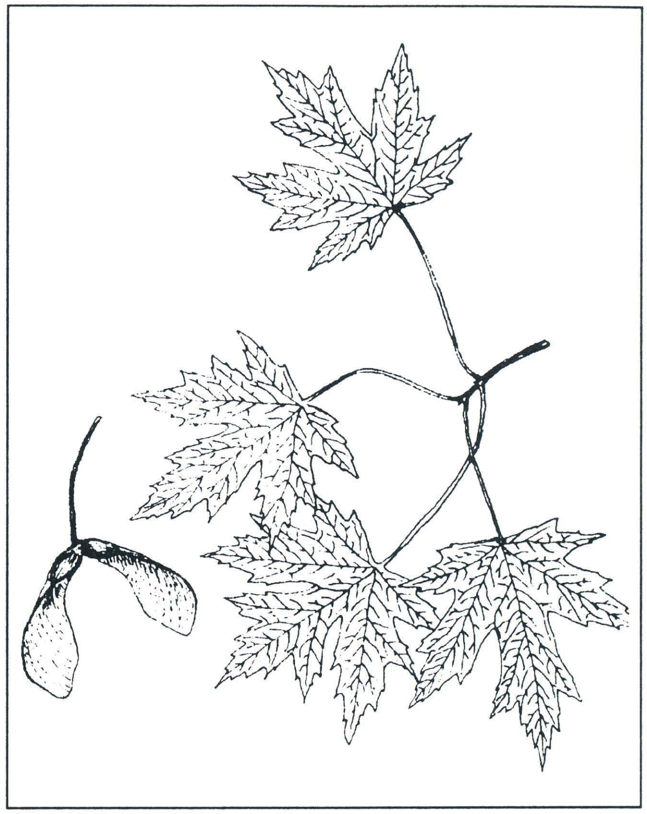


Figure 5.15. Silver maple.

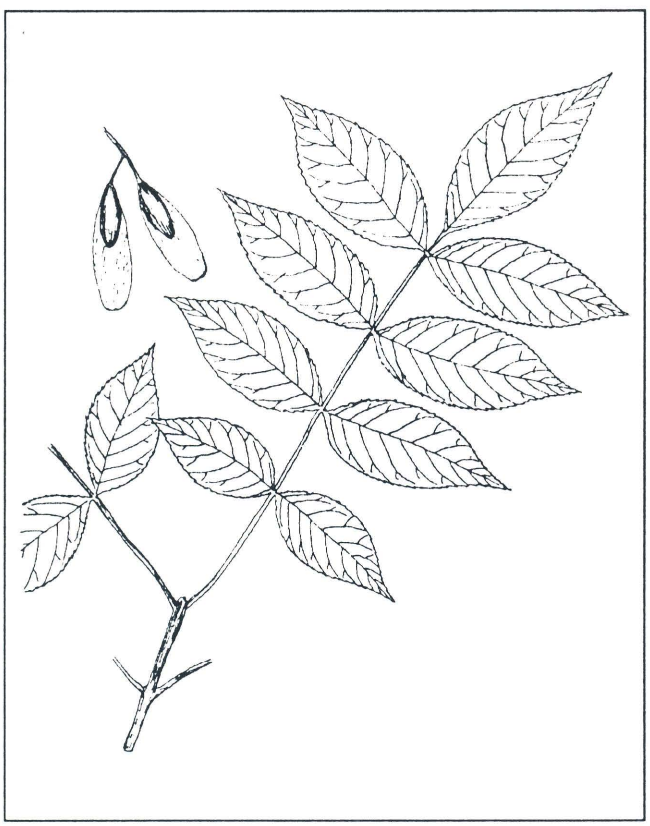


Figure 5.14. Black ash.

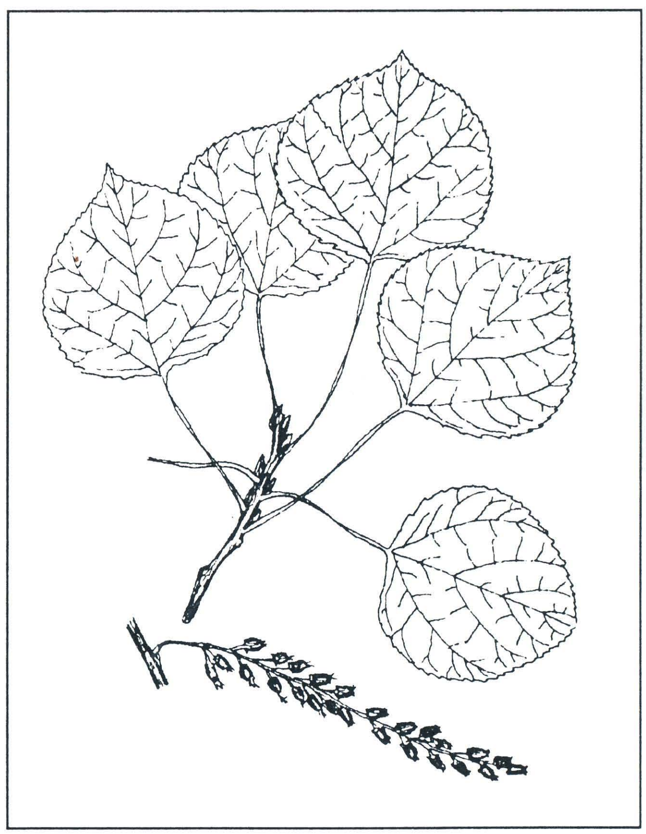


Figure 5.16. Eastern cottonwood.

Pine

The pine forest type is generally dominated by one of three native species of pine. Though all may be found primarily growing on upland, well drained sandy soils throughout Michigan, there is some variability. Jack pine is generally found on the driest of sites on deep, well drained sands. Jack pine is often found growing by itself in pure stands or with common associates including northern pin and black oak, quaking aspen, red maple, and red and white pine. Red pine makes its best growth and development on well drained sandy loam soils. Though there are some native red pine stands, the majority of the red pine in Michigan is growing in man-made plantations, especially in the northern Lower Peninsula. Eastern white pine can be found growing on a wide range of sites, from dry sands to poorly drained soils, in a number of forest types, from jack pine to northern hardwoods to swamp conifers. Occasionally, white pine does grow in fairly pure native stands, but this species has also been widely planted. Because of its midtolerance to shade (i.e., its preference to grow under lightly shaded conditions), 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. Jack pine (especially overmature stands) is attacked by jack 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 needlecast foliage diseases and white pine blister rust to drought and other environmental problems have occasionally caused damage to red and white pine stands.

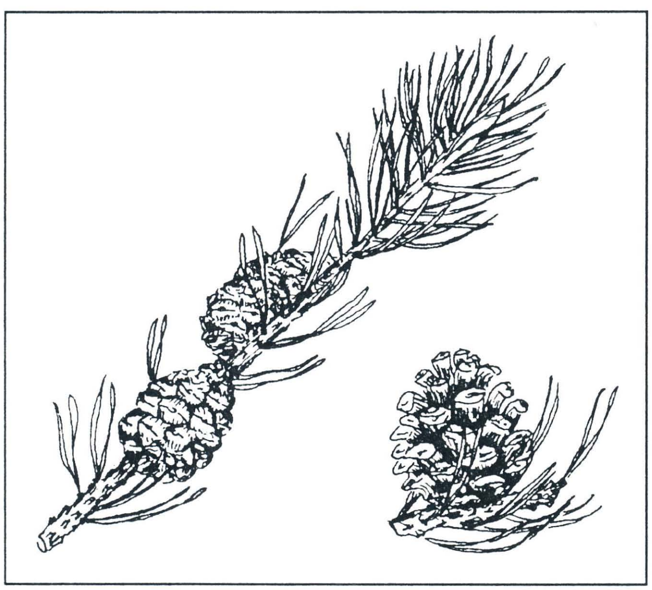


Figure 5.17. Jack pine.

The remainder of the forest types that can be found growing in Michigan 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 needlecast diseases of non-native species such as Scotch pine and Douglas-fir.

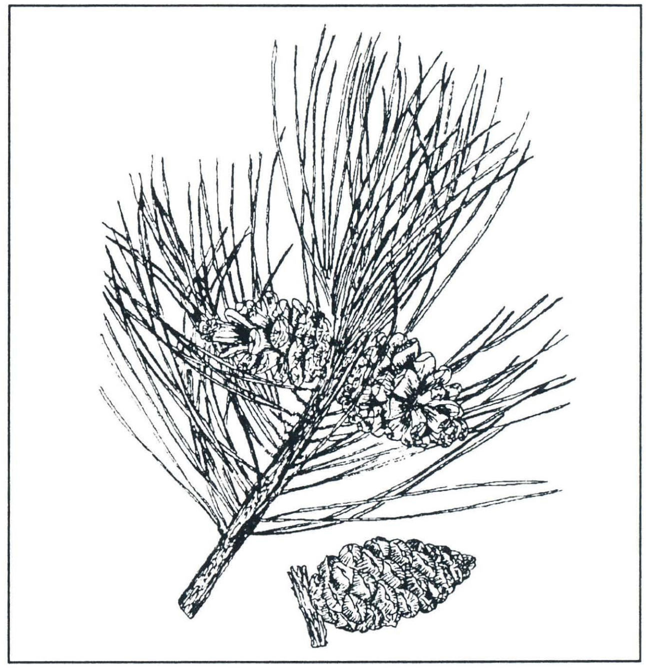


Figure 5.18. Red pine.

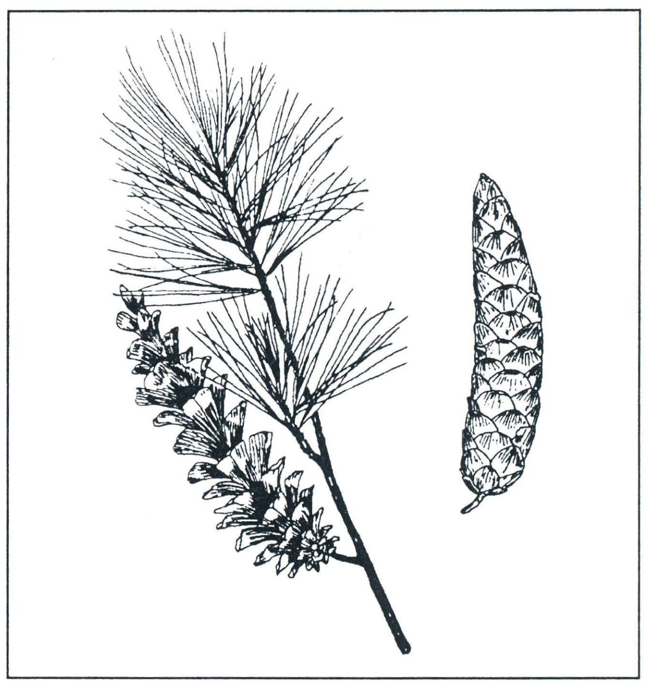


Figure 5.19. Eastern white pine.

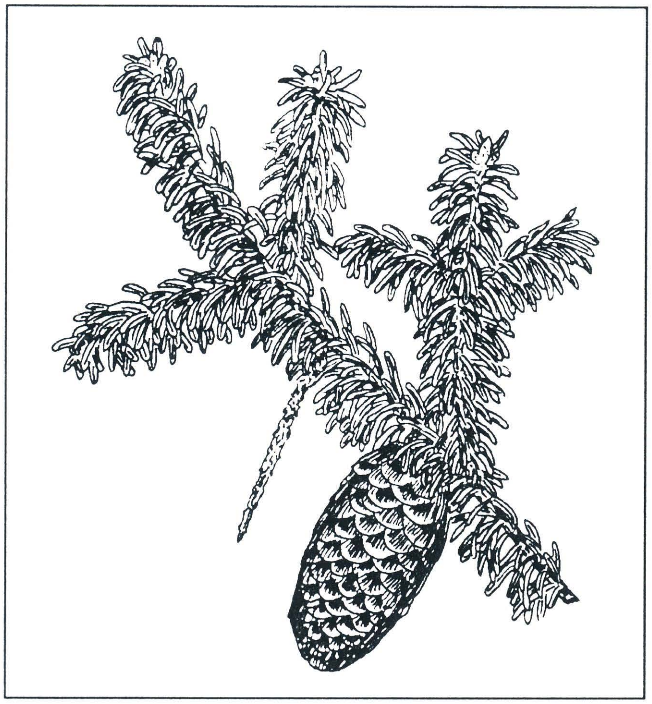


Figure 5.20. Balsam fir.

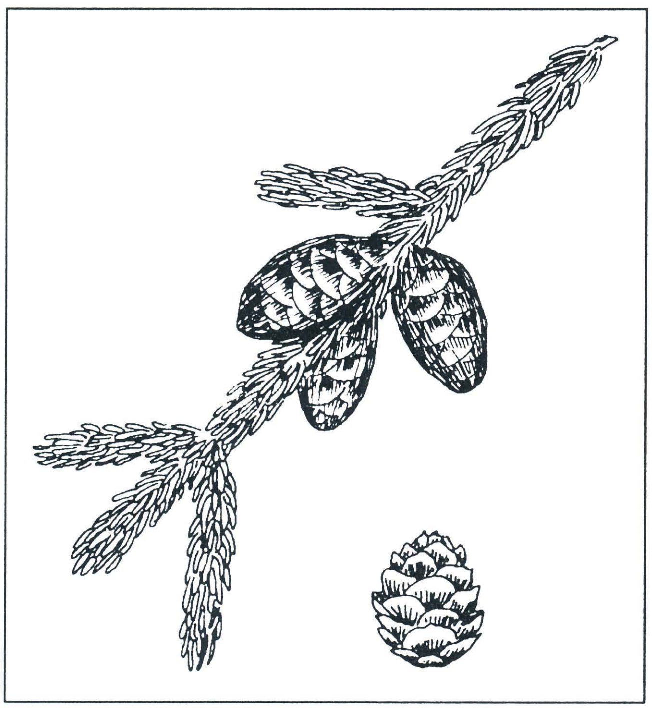


Figure 5.21. Black spruce.

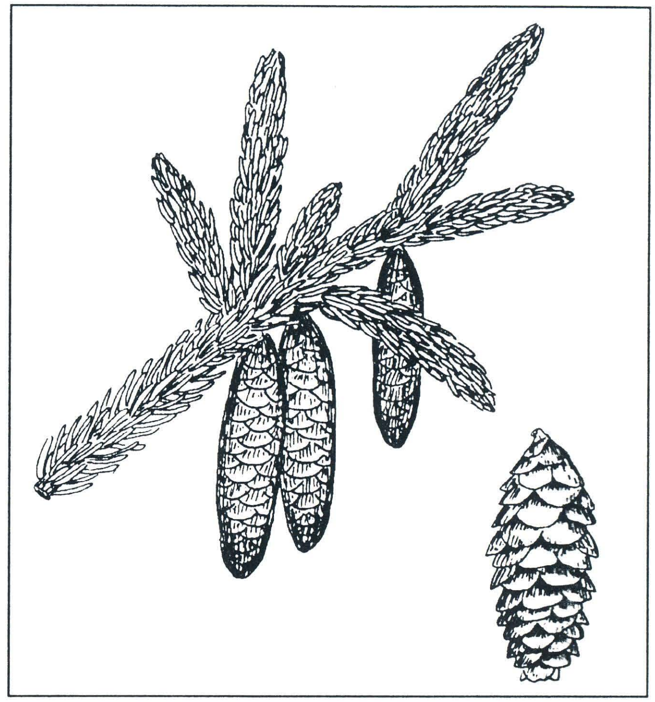


Figure 5.22. White spruce.

Figure 5.23. Northern white cedar.

Review Questions

Chapter 5: Forest Types in Michigan

Write the answers to the following questions and then check your answers with those in the back of the manual.

1. Understanding tree/pest relationships is easier if you have basic knowledge of the habitats and associations of the tree types in your area.

   A. True

   B. False.

2. What percentage of Michigan land is forested?

   A. 15 percent

   B. 25 percent

   C. 50 percent

   D. 75 percent

3. Pests destroy a large amount of timber in Michigan each year because forest growth is:

   A. Declining.

   B. Stable—neither increasing nor declining.

   C. Increasing slightly.

   D. Excessive.

4. IPM in forest situations depends heavily on pesticide use.

   A. True

   B. False

5. One or more tree species growing together because of similar environmental requirements and similar tolerance to light is called a:

   A. Forest type.

   B. Timberland.

   C. Park.

   D. Bog.

6. The most common forest type in Michigan is:

   A. Pine.

   B. Oak-hickory.

   C. Aspen-birch.

   D. Maple-beech.

7. Eighty-five percent of forested land in Michigan is made up of:

   A. Three forest types.

   B. Four forest types.

   C. Five forest types.

   D. Six forest types.

8. *Hypoxylon* canker is a major disease problem in maple-beech forest types.

   A. True

   B. False

9. Maple-beech forests are often called:

   A. Northern hardwoods

   B. Northern softwoods.

   C. Eastern softwoods.

   D. Coniferous.

10. Aspen-birch forest type is restricted to:

    A. Low sites.

    B. Dry sites.

    C. Wet sites.

    D. Both wet and dry sites.

11. The replacement of one plant community with another is called:

    A. Evolution.

    B. Plant succession.

    C. Adaptation.

    D. Resistance.

12. Aspen-birch forest type is considered:

    A. Long-lived.

    B. Short-lived.

    C. Both long- and short-lived.

    D. All of the above.

13. When several pest problems occur in quick succession in the oak-hickory forest type, the effect of the combination of stresses is called:

A. Oak decline.

B. Oak decay.

C. Oak wilt.

D. Oak mortality.

14. Oak-hickory is considered a pest-free forest type.

A. True

B. False

15. Elm-ash-soft maple forest type prefers:

A. Lowlands.

B. High, open sites.

C. Dry, sandy soils.

D. Slopes.

16. Dutch elm disease has had what type of impact on the elm-ash-soft maple forest type?

A. High impact

B. Low impact

C. Moderate impact

D. No impact

17. What characteristics are common to the elm-ash-soft maple forest type?

A. Subject to flooding

B. Shallow rooted

C. High amount of defect

D. All of the above

18. The native pine best adapted to both wet and dry soils in Michigan is:

A. Red pine.

B. Eastern white pine.

C. Jack pine.

D. Pitch pine.

19. Eastern white pine is often found growing as an understory tree because of its tolerance for:

A. Light.

B. Shade.

C. Dry soil.

D. Wet soil.

CHAPTER 6

DISEASE MANAGEMENT

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 manor.
- Understand how knowledge of the life cycle of disease organisms enables proper and timely management decisions.
- Know the silvicultural techniques available for preventing and managing disease.
- Know the important tree diseases in Michigan 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 period of time and considers the stand as a 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.
- Reduction 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 Michigan. 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 MICHIGAN

Within the scope of this chapter, we cannot discuss all of the major forest tree diseases in Michigan. 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.

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

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.

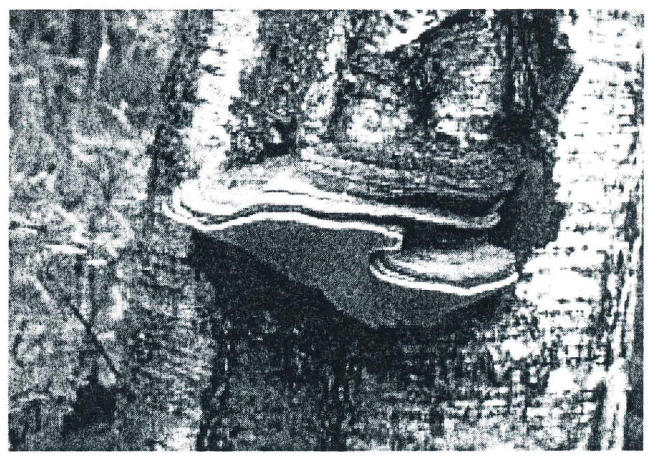


Figure 6.2. Fruiting bodies of *Ganoderma applanatum*, one type of wood decay fungi (T. Laurent, USDA Forest Service, *Forest Pests of North America, Integrated Pest Management Photo CD Series*, 1999, Bugwood and the University of Georgia, Tifton, Ga.).

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, 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.
- Overmature stands appear more susceptible to the disease, so shorter rotations can minimize losses.
- Chemical control is not effective.

Figure 6.3. ***Hypoxylon*** **canker (Minnesota Dept. of Natural Resources,** ***Forest Pests of North America, Integrated Pest Management Photo CD Series,*** **1999, Bugwood and the University of Georgia, Tifton, Ga.).**

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.

Figure 6.4. ***Armillaria*** **fruiting bodies (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.).**

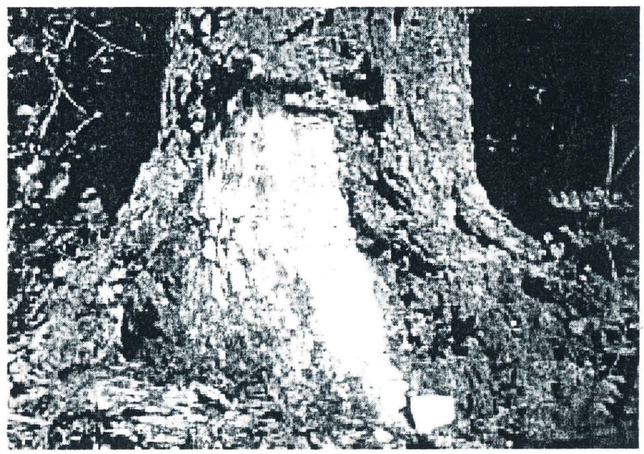


Figure 6.5. ***Armillaria*** **mycelial fan under bark at base of tree (USDA Forest Service Archives,** ***Forest Pests of North America, Integrated Pest Management Photo CD Series,*** **1999, Bugwood and the University of Georgia, Tifton, Ga.).**

Figure 6.6. ***Armillaria*** **rhizomorphs under bark (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.).**

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.

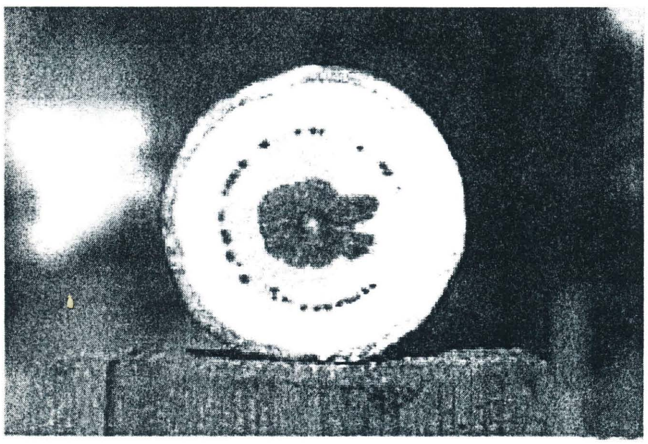


Figure 6.7. Oak wilt discoloration of water-conducting cells in white oak (F.A. Baker, Utah State University, *Forest Pests of North America, Integrated Pest Management Photo CD Series,* 1999, Bugwood and the University of Georgia, Tifton, Ga.).

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.).

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 woodlots, poison adjacent healthy oaks surrounding an oak wilt pocket.

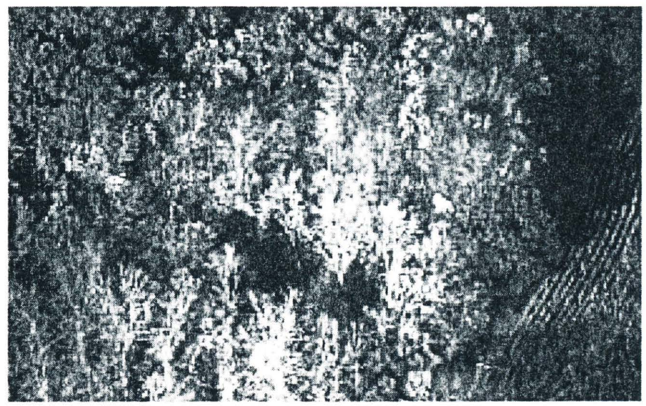


Figure 6.9. Oak wilt mortality center in oak stand (D.W. French, The University of Minnesota, *Forest Pests of North America, Integrated Pest Management Photo CD Series,* 1999, Bugwood and the University of Georgia, Tifton, Ga.).

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.

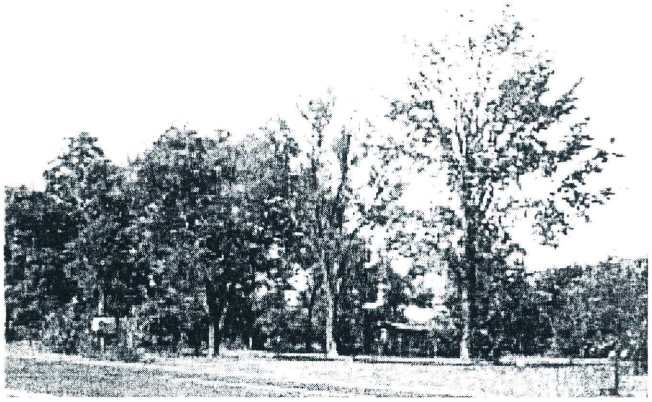


Figure 6.10. Symptomatic trees with Dutch elm disease (J.H. Ghent, USDA Forest Service, *Forest Pests of North America, Integrated Pest Management Photo CD Series,* 1999, Bugwood and the University of Georgia, Tifton, Ga.).

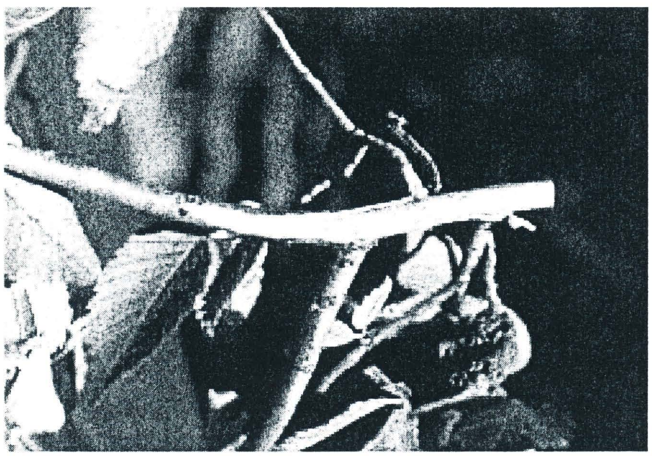


Figure 6.11. Dutch elm disease sapwood stain (J.E. Taylor, USDA Forest Service, *Forest Pests of North America, Integrated Pest Management Photo CD Series,* 1999, Bugwood and the University of Georgia, Tifton, Ga.).

Management strategy:

The best control program uses a combination of the following methods, selected depending on the site and value of the trees:

- Promptly remove and dispose of weakened, dying, and dead elms, elm logs, and elm firewood to eliminate vector breeding sites and pathogen reservoirs.
- Sever connected roots between adjacent healthy and diseased elms by soil fumigation or mechanical trenching.
- Deep-girdle infected trees.
- Apply insecticide to control the bark beetle insect vectors.
- Inject systemic fungicides to prevent or treat disease in individual trees of high value.
- Harvest elms in woodlands.

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.

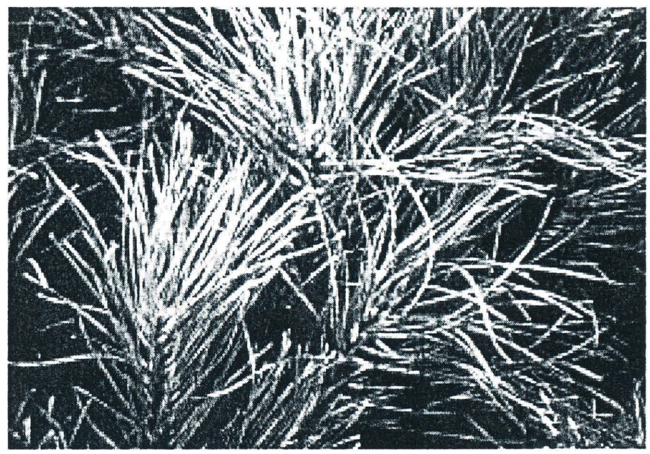


Figure 6.12. *Sclerroderris* canker—orange needle bases found in May and June (Minnesota Dept. of Natural Resources—FIA, Forest Pests of North America, *Integrated Pest Management Photo CD Series,* 1999, Bugwood and the University of Georgia, Tifton, Ga.).

Management strategy:

- 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 undersides of the leaves. Orange masses form on the leaf spots in early summer, followed by brownish, hairlike 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.

Figure 6.13. White pine blister rust—tree with stem canker showing resin flow from bark cracks (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.).

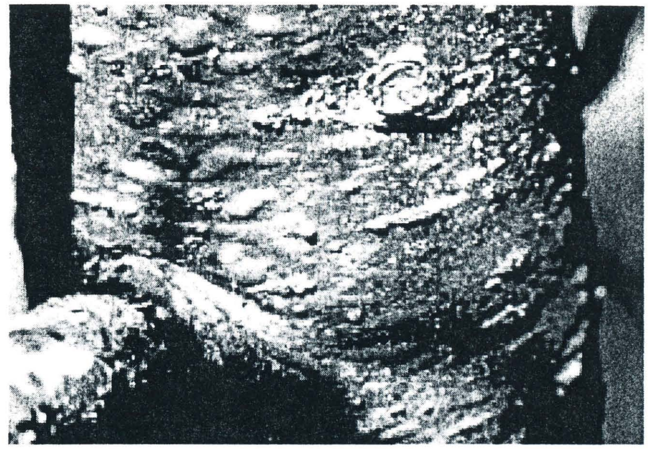


Figure 6.14. White pine blister rust—yellow-orange spores from canker on main stem (R.L. Anderson, USDA Forest Service, *Forest Pests of North America, Integrated Pest Management Photo CD Series,* 1999, Bugwood and the University of Georgia, Tifton, Ga.).

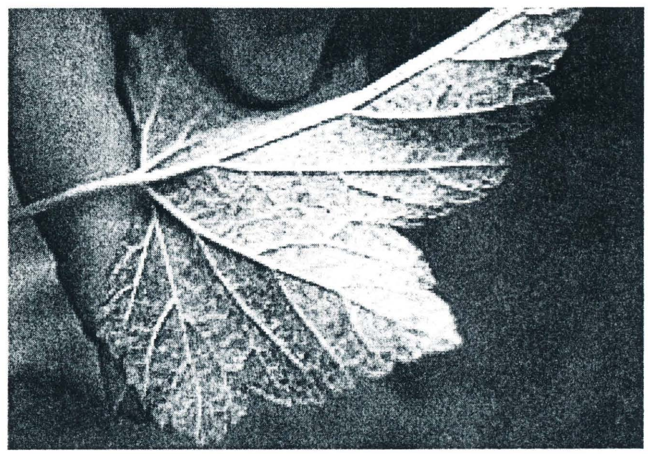


Figure 6.15. White pine blister rust spores on underside of wild currant leaf (R.L. Anderson, USDA Forest Service, *Forest Pests of North America, Integrated Pest Management Photo CD Series, 1999,* Bugwood and the University of Georgia, Tifton, Ga.).

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.

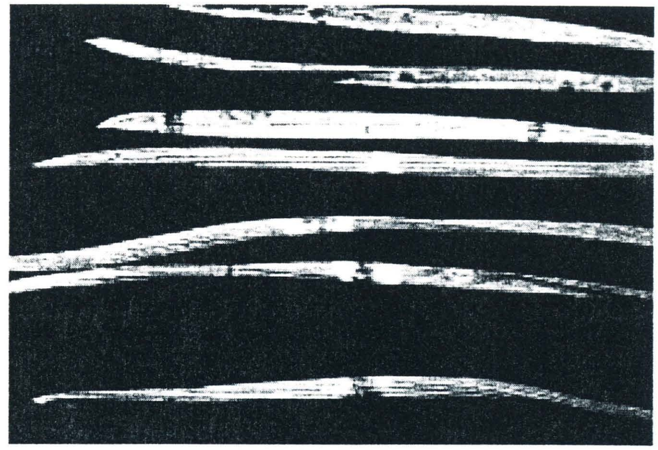


Figure 6.16. ***Lophodermium*** **needlecast—brown spots with yellow margins (R.L. Anderson, USDA Forest Service,** ***Forest Pests of North America, Integrated Pest Management Photo CD Series,*** **1999, Bugwood and the University of Georgia, Tifton, Ga.).**

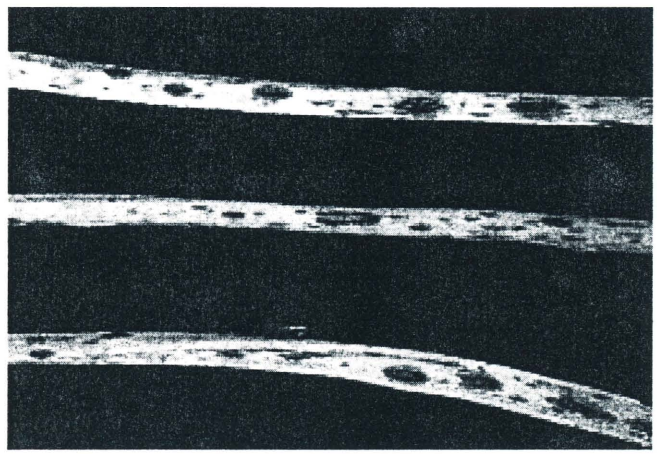


Figure 6.17. ***Lophodermium*** **needlecast—football-shaped fruiting bodies in fall (R.L. Anderson, USDA Forest Service,** ***Forest Pests of North America, Integrated Pest Management Photo CD Series,*** **1999, Bugwood and the University of Georgia, Tifton, Ga.).**

Table 6.2. Christmas tree species and some important diseases.

Christmas Tree Species	Important Diseases
Scotch pine	*Lophodermium* needlecast *Sphaeropsis* (Diplodia) blight
Fraser fir	*Phytophthora* root rot
Douglas-fir	Swiss needlecast, *Rhabdocline*
White spruce, Blue spruce	*Rhizosphaera* needlecast

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.

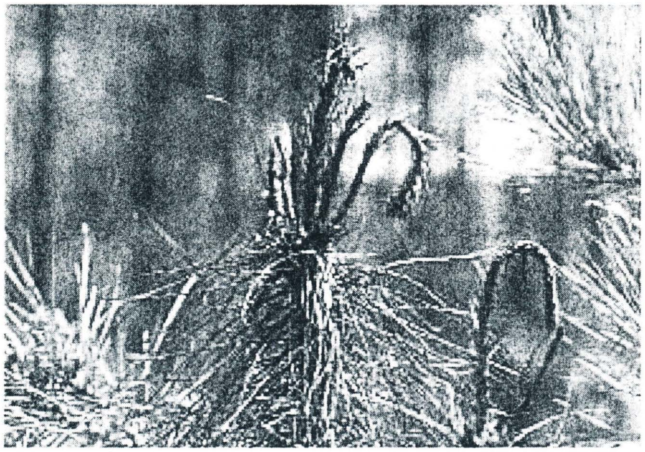


Figure 6.18. Curled branch end of young red pine from *Sphaeropsis* blight (C.J. Randall, Michigan State University).

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.

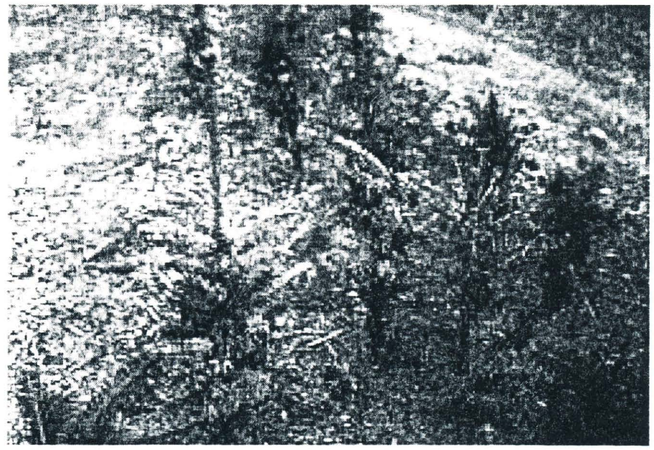


Figure 6.19. *Phytophthora* root disease on Fraser fir (R.L. Anderson, USDA Forest Service, *Forest Pests of North America, Integrated Pest Management Photo CD Series,* 1999, Bugwood and the University of Georgia, Tifton, Ga.).

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 porelike openings (stomata) on the undersides of the needles.

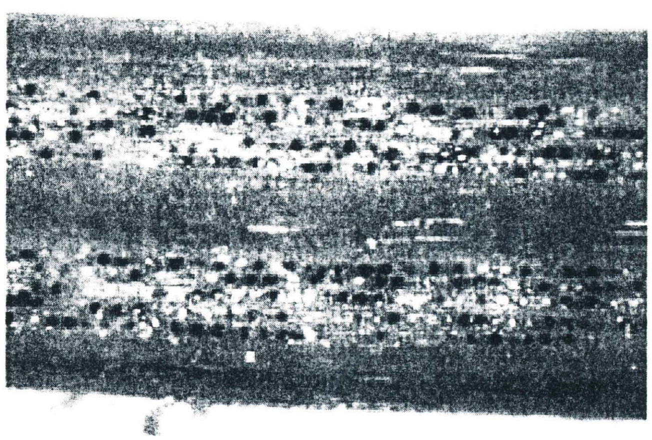


Figure 6.20. Swiss needlecast—close-up view of infected needle (USDA Forest Service Archives, Forest Pests of North America, Integrated Pest Management Photo CD Series, 1999, Bugwood and the University of Georgia, Tifton, Ga.).

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 purple-brown by July/August. The lower portions of the tree generally show the most brown needles, which drop off by late fall.

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.

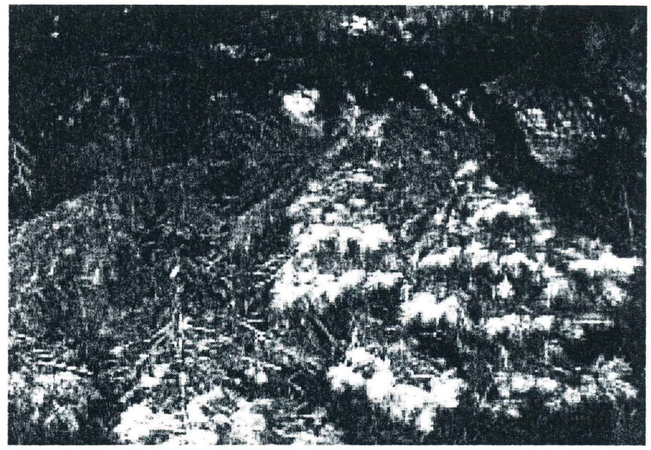


Figure 6.22. *Rhizosphaera* needlecast symptoms showing typical pattern/color (Minnesota Dept. of Natural Resources—FIA, *Forest Pests of North America, Integrated Pest Management Photo CD Series,* 1999, Bugwood and the University of Georgia, Tifton, Ga.).

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 soilborne 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 soilborne 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.

CHAPTER 6

Review Questions

Chapter 6: Disease Management

Write the answers to the following questions and then check your answers with those in the back of the manual.

1. The primary causes of disease in trees are pathogens and:

   A. Insects.

   B. Nematodes.

   C. Environmental factors.

   D. Fungicides.

2. Trunk rots are caused by:

   A. Parasitic higher plants.

   B. Fungi.

   C. Bacteria.

   D. Viruses.

3. If a tree is severely damaged by a windstorm, can it be called diseased?

   A. True

   B. False

4. In general, tree diseases are:

   A. Easier to prevent than to control.

   B. Easier to control than prevent.

   C. Impossible to treat.

   D. Impossible to prevent.

5. The difference in the way tree diseases are managed in a forest and a Christmas tree plantation is based on the ______________ of the individual trees.

   A. Value

   B. Height

   C. Condition

   D. Shape

6. Chemical control measures must never be applied before tree disease symptoms are visible.

   A. True

   B. False

7. What is the most important principle in forest disease management? List some silvicultural methods for achieving this objective.

8. Vigorous early growth of trees in a plantation assures satisfactory long-term development.
   A. True
   B. False

9. What is the fist step in forest disease management?
   A. Conduct a disease survey.
   B. Thin out the stand.
   C. Use prescribed burning.
   D. Control weeds.

10. A canker disease is usually found in the:
    A. Leaves of a tree.
    B. Bark of the tree.
    C. Heartwood of the tree.
    D. Feeder roots of the tree.

11. Canker disease is usually caused by:
    A. A virus.
    B. A bacterium.
    C. A fungus.
    D. A nematode.

12. Canker diseases not only disfigure a tree, they also create entry points for:
    A. Lightning strikes.
    B. Wood decay.
    C. Leaf-spotting organisms.
    D. Beneficial insects.

13. The best way to avoid decay in northern hardwoods is to avoid _______ the trees.
    A. Overfertilizing
    B. Wounding
    C. Pruning
    D. Spraying

14. The spores that spread wood decay fungi are shed from:
    A. Buds.
    B. Cambium.
    C. Barrier zone.
    D. Fruiting bodies.

15. If you come upon a stand of trees where many trunks have broken off at the point of a canker and the bark shows alternating light and dark bands when sliced open, the trees are most likely:
    A. Aspen
    B. Maple.
    C. Pine.
    D. Oak.

16. The fungus causing *Armillaria* root rot can live on in the stump even after the infected tree is cut down.
    A. True
    B. False

17. The brown, stringy fungus "shoestrings" that give *Armillaria* root rot the nickname shoestring root rot can be found in an infected tree along the roots and:
    A. In the heartwood.
    B. In the fruiting bodies.
    C. On the twigs.
    D. Under the bark.

18. Which is NOT true concerning oak wilt?
    A. It kills trees by plugging water-conducting cells.
    B. Spread by insects is most serious in late spring and early summer.
    C. Once established, the disease spreads quickly via root grafts.
    D. White and bur oaks are more susceptible than red or black oaks.

19. Which disease management strategy will help control oak wilt?
    A. Use systemic fungicides on infected trees.
    B. Prune out diseased branches.
    C. Sever root grafts and remove and destroy all diseased trees.
    D. Eradicate *Ribes* spp. in the area.

20. What are the diagnostic symptoms of Dutch elm disease?

21. How is Dutch elm disease transmitted?

A. Elm bark beetles and wind-blown spores

B. Elm bark beetles and underground root grafts

C. Underground root grafts and wind-blown spores

D. Elm bark beetles only

22. Use of systemic fungicides to control Dutch elm disease is justified when trees are of high value.

A. True

B. False

23. Which is NOT true of *Scleroderris* canker?

A. Red, jack, and Scotch pines are the most important hosts.

B. Infected needles turn orange at the base during early May.

C. Cankers form on infected twigs, branches, and trunks.

D. It's found mainly in older, mature plantations.

24. Fungicides are not useful for control of *Scleroderris* canker.

A. True

B. False

25. Which is NOT a disease management strategy for control of *Scleroderris* canker?

A. Burn or bury infected trees.

B. Plant in open areas.

C. Avoid low sites with poor air drainage.

D. Protect from frost injury.

26. What is the alternate host for white pine blister rust?

A. Wild currant

B. Raspberry

C. Elderberry

D. Juniper

27. Which is NOT a control for white pine blister rust?

A. Eradicate alternate host.

B. Prune out branch galls from high-value trees.

C. Plant disease-resistant trees.

D. Sever connected roots.

28. What are the symptoms of white pine blister rust on pine? What are the alternate host's symptoms?

29. Where would you least likely rely on chemicals to control tree disease?

A. Forest nursery

B. Seed orchard

C. Christmas tree plantations

D. Forest stands

30. Which disease causes needles of spruce to turn purplish brown and fall prematurely?

A. *Lophodermium* needlecast

B. *Sphaeropsis* blight

C. *Phytophthora* root rot

D. *Rhizosphaera* needlecast

31. Which Christmas tree disease causes brown spots with yellow margins on the needles with needles turning 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, tiny black, football-shaped fruiting bodies with a lengthwise slit down the middle form on the dead needles.

A. *Lophodermium* needlecast

B. *Sphaeropsis* blight

C. Swiss needlecast

D. *Rhizosphaera* needlecast

32. Which Christmas tree disease is associated with wet soils and poor drainage? Infection causes a reddish brown decay of rootlets as well as larger woody roots.

A. Swiss needlecast

B. *Sphaeropsis* blight

C. *Phytophthora* root rot

D. *Rhabdocline* needlecast

33. Which Christmas tree disease causes browning and early needle loss? Yellow spores appear on infected needles in the fall. In spring, spotted needles turn yellowish brown to reddish brown.

A. Swiss needlecast

B. *Sphaeropsis* blight

C. *Phytophthora* root rot

D. *Rhabdocline* needlecast

34. Which Christmas tree disease causes browning and early needle loss? One to three years after infection, needles turn yellow-green mottled with brown or entirely brown before falling.The black, fuzzy fruiting bodies of the fungus are visible in the rows of porelike openings (stomata) on the undersides of the needles.

A. Swiss needlecast

B. *Sphaeropsis* blight

C. *Phytophthora* root rot

D. *Rhabdocline* needlecast

35. Which Christmas tree disease kills current-year shoots of Scotch, Austrian, and red pine? 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.

A. Swiss needlecast

B. *Sphaeropsis* blight

C. *Phytophthora* root rot

D. *Rhabdocline* needlecast

36. Which would NOT be a good cultural control method for preventing fungal diseases of Christmas trees?

A. Plant disease-free nursery stock.

B. Select disease-resistant varieties.

C. Control weeds on the site.

D. Shear trees when needles are wet.

37 - 40. Match the following forest nursery chemical control methods to the appropriate description.

A. Soil fumigation

B. Seed treatment

C. Soil drenches

D. Foliar applications

_____ 37. 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.

_____ 38. Used in forest nurseries to suppress soilborne plant pathogens in seed and transplant beds. Effective as preventative treatments.

_____ 39. Requires a special pesticide certification standard. May be used to eradicate the pathogen.

_____ 40. Protection/prevention of fungal diseases with the use of sprays.

41. What are the methods for preventing or postponing disease resistance to fungicides other than following the label directions?

CHAPTER 7

INSECT MANAGEMENT

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 Michigan, 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.

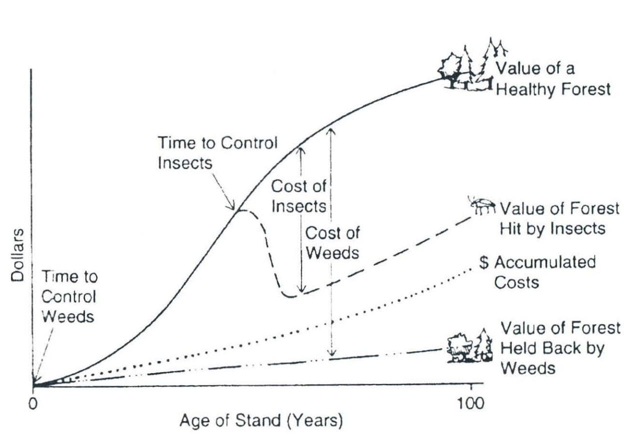
All species of trees are affected by a complex of insect pests. Every part of a tree—its roots, trunk, branches, twigs, buds, leaves, needles, cones, and seeds—may be fed upon by insects. Insects may attack trees of any age. The types of insect pests affecting a specific tree will depend on the age,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

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

SOME COMMON FOREST INSECT PESTS IN MICHIGAN

Within the scope of this chapter, we cannot discuss all of the major insect forest pests in Michigan. 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 refoliate 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.

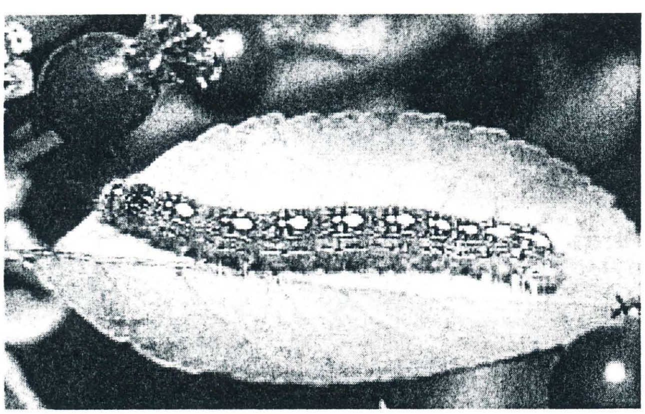


Figure 7.1. Larva of forest tent caterpillar (K.E. Gibson, USDA Forest Service, *Forest Pests of North America, Integrated Pest Management Photo CD Series,* 1999, Bugwood and the University of Georgia, Tifton, Ga.).

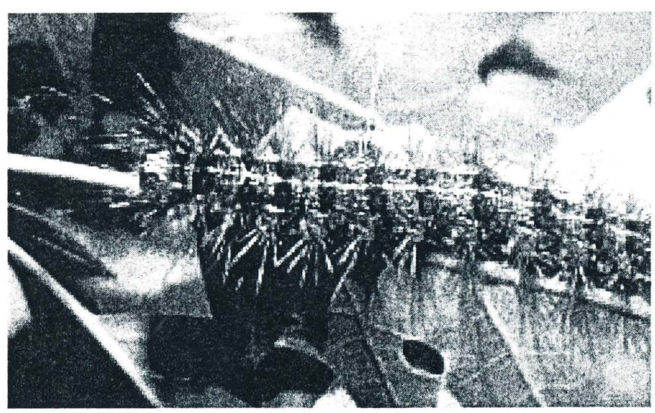


Figure 7.2. Gypsy moth larva on leaf (J.H. Ghent, USDA Forest Service, *Forest Pests of North America, Integrated Pest Management Photo CD Series,* 1999, Bugwood and the University of Georgia, Tifton, Ga.).

Figure 7.3. Gypsy moth adult female (R.S. Kelley, Vermont Dept. of Parks and Forests, *Forest Pests of North America, Integrated Pest Management Photo CD Series,* 1999, Bugwood and the University of Georgia, Tifton, Ga.).

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.

Figure 7.4. Larva and galleries of two-lined chestnut borer (R.A. Haack, USDA Forest Service).

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.

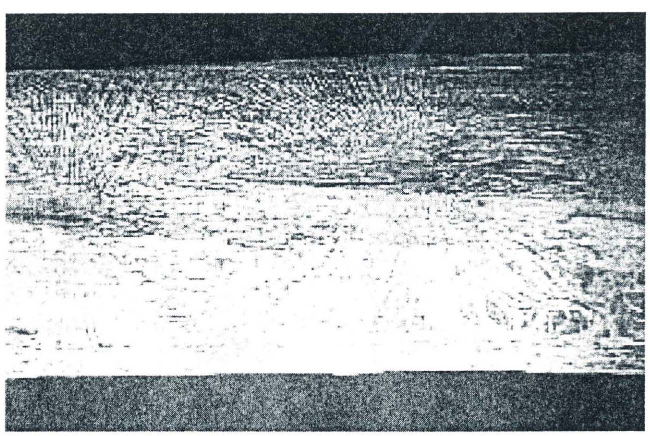


Figure 7.5. The egg-laying galleries of European elm bark beetles run parallel to the wood grain (C. DiFonzo, Michigan State University).

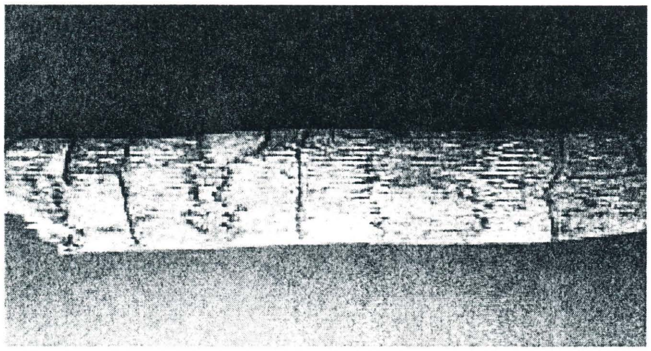


Figure 7.6. The egg-laying galleries of native elm bark beetles run perpendicular to the wood grain (C. DiFonzo, Michigan State University).

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.

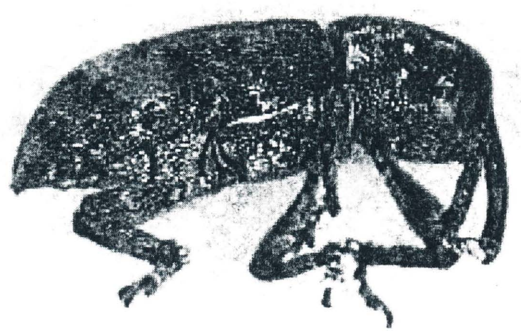


Figure 7.7. White pine weevil adult (E.B. Walker, Vermont Department of Forests, Parks & Recreation, *Forest Pests of North America, Integrated Pest Management Photo CD Series,* 1999, Bugwood and the University of Georgia, Tifton, Ga.).

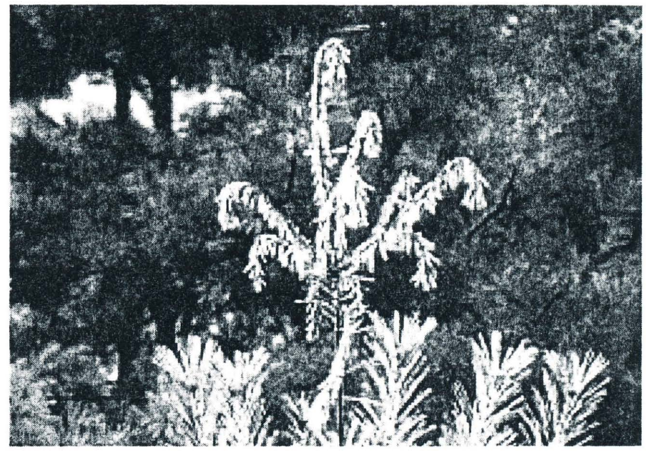


Figure 7.8. White pine weevil damage to terminal (E.B. Walker, Vermont Department of Forests, Parks & Recreation, *Forest Pests of North America, Integrated Pest Management Photo CD Series, 1999,* Bugwood and the University of Georgia, Tifton, Ga.).

Management strategy:

- Plant densely so that damaged trees quickly reestablish dominance.
- Plant below an overstory 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 overmature or low-vigor trees. Significant growth loss and topkill also occur.

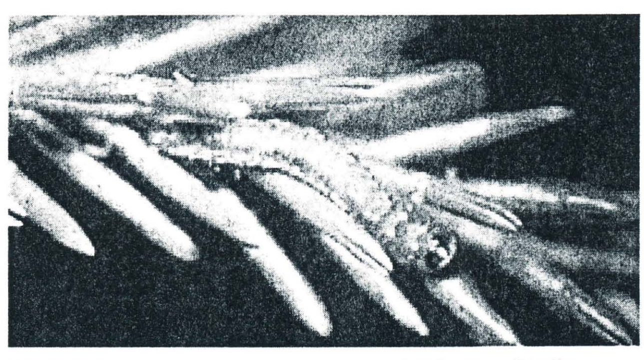


Figure 7.9. Late instar of jack pine budworm (B. Conway, Michigan State University).

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 to110 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.

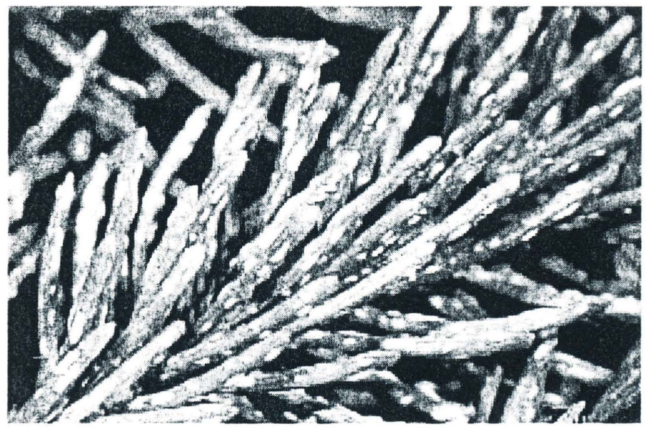


Figure 7.10. Pine needle scale infestation (J.B. Hanson, USDA Forest Service, *Forest Pests of North America, Integrated Pest Management Photo CD Series,* 1999, Bugwood and the University of Georgia, Tifton, Ga.).

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.

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

- 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

Grublike 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.

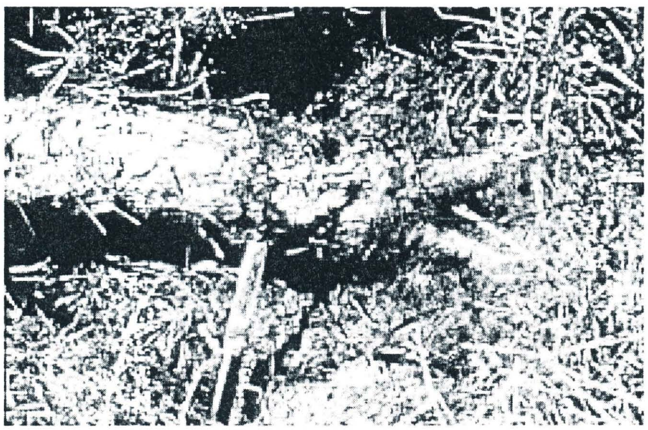


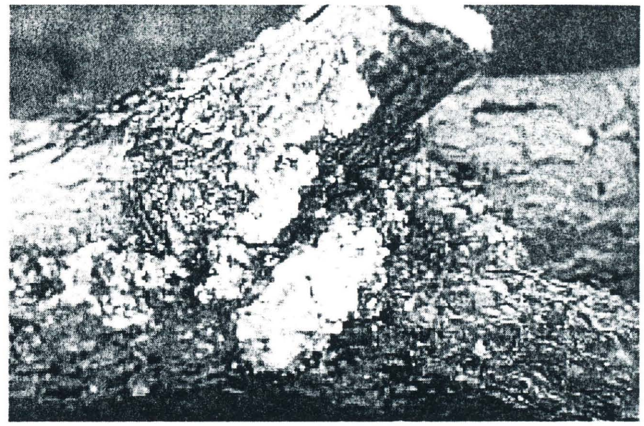
Figure 7.11. Damage by pine root collar weevil on Scotch pine.

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, 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 (D. McCullough, Michigan State University).

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.

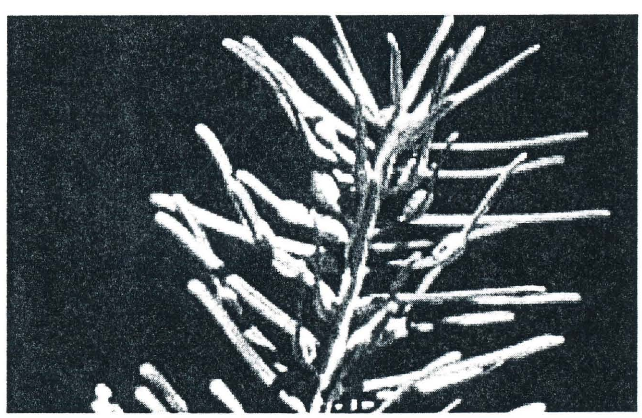


Figure 7.13. Needle galls caused by balsam gall midge on fir.

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.

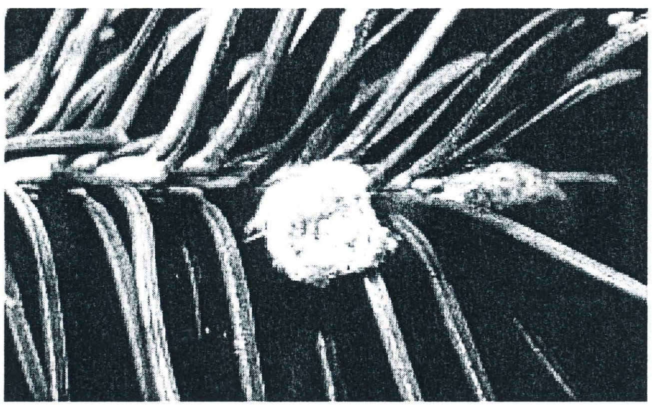


Figure 7.14. Cooley spruce gall adelgid egg mass (P.C. Johnson, USDA Forest Service, Parks & Recreation, *Forest Pests of North America, Integrated Pest Management Photo CD Series,* 1999, Bugwood and the University of Georgia, Tifton, Ga.).

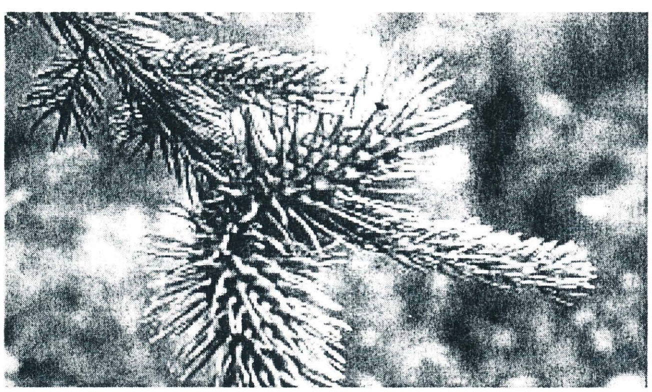


Figure 7.15. Cooley spruce gall adelgid galls on spruce (K.E. Gibson, USDA Forest Service, Parks & Recreation, *Forest Pests of North America, Integrated Pest Management Photo CD Series,* 1999, Bugwood and the University of Georgia, Tifton, Ga.).

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.

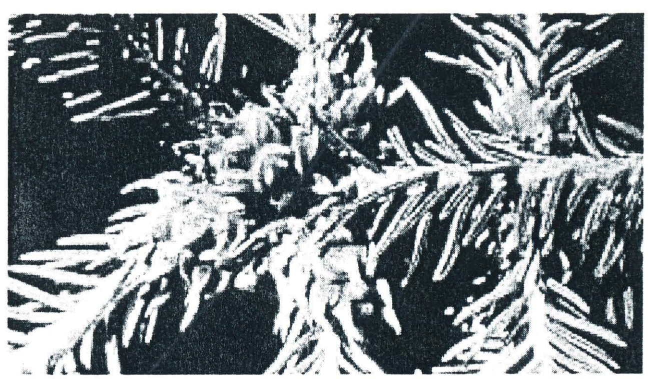


Figure 7.16. Galls on white spruce caused by eastern spruce gall adelgid.

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 webbing 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.

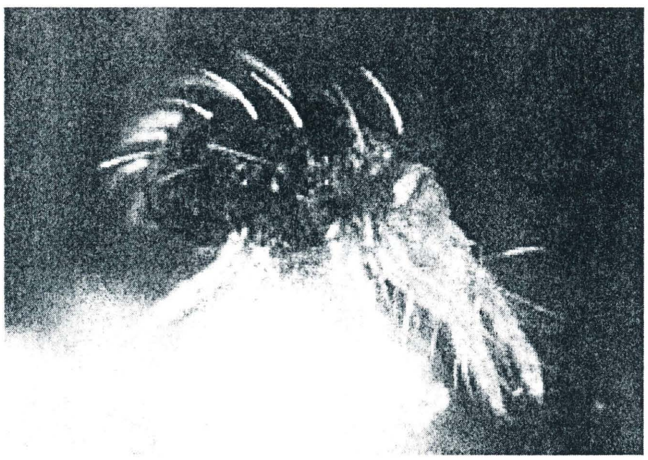


Figure 7.17. Adult spruce spider mite.

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.

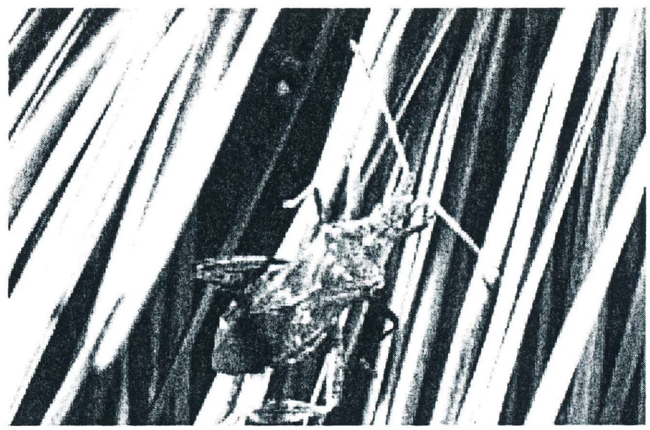


Figure 7.18. Leaffooted pine seed bug adult (L.R. Barber, USDA Forest Service, Parks & Recreation, *Forest Pests of North America, Integrated Pest Management Photo CD Series,* 1999, Bugwood and the University of Georgia, Tifton, Ga.).

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.

CHAPTER 7

Review Questions

Chapter 7: Insect Management

Write the answers to the following questions and then check your answers with those in the back of the manual.

1. What steps should be taken before making a decision about the control of a forest insect pest?

2. What is meant by the economic threshold when controlling forest insect pests?

   A. The pest population level at which it becomes economically beneficial to apply control measures.

   B. The pest population level at which controls are no longer a viable alternative.

   C. The market value of the stand and the overall stand condition.

   D. The market value of the stand and the average age class.

3. The environment applies many pressures—i.e., natural controls—that limit the abundance or distribution of pest species.

   A. True

   B. False

4. Give an example of a natural biotic control.

5. Give an example of a natural abiotic control.

6-14. Match the following applied control methods to the example given.

A. Regulatory control
B. Mechanical control
C. Cultural control
D. Biological control
E. Chemical control

_____ 6. Inspection of plant materials.
_____ 7. Introduction of new natural enemies from the original home of a foreign pest species.
_____ 8. Proper site and species selection.
_____ 9. Spraying in late May to control balsam gall midge on balsam and Fraser firs.
_____ 10. Establishment and enforcement of quarantines.
_____ 11. Placing sticky bands on trees to trap gypsy moth larvae.
_____ 12. Proper thinning.
_____ 13. Rearing and releasing beneficial predator and parasitoid species.
_____ 14. Minimizing the use of broad-spectrum insecticides that would kill beneficial insects.

15-23. Match the following forest insect pests to the appropriate description.

A. Forest tent caterpillar
B. Gypsy moth
C. Two-lined chestnut borer
D. European or native elm bark beetle
E. White pine weevil
F. Jack pine budworm

_____ 15. Larvae overwinter in silk shelters on the bark of pines.
_____ 16. Responsible for the spread of Dutch elm disease.
_____ 17. Adult beetles emerge from D-shaped holes in the bark of low-vigor oak trees from late May to mid-September.
_____ 18. Larvae clip off and web needles together with silk. The drying out of the clipped and webbed foliage results in a reddish appearance of the pine trees.
_____ 19. Larvae commonly defoliate hardwoods such as oak, birch, and aspen. When nearing maturity, larvae feed only at night and rest under bark, rocks, or litter during the day.
_____ 20. An important defoliator of aspens but will also damage maple, birch, oak, ash, and willow. Larvae often feed, molt, and rest in groups, massing on trunks during non-feeding periods.
_____ 21. Adults overwinter in duff below host trees until April, when they begin feeding on the terminal leader.

_____ 22. Egg-laying galleries are below the bark. As the eggs hatch, each larva chews a short tunnel (feeding gallery) radiating away from the egg-laying gallery.

_____ 23. Pupation occurs in the pith or wood of dead leaders, usually 1 to 3 years below the current growth; adults emerge in August-September and feed on upper lateral shoots, terminals, and other areas of the crown, then move down to the duff to overwinter.

24. Which would be an appropriate management strategy for control of gypsy moth?

A. Plant below an overstory so that trees are less suitable for attack.

B. Maintain stand stocking at 70 to 110 square feet per acre; optimal rotation age is 40 to 45 years.

C. Remove bark from infested trees or logs and destroy infested material by burning or chipping to prevent egg laying.

D. Use microbial pesticide sprays when insects are in the first to third instars.

25. Which would be an appropriate management strategy for control of European or native elm bark beetles?

A. Plant below an overstory so that trees are less suitable for attack.

B. Maintain stand stocking at 70 to 110 square feet per acre; optimal rotation age is 40 to 45 years.

C. Remove bark from infested trees or logs and destroy infested material by burning or chipping to prevent egg laying.

D. Use microbial pesticide sprays when insects are in the first to third instars.

26. Which would be an appropriate management strategy for control of two-lined chestnut borer?

A. Plant below an overstory so that trees are less suitable for attack.

B. Spray only the leader of the tree in the spring to kill feeding adults.

C. Sanitation harvests, salvage, or delay of any activity in the stand that may further reduce vigor or wound trees.

D. Use microbial pesticide sprays when insects are in the first to third instars.

27. Which would be an appropriate management strategy for control of jack pine budworm?

A. Plant below an overstory so that trees are less suitable for attack.

B. Maintain stand stocking at 70 to 110 square feet per acre; optimal rotation age is 40 to 45 years.

C. Spray only the leader of the tree in the spring to kill feeding adults.

D. Use microbial pesticide sprays when insects are in the first to third instars.

28. Which would be an appropriate management strategy for control of white pine weevil?

A. Remove bark from infested trees or logs and destroy infested material by burning or chipping to prevent egg laying.

B. Maintain stand stocking at 70 to 110 square feet per acre; optimal rotation age is 40 to 45 years.

C. Spray only the leader of the tree in the spring to kill feeding adults.

D. Use microbial pesticide sprays when insects are in the first to third instars.

29. Which would be an appropriate management strategy for control of forest tent caterpillar?

A. Remove bark from infested trees or logs and destroy infested material by burning or chipping to prevent egg laying.

B. Maintain stand stocking at 70 to 110 square feet per acre; optimal rotation age is 40 to 45 years.

C. Spray only the leader of the tree in the spring to kill feeding adults.

D. When needed, use microbial pesticide sprays in May when feeding begins.

30. The native elm bark beetle is more important than the European elm bark beetle as a vector of Dutch elm disease.

A. True

B. False

31-37. Match the following Christmas tree pests to the appropriate description.

A. Pine needle scale
B. Pine root collar weevil
C. Zimmerman pine moth
D. Balsam gall midge
E. Cooley spruce gall adelgid
F. Eastern spruce gall adelgid
G. Spruce spider mite

_____ 31. A pest on both Colorado blue spruce and Douglas-fir; forms galls on blue spruce but not on Douglas-fir.

_____ 32. Causes small galls to form on needles. Galled needles drop in October or November, leaving bare spots on branches.

_____ 33. Girdles the root collar, often resulting in pitch-soaked, blackened soil around the root collar.

_____ 34. Sucks the juices from needles, causing bronzing or grayish discoloration of needles. Fine webbing may also be present.

_____ 35. Sucks sap from the needles, weakening the tree; small, white, oyster-shaped bodies cover the needles.

_____ 36. Larvae overwinter in bark crevices and become active in early April to early May and bore in the stem at branch whorls. Pitch masses form on the stem at the entrance to the feeding tunnel.

_____ 37. Galls form along the twigs at the base of new growth (not at the tips of branches).

38. Which would be an appropriate management strategy for control of spruce spider mites?

   A. Remove lower two to three whorls of branches to allow sunlight to reach the root collar.
   B. Cut off and burn or bury galls before they open in July.
   C. Apply insecticides to the stem and bark of large branches in early to mid-April.
   D. Scout last year's damage in early June, checking older needles near the main stem. If necessary, use selective products to control.

39. Which would be an appropriate management strategy for control of Cooley spruce gall adelgid on blue spruce?

   A. Remove lower two to three whorls of branches to allow sunlight to reach the root collar.
   B. Cut off and burn or bury galls before they open in July.
   C. Apply insecticides to the stem and bark of large branches in early to mid-April.
   D. Rake away needle accumulation.

40. Which would be an appropriate management strategy for control of pine root collar weevil?

   A. Rake away needle accumulation.
   B. Use horticultural oil sprays to control.
   C. Use natural predators for light infestations.
   D. Keep Colorado blue spruce and Douglas-fir plantings separated.

41. Which would be an appropriate management strategy for control of balsam gall midge?

   A. Rake away needle accumulation
   B. Use horticultural oil sprays to control.
   C. Use natural predators for light infestations
   D. Keep Colorado blue spruce and Douglas-fir plantings separated.

42. Which would be an appropriate management strategy for control of Zimmerman pine moth?

   A. Remove lower two to three whorls of branches to allow sunlight to reach the root collar.
   B. Cut off and burn or bury galls before they open in July.
   C. Apply insecticides to the stem and bark of large branches in early to mid-April.
   D. Keep Colorado blue spruce and Douglas-fir plantings separated.

43. Which would be an appropriate management strategy for control of pine needle scale?

   A. Rake away needle accumulation.
   B. Use horticultural oil sprays to control.
   C. Use natural predators for light infestations.
   D. Keep Colorado blue spruce and Douglas-fir plantings separated.

44. Which would be an appropriate management strategy for control of eastern spruce gall adelgid?

   A. Use insecticide in April as buds begin to swell or in the fall after galls have opened.
   B. Use horticultural oil sprays to control.
   C. Remove lower two to three whorls of branches to allow sunlight to reach the root collar.
   D. Rake away needle accumulation.

45. How do white grubs cause damage in forest nurseries?

   A. By feeding on roots of tree seedlings.
   B. By infesting entire cones or individual seeds.
   C. By causing branch galls to form.
   D. By damaging the terminal leader.

46. What controls may help manage seed bugs, coneworms, or cone beetles in seed orchards?

47. What does cross-resistance in an insect population refer to?

CHAPTER 8

WEED MANAGEMENT

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 a 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 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, hatchets, 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.

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. A 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 a herbicides'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.

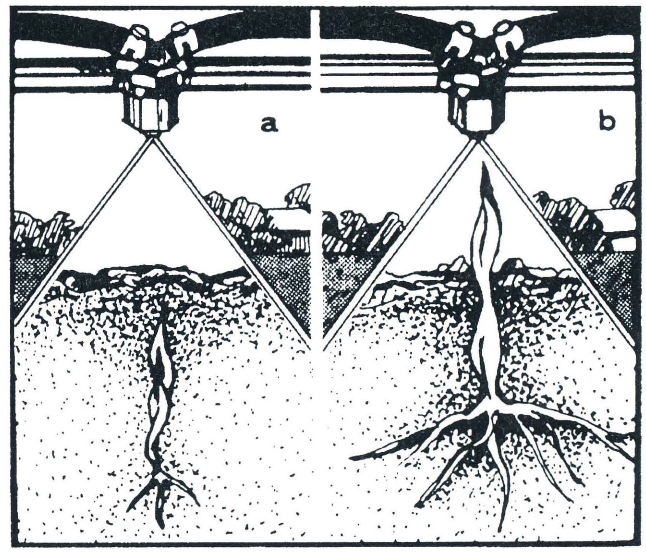


Figure 8.2. (a) Germinating weeds require preemergence herbicide; (b) postemergence herbicide is applied after weeds emerge.

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.

A 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 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 preemergent 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.

Figure 8.3. Crabgrass is an annual grass that reproduces by seed.

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.

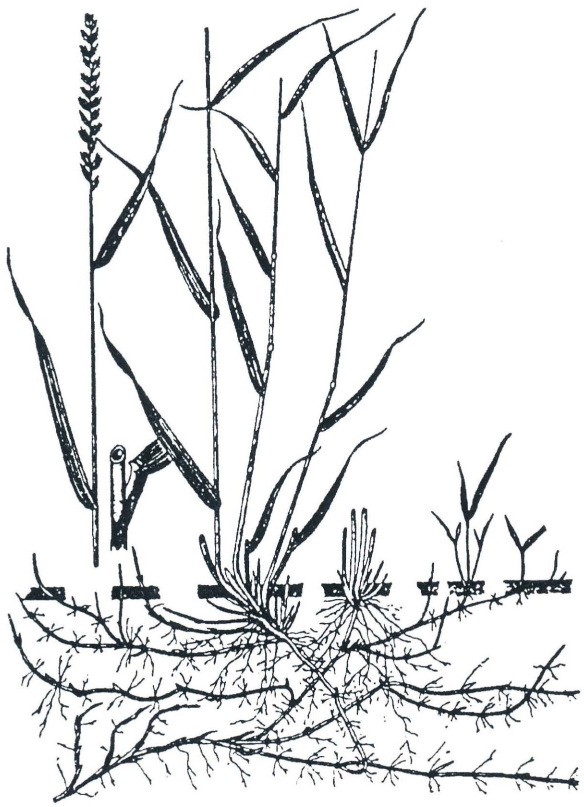


Figure 8.4. Quackgrass is a perennial grass that reproduces by seed and rhizomes.

Triazine-resistant common lamb's-quarters has been confirmed in sites throughout most of the corn production regions of Michigan. 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, simizine, 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 Michigan 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.

CHAPTER 8

Review Questions

Chapter 8: Weed Management

Write the answers to the following questions and then check your answers with those in the back of the manual.

1. What is the primary goal of forest weed management?

2. List five objectives of forest weed management.

3-7. Match the following types of weed control to the appropriate description.

A. Cultural control

B. Mechanical control

C. Chemical control

_____ 3. Plant seedlings at the appropriate spacing and replace those that die.

_____ 4. Manual cutting of species that are not too dense and do not resprout.

_____ 5. Use of herbicides during site preparation.

_____ 6. Select the best adapted species and varieties for planting.

_____ 7. Preparing or rehabilitating the site with specialized equipment.

8. Mechanical control is suitable to use in each case of vegetation management.

A. True

B. False

9. Where is mechanical thinning best practiced?

A. Where desired small trees are hidden by taller, brushy trees.

B. Where individual tree selection is desired.

C. In dense stands where clearing in strips is desired and no individual selection is necessary.

D. In stands of low density.

10. Chemical control of weed species is normally practical only once or twice in the life of a forest stand.

A. True

B. False

11. Which is NOT true about the evaluation of a vegetation management practice?

A. You must know the objectives of the control program to evaluate the results.

B. Initial herbicide activity and possible injury to desirable vegetation can be determined 2 to 4 weeks after application.

C. The results of vegetation control treatments should be evaluated after about 2 months, at the end of the season, and then for several years.

D. The effectiveness of brush and perennial weed control measures cannot be fully evaluated for at least 6 months.

12. Why must evaluation of vegetation management practices be an on-going activity?

13. List four to five objectives of a Christmas tree plantation weed control program.

14-17. Match the following herbicide characteristics to the appropriate description.

A. Selectivity or specificity

B. Mode of action

C. Residual nature

D. Formulation

_____ 14. The length of time the herbicide prevents the regrowth of vegetation after application.

_____ 15. Examples include being absorbed through the foliage or through the root system, killing only portions of the plant with which the herbicide has direct contact, etc.

_____ 16. Examples include solutions, emulsions, wet table powders, and granules.

_____ 17. The range of plants that the herbicide controls—examples are grasses only, broadleaf plants only, etc.

18. What factors affect a herbicide's residual properties?

19. What does preemergent control in a herbicide refer to?

A. It continues to kill weeds as their seeds germinate.
B. It kills weeds only when directly applied to the foliage.
C. It kills all vegetation that it has contact with.
D. It kills only the portion of the plant to which it is applied.

20. The application rates for various conditions are determined by reading the herbicide label.

A. True
B. False

21. With herbicides that do not form true solutions, herbicide effectiveness depends, in part, on maintaining proper agitation throughout the spray application.

A. True
B. False

22. How is herbicide effectiveness influenced by:

A. Application rate?

B. Equipment calibration?

C. Application method?

D. Targeted vegetation?

E. Soil-site characteristics?

F. Weather conditions?

23. Perennial grasses and weeds are more easily controlled than annual weeds and grasses with pre emergent herbicides.

A. True
B. False

24. Weather conditions are one of the most common reasons why herbicide applications fail to control weeds.

A. True
B. False

25. Triazine-resistant weeds have been identified in other states but not in Michigan.

A. True
B. False

26. What steps can be taken to prevent herbicide resistance in weeds?

CHAPTER 9

VERTEBRATE PESTS

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.

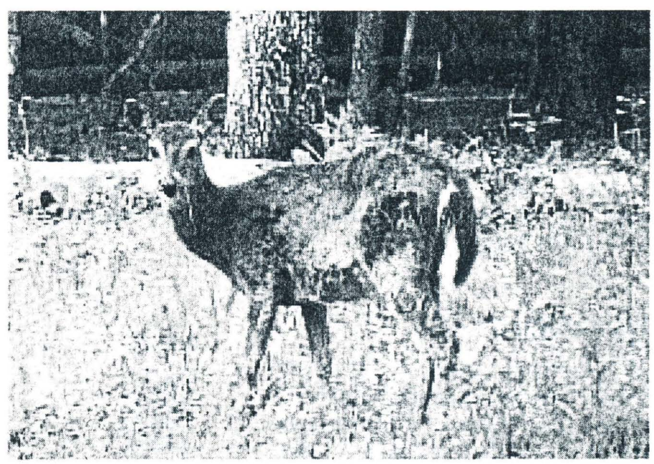


Figure 9.1. Browsing by white-tailed deer can prevent forest regeneration (C.J. Randall, Michigan State University).

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.

Damage	Species	Control Technique
Consumption of seed in tree nurseries	rodents birds	repellents, toxic baits repellents, physical barriers
Consumption of seedlings and saplings in tree nurseries and naturally occurring stands; consumption of bark or branches; deformation of trees	rodents deer, rabbits, porcupines, bears, and elk	repellents, toxic baits, physical barriers, biological controls, cultural techniques repellents, physical barriers, shooting, traps, silvicultural practices, dog restraint systems
Consumption of buds	squirrels, birds, deer	physical barriers, repellents
Flooding of trees; consumption of bark or branches; deformation of trees	beavers	destruction or modification of dam, trapping, shooting

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.

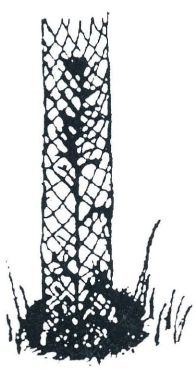


Figure 9.3. Plastic mesh seedling protector.

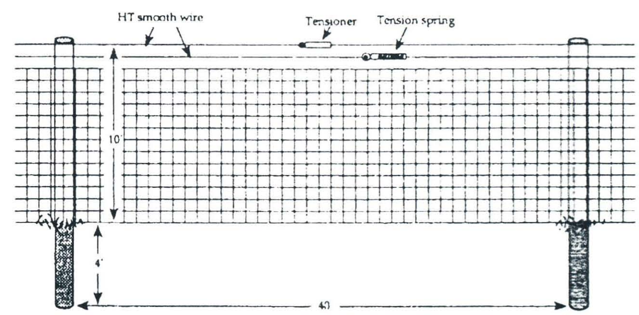


Figure 9.4. The deerproof woven wire fence.

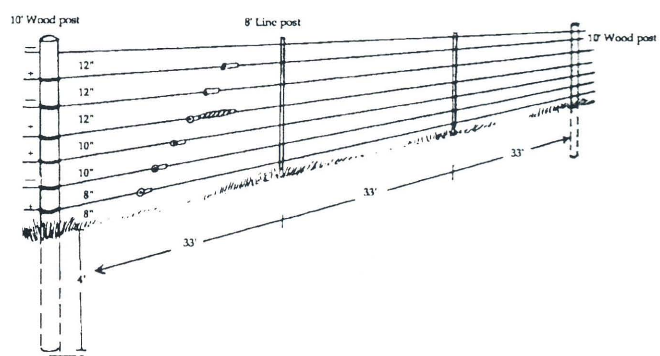


Figure 9.5. Electric seven-wire vertical deer fence.

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.

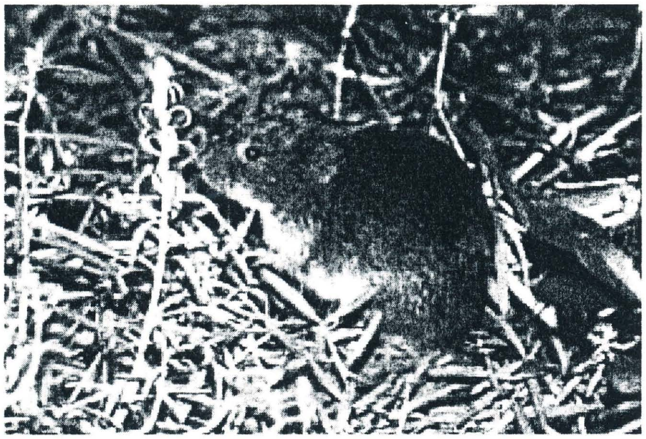


Figure 9.6. Meadow vole damage can be prevented by eliminating habitat (i.e., weeds, ground cover, litter) around plantation trees (L.L. Master, Mammal Images Library of the American Society of Mammalogists).

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.

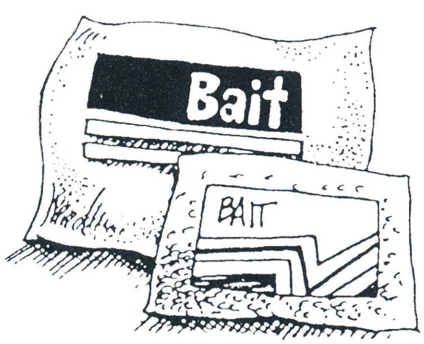


Figure 9.7. Various types of bait packs containing rodenticides are commercially available. Placing the bait packs inside PVC tubes will avoid killing non-target animals.

Trapping and Shooting

At times, damage may be caused by only a few individuals or be confined to a relatively small area. In these cases, shooting or trapping may be efficient damage control techniques. In Michigan, a permit is required for most trapping and shooting control situations. Check with the Michigan DNR Wildlife Division for a permit application. Also, always check local regulations before discharging any firearm. Hunting during the legal season can also reduce damage, especially over large areas, if the damage results from large numbers of animals. (Note: damage may result from habitat mismanagement, weather, or poor human choices instead of high numbers of animals.)

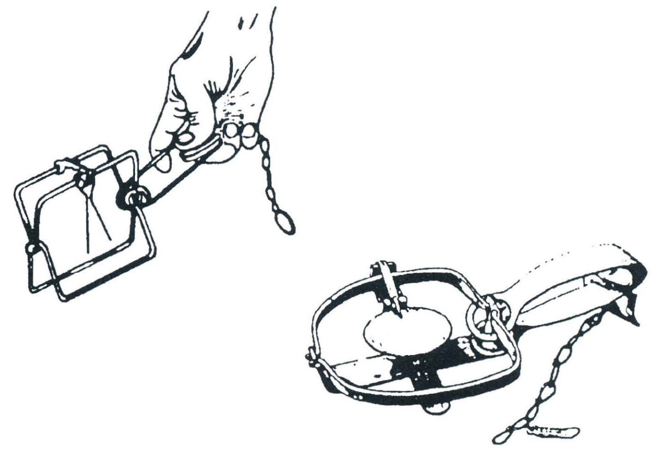


Figure 9.8. Two types of traps–body-gripping (top) and leghold (below).

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.

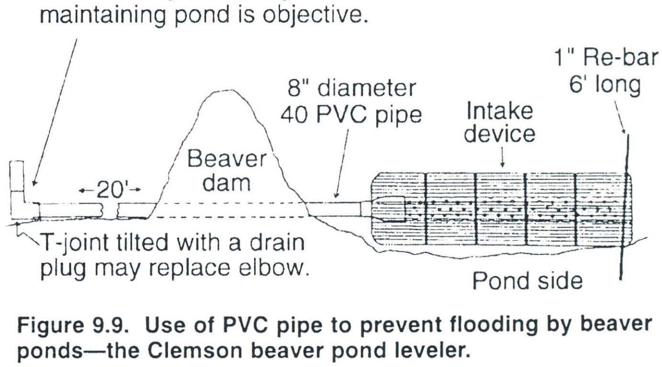


Figure 9.9. Use of PVC pipe to prevent flooding by beaver ponds—the Clemson beaver pond leveler.

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.

CHAPTER 9

Review Questions

Chapter 9: Vertebrate Pests

Write the answers to the following questions and then check your answers with those in the back of the manual.

1. When is it necessary to implement control of vertebrate pests in forest situations?

   A. Whenever vertebrate damage is evident in forest surveys.

   B. Whenever the deer population is abundant.

   C. Whenever it is economically and ecologically worthwhile.

   D Whenever there are not enough predators to keep the wildlife population in check.

2. Where are repellents most likely to be cost effective?

   A. In mature forest stands.

   B. In nurseries and Christmas tree plantations.

   C. In large clear-cuts.

   D. In uncultivated areas.

3-7. Match the following vertebrate damage control to the appropriate description.

   A. Repellents

   B. Physical barriers

   C. Cultural and silvicultural practices

   D. Toxic baits

   E. Biological controls

_____ 3. Devices used to exclude animals and prevent damage.

_____ 4. Mixed grains or food pellets treated with poison to reduce populations of rodents that would consume seeds or seedlings.

_____ 5. Devices or chemicals that irritate one or more of the senses of an animal and cause it to change its behavior.

_____ 6. One example would be placing nesting boxes for kestrels and perches for hawks and owls in or near a nursery or plantation.

_____ 7. Preventing damage through forest management techniques.

8. Which control method would be appropriate to prevent rodents from eating seed in tree nurseries?

   A. Toxic bait

   B. Shooting

   C. Physical barriers

   D. All of the above

9. Which control method would be appropriate to prevent squirrels from consuming tree buds?

   A. Shooting

   B. Trapping

   C. Repellents

   D. All of the above

10. Which control method would be appropriate to prevent flooding of trees by the dam building of beavers?

    A. Shooting

    B. Trapping

    C. Destruction or modification of dam

    D. All of the above

11. Which control method would be appropriate to prevent deer from consuming saplings in tree nurseries?

    A. Silvicultural practices

    B. Repellents

    C. Dog restraint systems

    D. All of the above

12. Which is NOT true concerning trapping or shooting to control vertebrate damage?

    A. Hunting during the legal season can reduce damage over large areas.

    B. A DNR permit is often required.

    C. It is not useful for controlling damage caused by a few individuals.

    D. You must know the local regulations regarding dis charging of firearms.

13. Give an example of a physical barrier for controlling animal damage.

14. Give an example of a cultural or silvicultural practice for controlling animal damage.

15. Describe how the dog restraint system works to limit deer and rabbit damage.

16. How do you control damage from beaver dams with out harming the beaver?

17. Before applying a pest damage control technique, you must first determine:

    A. If the technique(s) will work.

    B. What the problem is.

    C. If the technique(s) is efficient.

    D. If non-target species will be affected.

18. Lethal controls that affect non-target species should never be used unless the alternative loss is great.

   A. True

   B. False

19. Integrated damage control is not only always more efficient—it is often the only effective strategy.

   A. True

   B. False

20. Explain how the reduction of damage-causing animal numbers could possibly create additional or more serious problems. Give an example.

CHAPTER 10

LAWS AND REGULATIONS

LEARNING OBJECTIVES

After completely studying this chapter, you should:

- Understand laws that are designed to prevent introduction of exotic pests.
- Know what steps are taken to detect exotic pest introductions.
- Know what a regulatory pest is and what is done to prevent its spread.
- Know what options are available to decrease the impact of insecticide spray on natural enemies while still meeting regulatory requirements.
- Understand the federal Worker Protection Standard (WPS), including definitions, pesticide information requirements, requirements for protection from pesticide exposure, and requirements for mitigating pesticide exposures.

PREVENTION, DETECTION, AND REGULATION OF EXOTIC PESTS

Prevention of Exotic Pest Invasion

Invasions of exotic pests—e.g., those that are not native to North America—are a major concern in forest ecosystems. Damage can be severe when exotic pests become established without the complex of natural enemies that would normally hold them in check. There is also the potential for serious impacts on native species. Various quarantine laws and procedures are intended to prevent introduction of exotic pests into the United States. Rules govern international movement of plants and treatment of logs, crates, pallets, dunnage, and other potential methods of pest introduction. Inspections at shipping ports and borders help to reduce pest introductions. Given the volume of international trade that occurs between the United States and other countries, however, it is unlikely to expect that all potential pests will be intercepted.

Detection Systems

Once an exotic plant-feeding pest becomes established in Michigan, crews from federal and state regulatory agencies conduct delimitation surveys to identify the extent of the infestation. Counties where the pest is found are then quarantined for that pest. The Michigan Department of Agriculture and the federal Animal and Plant Health Inspection Service (APHIS) are required to prevent the spread of these exotic pests into new areas where they are not yet established. Because plant products such as Christmas trees, nursery stock, or logs can carry exotic plant-feeding pests and can introduce them into new areas, shipments of plants and trees out of quarantined areas are highly regulated.

Regulating Pests

The term ***regulatory pest*** is used here to refer to plant-feeding exotic insects that have become established in some states or regions. Gypsy moth and the pine shoot beetle are two important examples of regulatory pests that affect Christmas tree production in much of the northeastern and north central regions of the United States. Typically, Christmas trees grown in quarantined counties must pass inspection or meet other requirements to ensure that none of the trees are infested with the exotic pest. If the trees are determined to be free of the pest, then they can be shipped out of the quarantined county or state to an unquarantined area. If the pest is present, then trees can be sold only within the quarantined area.

Currently, many growers in counties infested with gypsy moths must meet regulations that include a mandatory application of an insecticide before Christmas trees can be inspected or certified and shipped. The insecticide spray is generally required regardless of actual pest presence or density within the field. Regulatory pests pose a special challenge to growers who wish to implement biological control in Christmas tree fields.

Optimizing Mandated Regulatory Sprays

Pest managers do have some options available that can decrease the impact of insecticide sprays on natural enemies while still meeting regulatory requirements.

Use the pesticide with the least impact on beneficial insects. Generally, growers are provided with a list of approved insecticides that can be used to control regulatory pests. Some pesticides on the list may be less disruptive than others at the time when sprays are required.

Use the regulatory spray for more than one purpose. When insecticide sprays are required, use the mandated spray to control more than one pest, whenever possible. For example, a single insecticide application can be timed to coincide with emergence of pine needle scale crawlers while meeting gypsy moth spray requirements.

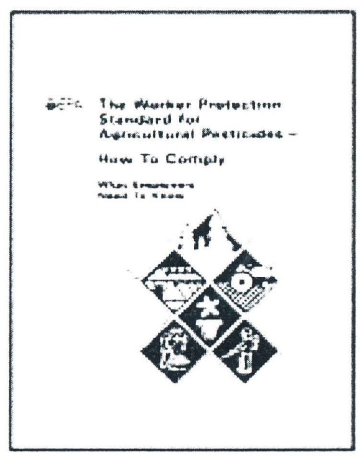
Use good cultural practices. Cultural management practices can sometimes be used to replace or enhance control of some regulatory pests and will conserve more natural enemies than repeated insecticide applications. Though the Pine Shoot Beetle Compliance Program does include one insecticide spray, it emphasizes cultural practices such as destruction of brood material and use of trap logs to reduce beetle populations within a field. These practices are effective and are less harmful to most beneficial insects than repeated sprays of broad-spectrum insecticide throughout the summer.

WHAT PESTS ARE REGULATED IN MICHIGAN?

Contact your regional Michigan Department of Agriculture office for a current list of regulated pests and details on how to comply with regulatory procedures.

WORKER PROTECTION STANDARD (WPS)

The federal Worker Protection Standard (revised in 1992) pertains to those who apply pesticides or who work in pesticide-treated areas of agricultural establishments—on farms and in forests, nurseries, and greenhouses. The WPS requires employers to provide workers and pesticide handlers with protection against possible harm from pesticides applied to agricultural plants. Operations producing Christmas trees and operations producing plants for wood fiber and timber products are specifically covered under the WPS as agriculture-related establishments. Forest nurseries and seed orchard operations are also included under WPS.

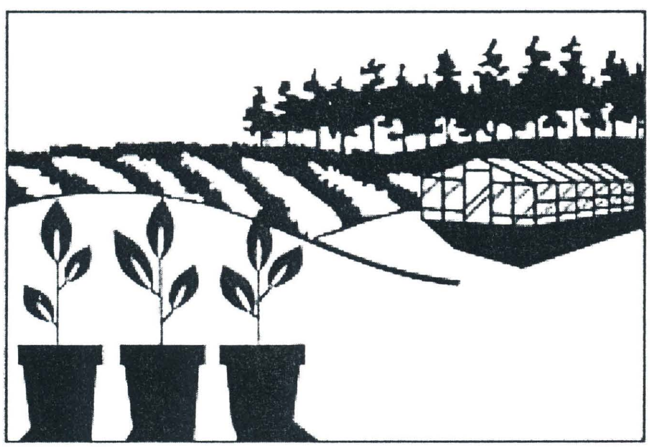


Owners and immediate family members who work on the establishment are exempt from some of the WPS requirements.

The WPS requires employers to take steps to protect workers and pesticide handlers from exposure to pesticides. A worker is anyone who is: employed (including self-employed) for any type of compensation and doing tasks such as harvesting, weeding, or watering relating to the production of agricultural plants on a farm or in a forest, nursery, or greenhouse. This term does not include persons who are employed by a commercial establishment to perform tasks as crop advisers.

A pesticide handler is anyone who is employed (including self-employed) for any type of compensation by an establishment that uses pesticides in the production of agricultural plants on a farm or in a forest, nursery, or greenhouse, and doing any of the following tasks:

- Mixing, loading, transferring, or applying pesticides.
- Handling opened containers of pesticides.
- Cleaning, handling, adjusting, or repairing parts of equipment that may contain pesticide residues.
- Assisting with the application of pesticides, including incorporating the pesticide into the soil after the application has occurred.
- Entering a greenhouse or other enclosed area to:
  - Operate ventilation equipment.
  - Adjust or remove coverings, such as tarps used in fumigation.
  - Check air concentration levels after application and before the inhalation exposure level (listed on the product labeling) has been reached or one of the WPS ventilation criteria has been met.
  - Entering a treated area outdoors after application of any soil fumigant to adjust or remove soil coverings, such as tarps.
  - Disposing of pesticides or pesticide containers.



WPS Requirements

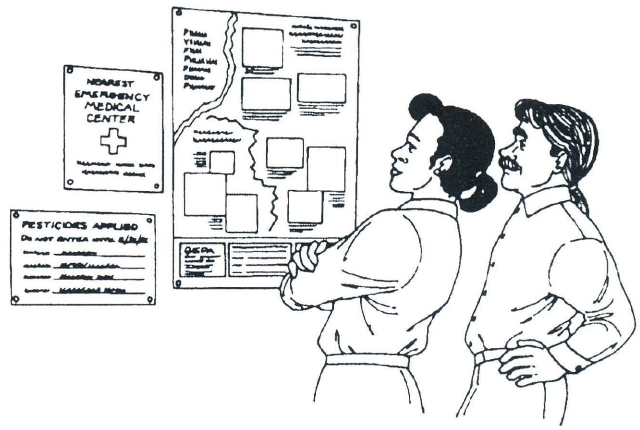
If you are an agricultural pesticide user and/or an employer of agricultural workers or pesticide handlers, the WPS requires you to provide to your employees and, in some cases, to yourself and to others:

- Information about exposure to pesticides.
- Protection against exposures to pesticides.
- Ways to mitigate (lessen or reduce) exposures to pesticides.

Information

To ensure that employees will be informed about exposure to pesticides, the WPS requires:

- Pesticide safety training—for workers and handlers. Michigan pesticide applicator certification credentials satisfy the requirement for both worker and handler training.
- Pesticide safety poster—to be displayed for workers and handlers.

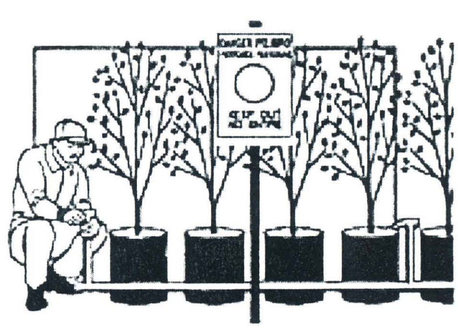


- Access to labeling information—for pesticide handlers and early-entry workers.
- Access to specific information—a centrally located application list of pesticide treatments on the establishment.

Protection

To ensure that employees will be protected from exposures to pesticides, the WPS requires employers to:

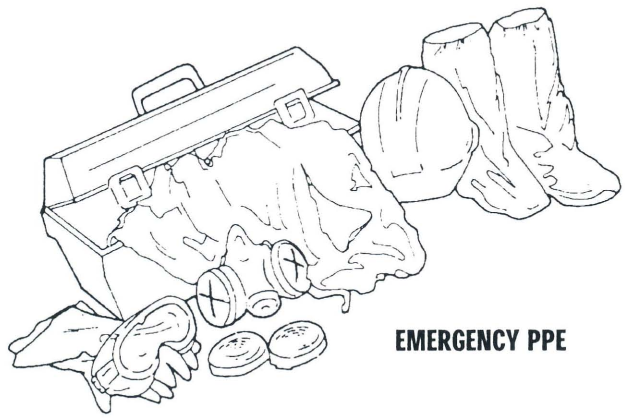
- Prohibit handlers from applying a pesticide in a way that will expose workers or other persons.
- Exclude workers from areas being treated with pesticides.
- Exclude workers from areas that remain under a restricted-entry interval (REI), with narrow exceptions.



- Protect early-entry workers who are doing permitted tasks in treated areas during an REI. Requirements include special instructions and duties related to correct use of personal protective equipment (PPE).

■ Notify workers about treated areas so they can avoid inadvertent exposures.

■ Protect handlers during handling tasks. Requirements include monitoring while handling highly toxic pesticides and duties related to correct use of PPE.

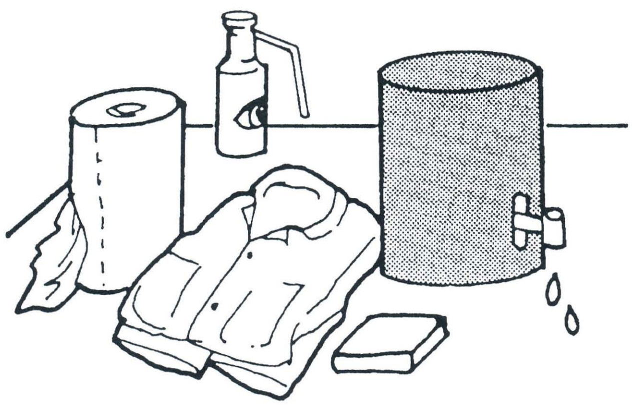


EMERGENCY PPE

Mitigation

To mitigate pesticide exposures that employees may receive, the WPS requires:

■ Decontamination sites—providing handlers and workers an ample supply of water, soap and towels for routine washing and emergency decontamination, and a change of clothing for handlers.



PERSONAL DECONTAMINATION EQUIPMENT

■ Emergency assistance—making transportation available to a medical care facility if an agricultural worker or handler may have been poisoned or injured by a pesticide, and providing information about pesticide(s) to which the person may have been exposed.

For detailed information about your responsibilities under the WPS, see the Environmental Protection Agency's manual *Worker Protection Standard for Agricultural Pesticides—How To Comply*. It will tell you what you need to do to comply with the federal worker protection requirements. The manual is available from EPA regional offices, state or tribal pesticide agencies, Extension Service offices, the Government Printing Office, and commercial sources.

OTHER REGULATIONS

Other federal regulations may affect some of the tasks you perform as a certified pesticide applicator. In some cases, the pesticide label will alert you to laws or regulations with which you must comply.

For more information about laws that affect all categories of certified applicators, see the *Pesticide Applicator Core Training Manual*, Chapter 2, Part A: "Laws and Regulations."

CHAPTER 10

Review Questions

Chapter 10: Laws and Regulations

Write the answers to the following questions and then check your answers with those in the back of the manual.

1. Why are exotic pests a danger to forest ecosystems?

2. Inspections at shipping ports and borders have prevented all introductions of exotic pests.

   A. True

   B. False

3. What is a regulatory pest? Give two examples.

4. What is the purpose of a delimitation survey?

   A. To determine the extent of an exotic pest infestation.

   B. To prevent exotic pest entry from foreign ports.

   C. To determine if pesticides have been misused in controlling exotic pests.

   D. To determine if natural predators are present to control exotic pests.

5. What agencies are required to prevent the spread of exotic pests in Michigan?

   A. Michigan Department of Natural Resources (MDNR) and the Environmental Protection Agency (EPA)

   B. MDNR and the Animal and Plant Health Inspection Service (APHIS)

   C. Michigan Department of Agriculture (MDA) and APHIS

   D. MDA and EPA

6. What happens to Christmas trees grown in quarantined counties in Michigan?

   A. They are inspected for exotic pests; if any are found, all trees in the plantation are destroyed.

   B. They are inspected for exotic pests; pest-free trees can be sold inside the quarantined area—all others must be destroyed.

   C. They are inspected for exotic pests; if pests are present, they can be sold only within the quarantined area—if pests are not found, they can be sold outside the quarantined area.

   D. They are inspected for exotic pests; if any are found, the plantation manager must agree to use pesticide sprays before selling the trees.

7. What must Christmas tree growers agree to in Michigan counties infested with gypsy moths?

   A. Must agree to apply an insecticide before the trees can be inspected, certified, or shipped.

   B. Must agree to attempt biological controls first before resorting to insecticides.

   C. Must agree to apply an insecticide if the gypsy moth is actually present in the field.

   D. Must agree to attach a label warning before shipping the trees to other counties.

8. What can pest managers do to decrease the impact of insecticide sprays on natural enemies when spraying has been mandated by law?

9. What controls are included in the Pine Shoot Beetle Compliance Program other than the insecticide spray? Why are these cultural controls added to the program?

10. Whom do you contact to find out which pests are regulated and how to comply with regulations?

A. MDNR

B. APHIS

C. MDA

D. EPA

11. The Worker Protection Standard (WPS) requirements apply to Christmas tree operations and operations producing plants for wood fiber and timber products but not to forest nurseries and seed orchard operations.

A. True

B. False

12. What is required by WPS?

A. Employers must take steps to protect only the employees that handle pesticides from pesticide exposure.

B. Employers must take steps to protect employees including pesticide handlers and other agricultural workers from pesticide exposure.

C. Persons hired as crop advisers are required to protect employees (pesticide handlers and other agricultural workers) from pesticide exposure.

D. Workers who are non-pesticide handlers are required to provide information to others to protect them from pesticide exposure.

13. According to WPS, a pesticide handler does not include people who enter a greenhouse to perform routine tasks such as operating ventilation equipment or removing coverings or tarps used in fumigation.

A. True

B. False

14. According to WPS, what information must be provided to protect employees from pesticide exposure?

15. Which is NOT a protection requirement of WPS?

A. Employers must train employees in IPM techniques.

B. Workers must be excluded from areas being treated with pesticides.

C. Employers must provide special instructions and duties related to correct use of personal protective equipment (PPE).

C. Early-entry workers doing permitted work in an area under a restricted-entry interval (REI) must be protected.

16. What are the WPS requirements for mitigating exposure to pesticides?

APPENDIX A

ANSWERS TO REVIEW QUESTIONS

Chapter 1 Principles of Pest Management

(1) Many factors—such as crop value, pest biology, degree of damage, and possible effects on the environment—must be considered and prioritized before choosing a control strategy.

(2) C (3) B

(4) Collect a sample of the pest and look at it under magnification. Check it against a book with pictures and descriptions. If still uncertain, submit the sample to MSU for identification.

(5) The threshold level is the point at which the pest or its damage becomes unacceptable.

(6) When the value of the crop is less then the cost of the control procedure.

(7) Pesticides kill beneficial organisms as well as pests.

(8) D (9) B (10) A (11) True

(12) False. Biological control organisms are also sensitive to pesticides.

(13) D

(14) To determine if the strategies were effective.

(15) D (16) D

(17) Observations about where pests first showed up, what kinds of natural enemies were observed, where and when specific treatments were applied, and what the results were.

(18) True

Chapter 2 Minimizing Pesticide Impact

(1) D (2) D (3) True (4) A

(5) False. FIFRA regulates the registration, distribution, sale, and use of all pesticides.

(6) B (7) True (8) D (9) A

(10) False. Point source pollution is easier to trace back because it is from a specific site; non-point source pollution is from a generalized area or weather event.

(11) False. Keeping pesticides from polluting groundwater is easier than cleaning up polluted water.

(12) False. Pesticide use may be part of an IPM program. IPM allows minimization of the use of pesticides.

(13) True

(14) B (15) A (16) B (17) C (18) C (19) True

(20) A (21) True (22) B

(23) False. Resistance management practices can be used to prevent, delay, or reverse the development of resistance.

(24) A

(25) To avoid creating situations of conflict and confrontation with those who may be near or affected by a pesticide application.

(26) D

Chapter 3 Application Methods and Equipment

(1) D

(2) Nature and habits of the target pest, the site, the pesticide, available equipment, cost, efficiency.

(3) C (4) A (5) A (6) True (7) D (8) C

(9) False. You must choose a pump made of materials resistant to corrosion by pesticides.

(10) A

(11) False. A mechanical agitator consists of a shaft with paddles located near the bottom of the tank. Hydraulic agitators discharge the spray mixture at a high velocity in the tank

(12) B (13) B (14) C

(15) False. Strainers need to be checked for clogs and rinsed frequently.

(16) A

(17) It controls pressure, thereby protecting pump seals, hoses, and other sprayer parts, and it bypasses the excess spray back into the tank.

(18) C (19) True

(20) False. Low-pressure sprayers often use roller-type pumps on small tanks or centrifugal pumps on large tanks. High-pressure sprayers have piston pumps that can deliver up to 50 gallons of spray per minute.

(21) B (22) D (23) A (24) C

(25) False. Tree injectors treat only one tree at a time.

(26) True

(27) 1. Check for leaks and see if all parts are working properly by filling the tank with water and pressurizing the system; 2. calibrate the sprayer.

(28) False. When making emergency repairs or adjustments in the field, wear all protective clothing listed on the label as well as chemical-proof gloves.

(29) C (30) B

Chapter 4 Calibration

(1) Because each spraying system is a unique combination of components.

(2) True (3) B (4) C (5) C (6) B (7) D
(8) A (9) C (10) B (11) A (12) A (13) D
(14) D (15) B (16) D (17) C (18) A (19) C

(20) B (21) A (22) B (23) D (24) A (25) D
(26) C (27) A

(28) False. The range should be between 9.12 and 10.08. Twelve ounces is greater than a 5 percent difference.

(29) False. Drop-through spreaders are more precise (less chance for pesticide to be distributed beyond the target boundaries).

Chapter 5 Forest Types in Michigan

(1) True (2) C (3) D

(4) False. It is rarely economically feasible or environmentally favorable to apply pesticides to large acreages of forestland.

(5) A (6) D (7) C

(8) False. *Hypoxylon* canker is found in aspen-birch forests.

(9) A (10) D (11) B (12) B (13) A

(14) False. There are a number of pest problems in oak-hickory forests that occur periodically (perhaps every 15 to 20 years) that have caused localized areas of mortality throughout the state.

(15) A (16) A (17) D (18) B (19) B

Chapter 6 Disease Management

(1) C (2) B (3) True (4) A (5) A

(6) False. Chemical control measures must be applied to the plant when infection is most likely to occur.

(7) 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 attempts to stop the damage after it is underway.

General methods of silvicultural control may include:

- Decay reduction through rotation.
- Fire prevention and care when logging.
- Reduction 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.

(8) False. Vigorous early growth is no assurance of satisfactory long-term development. 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.

(9) A (10) B (11) C (9) C (12) B (13) B
(14) D (15) A (16) True (17) D

(18) D (19) C

(20) 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 that is evident when the bark is peeled back. Vectors breed only in weakened, dying, or dead elms with tight bark.

(21) B (22) True (23) D

(24) False. *Scleroderris* canker is easily controlled with fungicide sprays in nurseries.

(25) B (26) A (27) D

(28) On pine: swollen branches and/or main stem; 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. In May and June, blisters filled with yellow-orange spores appear on the cankered areas of the pines.

On alternate host: spots on the underside of the leaf; orange masses form on the leaf spots in early summer, followed by brownish, hairlike projections that produce spores to infect pines in the fall.

(29) D (30) D (31) A (32) C (33) D (34) A
(35) B (36) D (37) B (38) C

(39) A (40) B

(41) Use integrated control strategies.
Limit the use of pesticides as much as possible.
Rotate different brands and classes of fungicides.

Chapter 7 Insect Management

(1) Proper decisions can be made after trees have been monitored for the level of pest activity, injury potential has been evaluated, and a cost-benefit analysis has been made.

(2) A (3) True

(4) Any one of the following:

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.

(5) Any one of the following:

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 makeup, and moisture content.

Disturbances such as wildfire, prescribed fire, thinning, or harvesting.

(6) A (7) D (8) C (9) E (10) A (11) B
(12) C (13) D (14) D

(15) F (16) D (17) C (18) F (19) B (20) A
(21) E (22) D (23) E (24) D (25) C (26) C
(27) B (28) C (29) D

(30) False. The European elm bark beetle is a more important vector of Dutch elm disease because of its breeding dominance over the native beetle.

(31) E (32) D (33) B (34) G (35) A (36) C
(37) F (38) D (39) B

(40) A (41) C (42) C (43) B (44) A (45) A

(46) Management of seed and cone insects may include cultural strategies and insecticides. Prescribed fire can be used to control insects that overwinter in the 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.

(47) 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.

Chapter 8 Weed Management

(1) To manage timber species, ground vegetation, and wildlife so that each component is maximized yet balanced.

(2) Any five of the following:

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.

(3) A (4) B (5) C (6) A (7) B

(8) False. 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.

(9) C (10) True (11) D

(12) Evaluation of vegetation management is ongoing to allow for adjustments in rates, products, and timing of herbicide applications, and to plan any additional control measures that may be needed.

(13) Any four or five of the following:

Increasing survival, nutrition, and growth of newly planted trees by eliminating competition.

Reducing rodent damage.

Developing better quality foliage on the lower part of the tree by eliminating the shading effect of weed growth.

Permitting easier and higher quality shearing.

Reducing the probability of foliage diseases.

(14) C (15) B (16) D (17) A

(18) Application rate, soil texture (particularly clay content), soil organic matter content, soil moisture level, and herbicide solubility.

(19) A (20) True (21) True

(22) A. Application rate—the amount of herbicide required per acre to obtain effective control. Too little will result in lack of control; too much will result in environmental or plant damage.

B. Equipment calibration—equipment must be properly calibrated to ensure the proper application rate.

C. Application method—must be considered to ensure uniform coverage.

D. Targeted vegetation—because of differences in anatomy and physiology, some plants are more affected by herbicides than others.

E. 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.

F. Weather conditions—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.

(23) False. Annual weeds and grasses are easily con trolled with preemergent products; perennial grasses and weeds, particularly those with deep root systems, are more difficult to control chemically.

(24) True

(25) False. Triazine-resistant common lamb's-quarters has been confirmed in sites throughout most of the corn-producing regions of Michigan.

(26) 1) Scout regularly and identify weeds present.

2) Combine mechanical control practices such as cultivation with herbicide treatments.

3) 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.

4) 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.

Chapter 9 Vertebrate Pests

(1) C (2) B (3) B (4) D (5) A (6) E (7) C
(8) A (9) C (10) D (11) D (12) C

(13) Any one of the following:

Physical barriers to individual trees such as sheet metal, wire mesh, or plastic around the trunk.

Area barriers: permanent 8-foot-high woven wire fences or 7- or 8-wire high tensile strength steel electric fences are examples of area barriers.

(14) Any one of the following:

Increasing the size of irregularly shaped clear-cuts to produce more seedlings than a deer herd can consume.

Growing species or varieties of trees less palatable to wild animals.

Eliminating vole habitat in nurseries and plantations.

(15) Dogs (preferably two males) are confined to a tree area by electric shock collars and a perimeter antenna wire. The dogs must be housed, watered, and fed within the perimeter wire and must be trained not to cross the wire.

(16) Modify the dam to permanently reduce or eliminate the beaver pond by properly using and installing perforated plastic pipe.

(17) B (18) True (19) True

(20) 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.

Chapter 10 Laws and Regulations

(1) Exotic pests can cause severe damage to forests where there are no natural enemies to keep them in check. They may also displace native insect species.

(2) False. It is unlikely that all exotic pests will be intercepted, given the volume of international trade that occurs.

(3) A regulatory pest is a plant-feeding exotic insect that has become established in a particular state or region so that management of the pest is subject to certain federal or state regulations. Gypsy moth and pine shoot beetle are two important regulatory pests that affect Christmas tree production.

(4) A (5) C (6) C (7) A

(8) 1. Use the pesticide with the least impact on beneficial insects.

2. Use the regulatory spray for more than one purpose.

3. Use good cultural practices.

(9) Cultural practices such as destruction of brood material and use of trap logs to reduce beetle populations within a field are included in the program. These practices are effective and are less harmful to most beneficial insects than repeated sprays of broad-spectrum insecticide throughout the summer.

(10) C

(11) False. The WPS requirements apply to those who apply pesticides or who work in pesticide-treated areas of agricultural establishments—on farms and in forests, nurseries, and greenhouses. These include Christmas tree operations, wood fiber and timber products operations, tree nurseries, and seed orchards.

(12) B

(13) False. These workers are defined as pesticide handlers, according to the WPS.

(14) 1. Pesticide safety training—for workers and handlers. Michigan pesticide applicator certification credentials satisfy the requirement for both worker and handler training.

2. Pesticide safety poster—to be displayed for workers and handlers.

3. Access to labeling information—for pesticide handlers and early-entry workers.

4. Access to specific information—a centrally located application list of pesticide treatments on the establishment.

(15) A

(16) Decontamination sites—providing handlers and workers an ample supply of water, soap, and towels for routine washing and emergency decontamination, and a change of clothing for handlers.

Emergency assistance—making transportation available to a medical care facility if an agricultural worker or handler may have been poisoned or injured by a pesticide, and providing information about pesticide(s) to which the person may have been exposed.

APPENDIX B

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. LD_{50} and LC_{50} 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 Michigan 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.

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

LD_{50}—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. LD_{50} is expressed in milligrams of chemical per kilogram of body weight of the test animal (mg/kg). The lower the LD_{50}, 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, 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 economicl 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 breakdown 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:

- Pesticide Applicator Core Training Manual, E-2195, Michigan State University Extension.
- The Federal Insecticide, Fungicide, and Rodenticide Act, as amended. Public Law 92-516, October 21, 1972, as amended by Public Law 94-140, November 28, 1975, and Public Law 95-396, September 30, 1978.
- Federal Register, November 7, 1990, Part II Environmental Protection Agency 40, CFR Part 171 Certification of Pesticide Applicator; Proposed Rule.
- Region V Office of the EPA, Chicago, Ill.
- Michigan 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 C

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NOTES

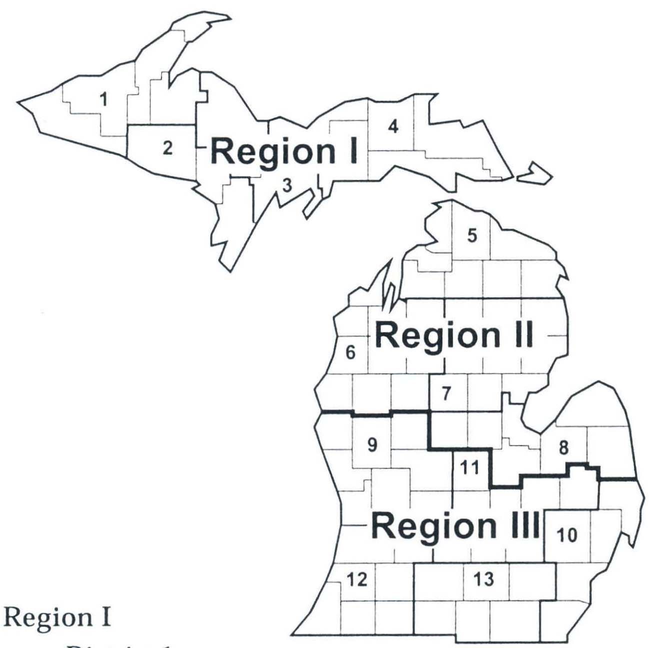
APPENDIX D

RESOURCES

For vertebrate pest control permits:

Permit Coordinator
DNR, Wildlife Division
Box 30444, Lansing, MI 48909-7944
517-373-1263

Or, contact a district wildlife or law enforcement supervisor at one of the district offices.



Region I

District 1:
North US-41
Box 440
Baraga, MI 49908
906-353-6651

District 2:
1420 Hwy. US-2 West
Crystal Falls, MI 49920
906-875-6622

District 3:
6833 Hwy. 2, 41 and M-35
Gladstone, MI 49837
906-786-2351

District 4:
Newberry Operations Service Center
Route 4, Box 796
Newberry, MI 49868
906-293-5131

Region II

District 5:
Box 667
1732 West M-32
Gaylord, MI 49735
517-732-3541

District 6:
8015 Mackinaw Trail
Cadillac, MI 49601
616-775-9727

District 7:
Box 939
191 S. Mt. Tom Road
Mio, MI 48647
517-826-3211

District 8:
503 North Euclid
Suite 1
Bay City, MI 48706
517-684-9141

Region III

District 9:
State Office Building
Sixth Floor
350 Ottawa Street, N.W.
Grand Rapids, MI 49503

District 10:
38980 Seven Mile Road
Livonia, MI 48152
313-953-0241

District 11:
10650 S. Bennett
Morrice, MI 49080
616-685-6851

District 13:
301 E. Louis Glick Hwy.
Jackson, MI 49201
517-780-7900

Web site for Material Safety Data Sheets:
http://www.ilpi.com/msds/index.chtml

PESTICIDE EMERGENCY INFORMATION

For any type of an emergency involving a pesticide, immediately contact the following emergency information centers for assistance.

Current as of August 2000

Human Pesticide Poisoning

MICHIGAN POISON CONTROL SYSTEM

From anywhere in Michigan, call

1-800-POISON 1

1-800-764-7661

Special Pesticide Emergencies

Animal Poisoning

Your veterinarian:

Phone No.

or

Animal Health Diagnostic Laboratory (Toxicology) Michigan State University:

(517) 355-0281

Pesticide Fire

Local fire department:

Phone No.

and

Fire Marshal Division, Michigan State Police:
M–F: 8–12, 1–5

(517) 322-1924

Traffic Accident

Local police department or sheriff's department:

Phone No.

and

Operations Division, Michigan State Police:

****(517) 336-6605***

* ***Telephone Number Operated 24 Hours***

Environmental Pollution

Pollution Emergency Alerting System (PEAS), Michigan Department of Environmental Quality:

District MDEQ Office Phone No.

and

For environmental emergencies:

****1-800-292-4706***

also

****1-800-405-0101***

Michigan Department of Agriculture Spill Response

Pesticide Disposal Information

Michigan Department of Environmental Quality. Waste Management Division.

Monday– Friday: 8 a.m.–5 p.m.

(517) 373-2730

National Pesticide Telecommunications Network

Provides advice on recognizing and managing pesticide poisoning, toxicology, general pesticide information and emergency response assistance. Funded by EPA, based at Oregon State University

7 days a week; excluding holidays

6:30 a.m. – 4:30 p.m. Pacific Time Zone

1-800-858-7378

FAX: 1-541-737-0761

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