Ornamental Pest Management A Training Manual for Commercial Pesticide Applicators (Category 3b)

Michigan State University
Cooperative Extension Service
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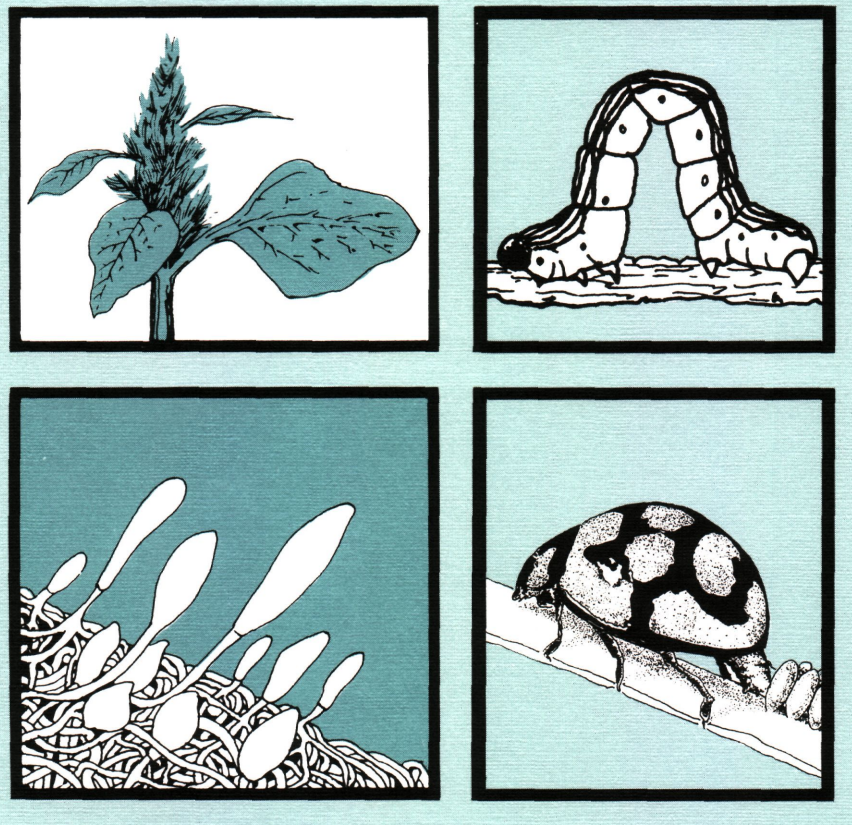

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A Training Manual For Commercial Pesticide Applicators (Category 3b)

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Preface

This manual is intended to prepare pesticide applicators in Category 3B, ornamental pest management, for initial certification under the Michigan Pesticide Control Act of 1976, as amended. This category includes the management of pests of outdoor ornamental plants including evergreens, shrubs, shade trees, ground covers, and flowering plants. Included in this category are commercial applicators managing pests of nursery stock. Christmas trees are *not* included and are designated as part of Category 2, Forest Pest Management. The "Commercial and Private Pesticide Applicator Manual: Core Initial Certification" (E-2195) which explains safety considerations, pesticide laws, and integrated pest management principles, should also be studied to prepare for certification.

Some suggestions for studying the manual are:

1. Find a place and time for study where you will not be disturbed.
2. Read the entire manual through once to understand the scope and form and presentation of the material.
3. Then study one section of the manual at a time. You may want to underline important points in the manual or take written notes as you study the section.
4. Write answers to the review questions at the end of each section. These questions help you learn and evaluate your knowledge of the subject. They are an important part of your study.
5. Reread the entire manual once again when you have finished studying all of the sections. Review with care any sections that you feel you do not fully understand.

After completing your study of this manual and the core manual (E-2195), take the core exam and category 3B exam administered by the Michigan Department of Agriculture to become a certified commercial pesticide applicator for ornamental pest management.

Acknowledgements

Cooperative Extension Service publications from Cornell University, Ohio State University, the University of Illinois, and the University of Wisconsin were invaluable resources for this manual.

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CHAPTER 1

PRINCIPLES OF PEST MANAGEMENT

A pesticide applicator is not merely a person who applies pesticides. Much social and legal responsibility accompanies the use of toxic materials. A pesticide application must protect plant material from pest injury without endangering nontarget organisms. To meet this goal, you will be required to evaluate many factors influencing the need for, and type and timing of pest controls. This chapter discusses a pest management program which, through the use of integrated pest management, coordinates the biology of the landscape with control activities.

As defined in the core manual, **integrated pest management,** or **IPM,** is the use of all available strategies to manage pests so that an acceptable yield and quality can be achieved economically with the least disruption to the environment. The goal of IPM is to reduce and maintain pest populations at levels where aesthetic and economic losses are tolerable. Any practices which help prevent or reduce plant injury are implemented. Integrated pest management is not "anti-pesticide," but rather incorporates a wide range of pest controls such as resistant plant varieties, cultural practices, natural enemies, mechanical controls, and pesticides.

IPM was initially developed for agricultural systems based on the concepts that: 1) no one method will adequately achieve long-term pest management and 2) pest management should be an integrated part of plant care management. These concepts were learned as hard lessons by the agricultural community in the 1960's. Before the introduction of DDT, crop pests were managed by a variety of cultural practices including crop selection and rotation, tilling, and sanitation. As farmers became dependent on chemical controls like DDT, other methods were no longer routinely used. Within a decade the negative consequences of pesticide overuse became apparent. Pest resistance and destruction of natural enemies resulted in poor crop yield and quality, and pesticide levels in the environment led to poisoning of wildlife and exposure to people. *The inevitable result of over-simplifying plant problems and relying too heavily upon one method of control is unacceptable pest injury to plants.*

Commercially-implemented IPM has achieved good pest management with a minimal amount of pesticides. Decreasing the amount of pesticide applied reduces the need for toxic chemical disposal and storage sites. Landscape IPM programs are also cost effective. A flower garden IPM program in San Francisco's Golden Gate Park not only realized better pest management than the previous program, but also was 75% less expensive to operate. Because it is the most effective and least hazardous way to manage pests, IPM programs are ideal for parks, schools, and other areas frequented by people. Public awareness of the benefits of urban IPM programs lessens the friction between environmentally-concerned citizens and landscape managers.

The steps of IPM for landscapes are:

1. Detection of Agents Injuring Plants
2. Identification of Agents Injuring Plants
3. Economic Significance
4. Selection of Methods
5. Evaluation

These components relate closely to the IPM program outlined in the core manual. The steps have been modified for managing established landscape plants.

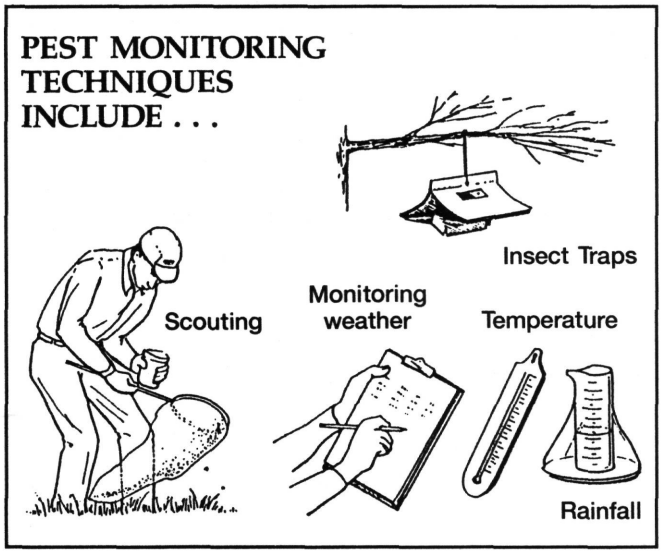
Detection

There are several IPM goals accomplished by monitoring pests. Accurate and early detection of pest presence, density, and life stages allows applicators to use the full range of control options. For example, the Michigan Department of Agriculture monitors the immigration of the gypsy moth into Michigan counties with pheromone (sex attractant) traps. Early detection allows city foresters and park managers to plan education and suppression programs long before a gypsy moth outbreak occurs. Detection of low-level pest populations is doubly beneficial. Action to manage pests can be taken before host plants have suffered serious injury. In addition, pest populations are more easily maintained at, than reduced to, innocuous levels. Low-level pest populations can often be managed with less toxic controls.

Regular monitoring is also necessary to determine the presence of pest life stages susceptible to controls. Applying a herbicide to the summer annual weed lambsquarter in September would not protect landscape plants. Competition between ornamental plants and lambsquarter occurs throughout the season, and the weed seeds would have already been produced and released.

Monitoring Techniques

There are a number of ways to monitor the landscape for information used in a pest management program. Probably the most common detection method is the actual sighting of pests and their damage. This information can be gathered informally (hearsay from a coworker), or formally (statistical sampling). For established landscape plant monitoring, a moderately accurate monitoring method is appropriate. To keep detection information uniform, develop a system to rank plant condition. Record information useful for planning management strategies: life stage of pest present, type and level of damage, and specific plant and plant area being damaged. Use a standardized monitoring sheet such as the sample included in this section.



The developmental progress of plants or pests is a reliable cue to the onset of pest activity. For instance, the fungus causing rust on hawthorns enters through the microscopic pores of newly-formed leaves. Damage may not be visibly noticeable until the leaves are fully expanded. Therefore, hawthorn budbreak signals the start of rust infection. The rate of pest and plant development varies from year to year depending upon weather conditions. Those using spray calendars to time pest management activities often experience unsatisfactory results because of this variation.

You can more precisely measure pest development through the use of **degree day** information. One degree day is a 24-hour period of accumulated time in which the temperature was above a base level. The base temperature correlates with the onset of plant or pest activity. The Crop Advisory Team of Michigan State University records for various areas of Michigan the number of degree days over 50°F, the base temperature at which insect development occurs. This information can be used with pest management references such as *Coincide: The Orton System of Pest Management,* and the CAT Advisory Bulletin (see Resources).

Identification

An organism should not be classified and treated as a pest until it is proven to be one. There are thousands of species of insects, fungi, nematodes, and bacteria that are harmless or beneficial to landscape plants. Most species of pests are not damaging until the population increases to a certain density. It is therefore necessary to accurately determine which agents are causing plant injury before considering pest management options.

Know the Healthy Plant

You must be familiar with the plant's normal appearance and biological functions in order to recognize when it is being damaged. People who are not aware that evergreen plants routinely shed leaves become alarmed when the oldest needles of a white pine yellow and drop. Iron deficiency often results in abnormally yellow foliage on pin oaks in Michigan. However, the yellow leaves of a "Sunburst" honey locust are perfectly normal and ornamentally desirable. To the untrained eye, the small purple-red male cones of pine and spruce

Landscape Monitoring Sheet

Date:_____ Property: _____

Plant species/cultivar:_____ Location of plant(s): _____

Non-pest plant condition

Soil type, drainage, fertility: _____

Irrigation type and amount: _____

Mechanical damage: _____

Planting condition: _____

Unusual exposure to wind, sun, salt: _____

Plant landscape importance: _____

Client tolerance of pest damage: _____

Pest Damage

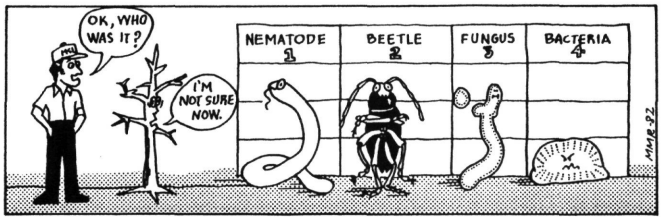
Where Detected	Type of Damage	% of Plant Area Damaged	Pest Stage Detected	Pest Enemies Detected
in soil or on roots				
branches				
trunk				
new foliage				
older foliage				
flowers				

trees look like irregular plant growth that might be caused by gall-forming pests.

As you gain experience with the common Michigan landscape plants, the symptoms of plant disorders become obvious. Landscape plant manuals help define what is normal for a particular plant (see Resources). Also use these manuals to identify the species of an injured plant. Many plant disorders are directly associated with a specific genus, species, or cultivar of ornamental plant. For these cases, correct plant identification greatly aids in identifying the problem. Most plant disorder reference books are organized by the scientific species name of the plant attacked.

Know the Agents Damaging Plants

Once you have discovered a damaged plant, you are faced with determining which one of an awesome array of agents is responsible: cultural or environmental conditions, weeds, diseases, insects, mites, snails and slugs, or vertebrates. The biological and damage characteristics of the plant injury agents are discussed in Chapters 5 and 6 of this manual.



Plants are able to respond to stress in a limited number of ways. Several plant disorders will result in similar symptoms. For instance, an American sycamore with dieback of new growth could be caused by a late spring frost or anthracnose disease. Weather records or evidence of twig cankers will help to indicate the causal agent. Some generalizations can be made about plants' injury symptoms and causal agents:

Symptoms	Causes
Injury first shows up at the inside or bottom of the plant.	Soil compaction or contamination; vascular disease.
Injury occurs on the top or on external portions of the plant.	Environmental conditions (air pollution, spray injury, cold injury); some insect pests.
Damage occurring on many different plant species.	Abiotic diseases—environmental or cultural problems; insects with a wide range of hosts.
Injury initiating from the wettest plant areas—usually progressing from the bottom to the top portions of a plant, or from the most shaded to the sunniest plant areas.	Biotic diseases (usually fungal).

Diagnosing Plant Disorders

With experience, you will learn to accurately diagnose plant problems. Adopt the following diagnostic techniques:

- Investigate the *whole* plant.
- Ask the client about activities occurring near the plant in the past few years including house painting, utility trenching, herbicide application, striking lightning, building construction, and sod laying.
- Bring along necessary tools for thorough investigation and root, soil, foliage, and wood sample collection. These may include hand and pole pruners, trowel, soil probe, sharp knife, binoculars, hand lens, and specimen bags.
- Have ready access to plant disorder references such as Extension bulletins and agents, books, your records, and fellow diagnosticians.
- Remember that there is often more than one damaging agent.

A checklist, such as the sample in this chapter, can help ensure that you are collecting and considering all pertinent information.

Economic Significance

All pest management activities have costs in terms of materials, time, or environmental contamination. The costs must be justified by an equal or greater benefit of the implemented management tactics. This cost-benefit principle is an important component of integrated pest management and is termed the **economic injury level.** The economic injury level is defined as the density of pests at which the cost to manage the pest is equal to the losses that pest causes. This definition, developed for IPM of cash crops, applies to established ornamentals when the well-being of the plant is threatened. Managing the deadly pathogen Dutch elm disease is a difficult and expensive task requiring intensive monitoring, pruning, and pesticide application. These tactics are only economically reasonable for an extremely valuable tree such as a mature, beautifully-shaped American elm gracing a public landmark.

Plant Diagnostic Checklist

1. Plant species or cultivar?

2. Age and/or size of the plant?

3. Specific location of the plant on the property?

4. Damage symptoms evident on other plants? If yes, what species and how far away?

5. How established is the plant? Is it recently transplanted?

6. Was the plant installed too shallow or deep?

7. What is the plant care history (pruning, fertilizing, pest infestations)? What, where, and when were treatments applied?

8. Is there evidence of mechanical injury (animal feeding, girdling twine, pruning cuts)?

9. Is the plant location excessively sunny, shady, or windy?

10. Is the plant exposed to deicing salt?

11. Unusual weather conditions for this and previous seasons (extreme temperatures, late/early frost, drought, ice storms)?

12. Soil conditions (soil texture, fertility, pH, excessive or poor drainage, recent change in grade)?

13. Appearance of foliage:
- ☐ off-color or spotted?
- ☐ symptoms on upper/lower surface?
- ☐ leaves deformed (galls, twisted, tattered, rolled, blistered)?
- ☐ feeding damage present?
- ☐ leaves wilted?

14. Appearance of twigs:
- ☐ off-color?
- ☐ deformed (swollen, lesions, cankers, galls)?
- ☐ streaks in cambium (layer just under bark)?
- ☐ channel/tunnels in wood?
- ☐ girdling?

15. Appearance of trunk and branches:
- ☐ oozing sap or resin?
- ☐ dark streaks in the wood under the bark?
- ☐ discolored bark?
- ☐ missing or peeling bark?
- ☐ presence of cankers?

16. Appearance of fruit and flowers:
- ☐ feeding damage present?
- ☐ off-color?
- ☐ deformed?
- ☐ presence of insects?

17. Appearance of roots:
- ☐ some roots exposed?
- ☐ exposed roots mechanically damaged?
- ☐ loss of turgor?
- ☐ unusual growth near soil line?
- ☐ mulch around plant (kind and how much)?
- ☐ roots restricted (and how)?
- ☐ presence of insects?

A definition incorporating pest damage which only diminishes the plant cosmetically can be called the **landscape injury level**: the pest density resulting in a level of damage that is unacceptable. The **action threshold** is the pest density at which measures must be taken to prevent the pest from reaching the landscape injury level. For a highly-visible dwarf crabapple, one eastern tent caterpillar web would meet the action threshold.

Note that injury and action thresholds do not apply to nursery stock which is required to be certified free from injurious insects and diseases.

Setting Landscape Injury Levels

The presence of a pest does not necessarily mean that management measures must be taken. Only under confined conditions such as a greenhouse is it possible to eradicate a pest, and rarely is it necessary to prevent plant injury. Plant pest populations may never reach damaging levels because of biological controls. Plants are more prone to serious pest problems when subjected to unnatural situations such as unsuitable growing conditions, exotic pests, and large plantings of the same species. Such circumstances are common in the landscape.

There are two types of injury to consider when establishing the landscape injury level: 1) damage to plant health and 2) damage to plant appearance. Pests sometimes threaten the health of ornamental plants. Often seriously injured plants do not immediately die, but are permanently weakened so that their ornamental value is greatly reduced. In such cases, the actual economic loss can only be measured as plant removal and replacement costs.

The most common landscape pest injury detracts from the aesthetic value of the plant, but does not seriously threaten its welfare. This includes unappealing changes in plant appearance, and visibility or nuisance caused by the pest or its activities. A few fungal spots on foliage, landscape plantings dotted with weeds, and houses covered with boxelder bugs are examples of aesthetic injury. What exactly constitutes aesthetic injury is a matter of personal opinion.

Helping clients to distinguish between the two types of plant injury is an important task faced by applicators. Education often results in less client anxiety and higher pest damage tolerance levels.

The landscape injury level is a subjective assessment based on the potential for serious injury and the landscape value of the plant. These factors are listed below.

Factors Influencing the Landscape Injury Level

1. Client (or other important person) tolerance of pest damage.
2. Landscape importance of host plant.
3. The greatest possible pest injury to host plant.
4. Pest ability to reproduce and spread.
5. Expected pest reduction by natural controls.

The following examples illustrate how these factors influence the injury level. Pests are easily spread from plant to plant when preferred hosts are close together. The exotic disease Chestnut blight is a dramatic example. Soon after it was introduced in the early 1900's, chestnut blight spread like wildfire through the American chestnut forests covering the eastern United States. American chestnuts are now considered to be extinct. A large grouping of the same plant species or cultivar is called a **monoculture**. Hedges and flower beds are common landscape examples of monocultures. Because nursery plantings are large monocultures, they are subject to pest problems that ordinarily would not affect ornamental trees and shrubs. The potential for widespread infestation is great, so a pest inhabiting a monoculture may require suppression at a lower density than usual.

The level of pests considered tolerable also depends upon how seriously the pest will affect a particular host. Aphids feeding on a four-foot spirea shrub will cause curling of the new growth and sooty mold. Although unsightly, this injury is not a serious threat to the spirea's welfare. The same population of aphids on a developing begonia will result in significant physical harm and possible death of the plant. There are a few pests which are so damaging or so rapidly spread that action must be taken at the first sign of the pest or on a preventive basis. Some examples of these destructive pests include stem and root rots, fire blight, poison ivy, pinewood nematode, and the bronze birch borer.

Personal and peer experience, and references will help you set the initial landscape injury level for a plant. Injury levels should be modified to reflect the pest damage tolerance of important people. Commonly, landscape managers inherit injury levels from previous managers. However injury levels are determined, you must use detection techniques to evaluate and reevaluate the injury level for each specific landscape situation. *Setting landscape injury levels which reflect specific pest and host conditions is the cornerstone of IPM.*

Selection of Methods

Many factors limit pest populations including weather, natural enemies of pests, plant defenses, and a host of controls implemented by people. The pest management methods most appropriate for a specific circumstance will depend upon the biology of the pest and host plant, and the landscape situation. You must consider all available management tactics and evaluate the benefits and risks of each for every pest problem. Choose methods that:

- are the least toxic to nontarget organisms.
- enhance natural controls.
- will most likely permanently limit the pest.
- are the least hazardous for the applicator to handle.
- are most likely to stay on the target area.

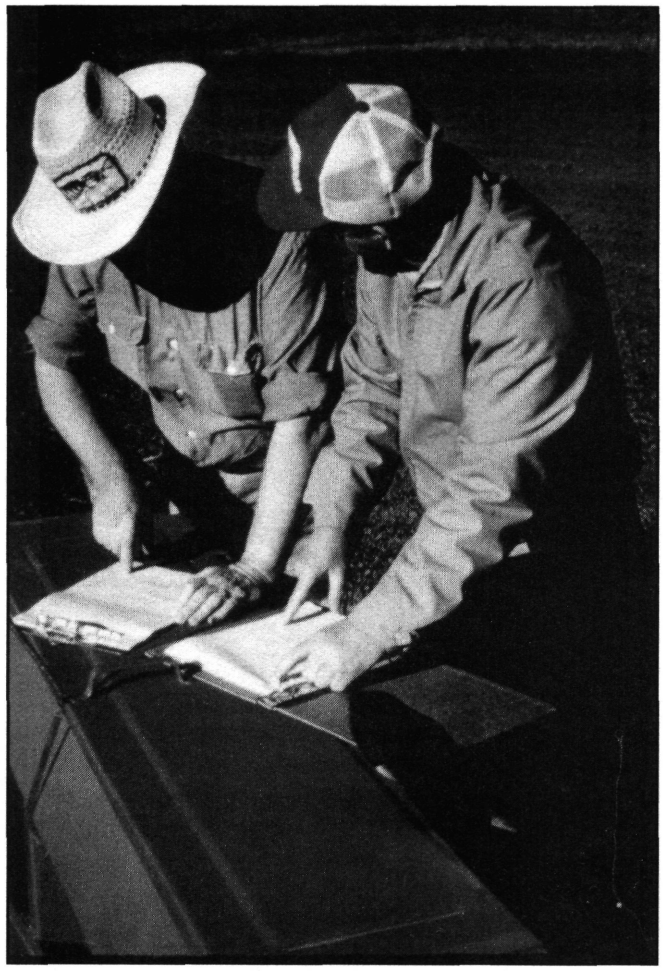
Chapter 2 explains alternative management tactics. Pesticide use is further discussed in Chapter 3.

Most likely, a combination of methods will make up your pest management program. No matter how environmentally-sound or effective the options are, a pest management program is only successful if it can be economically and practically implemented. Keep in mind the factors which limit the number of management options appropriate for use:

1. Budget.
2. Availability of equipment.
3. Availability of personnel.
4. Time frame allowed for management procedures.
5. Availability of products.
6. Public/client acceptance of management methods.

Evaluation

A frequently overlooked, but essential component of successful pest management is the evaluation of implemented tactics. Examination of the management program should answer several questions. Did the methods adequately protect plants from injury? Were there negative consequences of the tactics such as excessive environmental contamination, or promotion of other pest problems (secondary pests) due to the reduction in natural enemies? Were the methods proven to be impractical or too expensive? Pest management efforts are assessed by using the monitoring techniques described in this chapter. The management value of your evaluation directly depends upon how complete and accurate your records are.



Evaluate your pest management program.

Review Questions: Chapter 1

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

1. What is the definition of integrated pest management?

2. The inevitable result of over-simplifying plant problems and relying too heavily upon one method of control is unacceptable pest injury to plants. *(True or False?).*

3. List the five steps of IPM for landscapes.

4. Name two benefits from early detection of pest problems.

5. Explain why degree days are more useful for monitoring pest activity than the calendar.

6. There are thousands of species of insects, fungi, nematodes, and bacteria that are harmless or beneficial to landscape plants. *(True or False?).*

7. Name three normal plant functions that are often confused with pest injury.

8. Each plant disorder has its own unique symptoms. *(True or False?).*

9. List four useful tools for investigating plant disorders.

10. When diagnosing an injured plant, you should concentrate only on the portion of the plant showing damage. *(True or False?).*

11. Name the two kinds of plant injury caused by pests. How do they differ?

12. Why are monocultures subject to pest problems that ordinarily would not affect ornamental trees and shrubs?

13. List three questions that can be answered by the evaluation of your IPM program.

CHAPTER 2

PEST MANAGEMENT TECHNIQUES

After identifying the pest and understanding its biology and economic significance, you are ready to develop a program which provides effective, practical, economical and environmentally-sound pest management. Since the last of these criteria is no less important than the first three, incorporate cultural, mechanical, physical and other non-chemical methods into your IPM program. Remember that although applying pesticide is the most commonly used pest management tactic, pesticides are not the only or best way to manage all pests.

There are two categories of pest management tactics: immediate, short-term suppression; and long-term maintenance of pest levels. For example, a rose garden heavily infested with Japanese beetles would require immediate action, most likely multiple applications of a relatively toxic insecticide. This tactic alone will not in the long-run remedy the Japanese beetle problem. Because the ultimate goal of a pest management program is to create a landscape which can by itself maintain pest populations below injury thresholds, long-term as well as short-term suppression tactics must be used. In this instance, the rose garden could be permanently changed in a number of ways to discourage Japanese beetles:

1. Establish milky spore disease in the lawn to limit Japanese beetle grubs.

2. Plant varieties of roses that do not bloom in July when adult Japanese beetles are feeding.

3. Do not plant other preferred hosts like lindens, crabapples, Japanese maples, Virginia creeper, or weigela near the rose garden.

Various non-chemical and pesticide tactics, alone or in combination, will be appropriate for specific pest management programs. The benefits and drawbacks of several types of pesticides are discussed in Chapter 3 of this manual. The following is an overview of the alternative methods of pest management.

Plant Resistance

The first step in discouraging pest activity on a plant is to assure the health and vigor of susceptible plants (called pest **hosts**). Healthy plants are better able to combat pests and withstand pest injury. Matching the plant species' growing preferences to the site conditions is essential to plant vigor. Many ornamental plant species are naturally suited to living in suboptimal conditions. The London planetree and little leaf linden tolerate compacted soil and therefore do well as street trees. A few ornamental perennials, including Maltese-cross, speedwell, and Siberian iris, are able to withstand wet soil.

Certain species or cultivars of ornamental plants are resistant to damaging pests. Take note of resistant varieties of ornamentals mentioned in nursery catalogues and plant manuals. Likewise, avoid plant species that are particularly susceptible to damaging pests. When selecting plants for installation, take advantage of plant site preferences and pest resistance. In landscapes showing improper plant selection, the growing conditions should be altered to be more favorable to ornamental plants.

Cultural Controls

Cultural controls can be used to create an environment more hospitable to ornamentals and less suitable to pests. Many cultural controls are easily incorporated into existing plant care programs. There are various ways of altering the environment to meet specific plant growing preferences. Some are listed here.

1. Provide deep irrigation for trees and large shrubs (reset the irrigation system; water with a hose).
2. Improve drainage (alter terrain; install drain tiles).
3. Improve soil fertility (fertilize; change pH).
4. Increase soil aeration (vertical mulch; fertilize by soil injection).

5. Create shade (install plants, trellis, or awnings).
6. Increase sun exposure (prune away shading limbs; remove shading structures).
7. Increase crown aeration (thin out planting or plant crown).
8. Provide winter protection (fence or wrap with burlap; apply antitranspirant).
9. Improve water penetration (mulch; till or aerate soil).
10. Lessen plant competition (thin out plantings; remove weeds).

Cultural controls aimed at limiting the pest and pest inoculum are based on pest biology and behavior. **Inoculum** is any stage, structure, or form of a pathogen capable of initiating disease. Decay fungi mushroom and plant parts harboring stem rot bacteria are examples of sources of disease inoculum. **Sanitation** practices reduce pest habitat and inoculum in the landscape. For instance, rabbits require hiding places near feeding areas. Managers can prevent the destruction of ornamentals by removing brush heaps, trash piles, weed patches, and other rabbit refuges. Similarly, garden pests like grubs, thrips, and aphids take shelter and feed on plant debris. Spading under or removing flowering plants in the fall discourages these pests. Mowing seeding weed patches near landscape plantings and disposing of leaves infested with diseases are examples of reducing weed seeds and disease inoculum through sanitation practices. Many serious plant diseases including leafspots, mildews and crown rots are spread by splashing water created by overhead irrigation and falling rain. Reduce splashing by mulching around susceptible plants. Mulching also helps eliminate weed germination in landscape beds.

Some cultural controls outright kill pests. The shallow tilling of finished flower beds destroys the crown and underground parts of most weeds. A variety of pests including snails, slugs, leafhoppers, and beetles are fatally wounded when exposed to diatomaceous earth. Diatomaceous earth, a dust made from the ground-up shells of fossilized microorganisms, is easily handspread onto the soil and vulnerable plants. As they feed, pests travel over and ingest the tiny, sharp particles. The nematicide Clandosan, made of ground chitin, kills nematodes in a similar way.

Mechanical and Physical Controls

Mechanical and physical controls are a group of tactics which physically separate the pest from the host plant. Hand-removal, traps, barriers, and repellents are simply implemented and totally nontoxic, making them useful components of urban IPM programs. Mechanical and physical controls can be time-consuming, but are nonetheless cost-effective tactics.

Hand-removal

Hand-removal techniques are essential in managing some highly-infectious and harmful landscape diseases. The only management option for root, stem, and crown rots of herbaceous ornamentals is removing and destroying infected plants. The spread within a tree of some vascular diseases is best deterred by promptly removing infected plant parts. This tactic greatly prolongs the life of crabapples with fire blight and American elms with Dutch elm disease.

Physical removal of the pest is also an effective and practical means of managing many insects. Insects that exist in groups, like tent caterpillars and web worms, are readily eliminated from host plants. When resting, the caterpillars gather together inside of their protective web or tent. Removing the ugly protective structure during resting periods will also destroy the injurious caterpillars. Small, soft-bodied pests such as aphids, mites, and sawfly larvae may be blown off of plants with a sturdy stream of water. Hand-removal of immature weed plants is one of the most successful physical control tactics. Pulling weeds is a practical way to maintain established woody ornamental plantings, since repeated applications of herbicides can harm ornamentals.

Traps

Many pest species can be trapped and removed from the landscape. While trapping pests can be a useful management tactic, it is a labor-intensive practice better suited to maintaining, rather than reducing, pests at low levels. Routinely disposing of trapped pests will in itself provide suitable plant protection in some situations. The following are examples of traps that homeowners can use.

Pest	Trap
gypsy moth caterpillars	burlap band around the trunks of susceptible trees
slugs/snails	boards on soil under susceptible plants
boxelder bug	boards or folded paper near boxelder trees
European earwigs	boards or folder paper under flowering plants

These gypsy moth caterpillars resting beneath a burlap band trap are easily removed and destroyed.

The Michigan Department of Natural Resources (DNR) regulates the trapping of vertebrate pests. To trap or handle wildlife in Michigan, you must first obtain a Wildlife Damage Investigation and Control Permit from your district office of the DNR. Mice, rats, moles, voles, and chipmunks are vertebrate pests exempt from DNR regulation. For information about permits, contact your district office of the Michigan Department of Natural Resources.

Barriers

Barriers are used to prevent pests from coming in contact with ornamental plants. If used properly, they will eliminate pest injury. Here is a list of barrier methods:

Pest	Barrier
winter-feeding mice, voles, deer, and rabbits	fences; tree wraps of chicken wire, hardware cloth, or screen
iris borer	thick wood chip mulch around susceptible plants
ornamental tree borers	heavy tree wrap around trunk
fruit-consuming birds and large insects	cover fruit trees and shrubs with fine wire mesh
weeds	mulching; dense ground covers

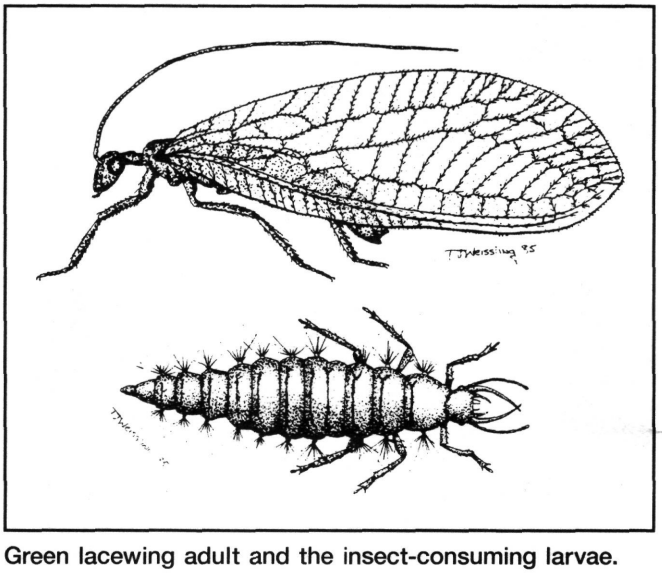
Repellents

Repellents reduce plant injury by rendering host plants less attractive to pests. Chemical repellents, which are applied directly to ornamental plants, alter the taste or odor of the host. There are numerous taste repellents available to limit deer, vole, mice, and rabbit feeding. An acceptable level of control is not guaranteed with taste repellents, however, since these pests will eat treated plants when food is scarce. Repellent devices emitting odors, noise, light, vibration, and other stimuli offensive to pests are also available. Flower beds can be protected from aphids and leafhoppers by covering the soil around plants with an aluminum foil mulch. The effectiveness of some of these devices is limited because over time pests are no longer intimidated by the repellent.

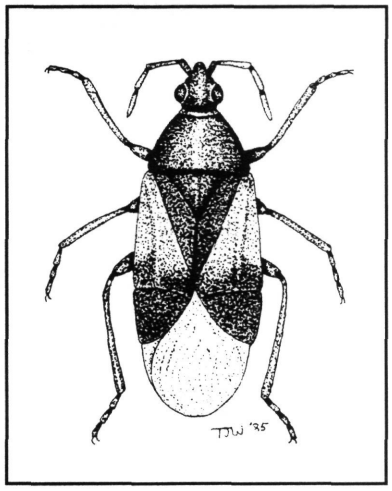
Biological Controls

Biological control limits pests through naturally-occurring and introduced parasites, predators, and diseases. Because the survival and population growth of beneficial organisms is directly dependent upon the availability of the pests, *a landscape cannot simultaneously be pest-free and benefit from biological control.* Natural enemies are slow to respond to building host populations and therefore do not dramatically or quickly reduce damaging pest levels. In stable environments, however, beneficial organisms are in large part responsible for keeping pest populations in check. The importance of beneficial organisms is seldom appreciated until the biological balance of the system is upset. For example, apple growers take for granted the natural control of aphids and scales until they use a product toxic to predaceous mites. Populations of beneficial organisms are often reduced in landscapes because of non-native species of plants, introduction of exotic pests, and heavy use of pesticides.

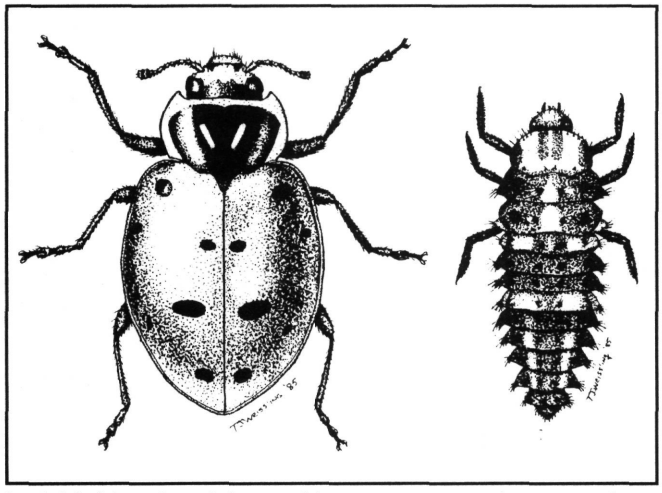
Thousands of species of beneficial disease pathogens, insects, mites, nematodes, and vertebrates occur in the landscape. For almost every species of aphid, there is a species of wasp to parasitize it. You should be able to recognize the various lifestages of some of the most important natural enemies found in Michigan landscapes. Three beneficial organisms are pictured here.



Green lacewing adult and the insect-consuming larvae.



The minute pirate bug (⅛ inch) is commonly found on flowers and plant crevices feeding on thrips, spider mites, and insect eggs.



Ladybird beetle adults and larvae consume large numbers of aphids and mites.

Biological control tactics for ornamental pests take advantage of natural enemies by encouraging the survival of existing natural enemies and by increasing populations of beneficial organisms.

Encouraging Existing Beneficials

Beneficial organisms require more than merely the presence of a host to thrive. The landscape can be manipulated in favor of natural enemies by providing alternative hosts and favorable habitat. Installing a wide variety of plant species creates a more biologically-stable landscape. Diverse plantings will support a greater number and assortment of organisms, including the food sources of natural enemies. For example, only the larvae of parasitic flies and wasps attack pests. The adults require pollen or nectar from flowering plants and weeds. Only a landscape containing a variety of blooming plants throughout the season will provide a stable alternative food source for these parasites.

Established populations of beneficials should be protected by avoiding any unnecessary environmental disturbances including, most obviously, pesticide applications. Broad-spectrum fungicides eliminate beneficial as well as plant disease fungi. Predaceous and parasitic insects usually are more sensitive to insecticides than are plant-feeding pests. Pesticide applicators must use pesticides judiciously to preserve biological controls.

Increasing Natural Enemy Populations

The United States government imports and studies hundreds of species of natural enemies to limit serious crop and forest pests. Researchers are currently exploring the use of weed-feeding insects and fungal diseases to suppress weeds. Past experience has shown that importation and release of any organism can result in new pest problems, so this management activity is restricted to government personnel. However, there are a few beneficial organisms that are commercially available to the public for release programs. Sources of praying mantid egg masses, ladybird beetles, and lacewing eggs are listed in the Resources section of this manual. After the release of large numbers of a beneficial organism, a majority of them will move out of the area in search of favorable habitat. The few that remain will aid in limiting pest populations. Natural enemy release programs are best used in an IPM program to increase public awareness or participation.

Several pest pathogens have been formulated into microbial insecticides. The most commonly used microbial insecticide is *Bacillus thuringiensis* or **Bt**. This bacterial disease kills many insect larvae including armyworm, eastern tent caterpillar, gypsy moth, and fall webworm. Another example of a bacteria microbial is *Bacillus popullae* or milky spore disease which attacks Japanese beetle and other white grubs. A parasitic nematode, *Steinernema carcocapsae* is commercially available to limit hundreds of species of maggots, caterpillars, and grubs. Insects may die as soon as 48 hours following *S. carcocapsae* application.

When properly applied, pathogens provide plant protection without endangering the environment or nontarget organisms. Unlike their chemical counterparts, however, microbial insecticides do not provide immediate suppression. In pest outbreaks, unacceptable plant injury can occur in the time it takes pests to succumb to the disease. However, microbials have been used successfully to maintain low pest levels. Because of public concern about exposure to toxic materials, many areas long infested with the gypsy moth have switched from chemical to microbial insecticides. Recently, the emphasis of the Michigan Department of Agriculture gypsy moth management program has changed from eradication through the use of the toxic insecticide carbaryl to low-level pest maintenance using Bt.

Review Questions: Chapter 2

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

1. Why is it important to use both short-term suppression and long-term maintenance tactics in pest management?

2. Healthy, vigorous plants better withstand injury by pests. *(True or False?).*

3. Name five of the ten ways cultural controls can alter the environment to meet specific plant growing preferences.

4. Name one sanitation practice that reduces pest inoculum in the landscape.

5. Give examples of two diseases and two insects that can be managed with hand-removal techniques.

6. The trapping of wildlife is regulated by the MDNR. Which landscape pests are exempt from such regulations?

7. How do barriers protect ornamental plants?

8. In order for a landscape to benefit from biological control, it should be free of all pests. *(True or False?).* Why?

9. Name three beneficial organisms common in Michigan landscapes.

10. List two ways to encourage beneficial organisms existing in the landscape.

11. What is the most commonly used microbial insecticide called? On what insect larvae is it effective?

CHAPTER 3

APPLICATION OF PESTICIDES

Properly selected and applied pesticides are useful tools in IPM programs. As with every pest management technique, pesticide applications should be as safe and simple to implement as possible. Attempting to "make do" with inadequate equipment, time, or personnel increases the chance of poor pest management, plant injury, and accidental pesticide contamination. As a result of such errors, you may be faced with legal fines as well as a diminished professional reputation. This chapter outlines points to consider when choosing pesticides and application equipment, and techniques to apply pesticides effectively.

Selecting a Pesticide

Pesticides are substances or mixtures of substances used to destroy, repel, or prevent pests. There are four ways of classifying pesticides: 1) type of pest controlled 2) pesticide chemistry 3) mode of action 4) pesticide formulation. These categories are discussed in the Pesticides chapter of the core manual and are summarized in the tables accompanying this section. The wide variety of commercially-available pesticides reflects the manufacturers' attempts to market products that will best handle various pest problems. Carefully consider the pesticide characteristics and how they will affect your particular problem.

Choose a pesticide that is:

- labeled for the pest
- able to produce the desired level of control
- minimally disruptive to the environment
- not damaging (phytotoxic) to the host and nearby plants
- compatible with other plant management strategies
- acceptable to the public

Your first and foremost concern when selecting a pesticide is that it is labeled for the pest, and for use on ornamental plants. *To use any pesticide in a manner inconsistent with its labeling is a violation of federal law.*

Classification of Pesticides For Landscape Use

Pesticide Classification	Targeted Pest
Insecticide	Insects and related animals
Acaricide	Mites and ticks
Miticide	Mites
Nematicide	Nematodes
Fungicide	Fungi
Bactericide	Bacteria
Herbicide	Weeds
Aquacide	Aquatic weeds
Molluscicide	Snails and slugs
Rodenticide	Rats, mice and other rodents

In many instances there will be several pesticides labeled for a pest. Which should you apply? This decision is based upon more than simply which pesticide kills the most pests the quickest. As has been stated previously, it is rarely necessary or desirable to eradicate a landscape pest. Other pesticide characteristics often prove more important.

Pesticide Toxicity

To help conserve natural enemies and limit public concern, first consider pesticides with the highest LD_{50} (lowest toxicity). Many useful pesticides are in Categories III and IV (see Signal Word Table on next page). Because they are considered to be only slightly toxic, Category III and IV pesticides have fewer regulations governing their use and less liability associated with pesticide accidents.

Pesticide Mode of Action

The manner in which a pesticide works, summarized in the accompanying table, influences its ability

Signal Word and Toxicity Categories (I-IV)				
Hazard Indicators	**Danger (I)**	**Warning (II)**	**Caution (III)**	**Caution (IV)**
Oral LD_{50}	Up to and including 50 mg/kg	From 50 through 500 mg/kg	From 500 through 5,000 mg/kg	Greater than 5,000 mg/kg
Inhalation LD_{50}	Up to and including .2 mg/liter	From .2 through 2 mg/liter	From 2.0 through 20 mg/liter	Greater than 20 mg/liter
Dermal LD_{50}	Up to and including 200 mg/kg	From 200 through 2,000 mg/kg	From 2,000 through 20,000 mg/kg	Greater than 20,000 mg/kg
Eye effects	Corrosive; corneal opacity not reversible within 7 days	Corneal opacity reversible within 7 days; irritation persists for 7 days	No corneal opacity; irritation reversible within 7 days	No irritation
Skin effects	Corrosive	Severe irritation at 72 hours	Moderate irritation at 72 hours	Mild or slight irritation at 72 hours

to limit pests and its potential for endangering nontarget organisms. **Broad-spectrum pesticides** are developed to suppress a wide range of organisms. This feature makes broad-spectrum pesticides convenient, but also environmentally destructive. Limit the use of these pesticides to situations where there is more than one target pest.

Pests which are highly mobile or destructive for long periods of time may best be managed by a **residual pesticide.** For instance, a **protectant fungicide** would ideally be effective during the entire period of disease inoculation. Aphids, mites, and scales are examples of relatively sedentary pests which can effectively be limited by pesticides that rapidly break down in the environment. Do not expose nontarget organisms to pesticides for a longer period of time than is necessary to manage pests.

Systemic herbicides travel inside of weeds, killing both top and underground plant portions. Their mode of action makes systemic herbicides superior to **contact herbicides** in treating persistent, perennial weeds. **Systemic insecticides** are absorbed into and travel within the host plant. Since the insecticide is contained within the host, only those insects that consume the plant are exposed to the poison.

Pesticide Formulation

There are advantages and disadvantages associated with the use of any one of the numerous pesticide formulations (see Table above). Formulations vary in their cost, ease of application, and potential threat to the applicator and other nontarget organisms:

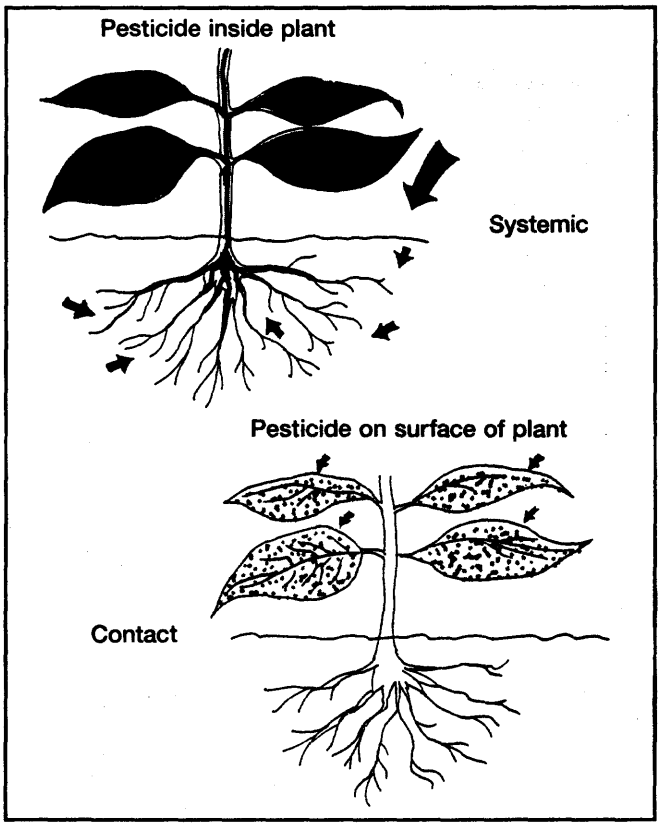
- Some formulations require constant spray tank agitation; others do not.

How Pesticides Work	
Type of Pesticide	**Mode of Action**
Contact:	Pesticides that kill pests by coming in contact with them.
Protectant:	Pesticides that prevent pests from becoming established on plants.
Systemic:	Pesticides that are absorbed into and move within a plant. Kills the pest without harming the host plant. Systemic herbicides that are applied to weed foliage will also kill the roots.
Broad-spectrum:	Pesticides which limit two or more pests of a particular plant. Sometimes labeled as multipurpose chemicals. A broad-spectrum pesticide may be protectant or systemic in its action.
Residual Pesticide:	Pesticides which continue to be effective for an extended period of time after application.
Nonselective Herbicide:	Herbicides that are toxic to all ornamental and weed plants.
Selective Herbicide:	Herbicides which kill some plants, but do little harm to others. Usually they destroy *either* broad- or narrow-leaf plants. They are useful for eliminating grass plants in flower beds and ridding lawns of broad-leaf weeds.

- Liquid formulations are easier than dry formulations to measure in the field.
- Compared to liquid formulations, dry formulations are less affected by subfreezing temperatures during storage.
- Some formulations of a pesticide cost more per pound active ingredient than others. Ready-to-use formulations are generally the most expensive.
- Spray solutions applied under high pressure have a great potential for drift.

Which formulation characteristics are regarded most important when choosing a pesticide depends upon the pest management situation. For instance, injection formulations are generally more costly per application, but less likely to contaminate nontarget organisms than a spray solution. You may opt to inject large willows on a college campus suffering from willow leaf beetle to eliminate the risk of exposing humans to drifting insecticide.

Your choice of pesticide formulations will in large part be limited by the application equipment available. The following section is an overview of the various application equipment used on ornamental plants.



Pesticide Formulations

Formulation	Application Method	Relative Risk When Handling	Risk of Moving Off Target	Advantages	Disadvantages
Emulsifiable Concentrates (E, EC)	manual and hydraulic sprayers; mist blower	high	moderate to high	little agitation required	can be phytotoxic; corrosive to equipment
Wettable Powders (WP)	hydraulic sprayer; mist blower	moderate	moderate to high	easy to store and transport; not phytotoxic	visible residue; requires thorough agitation
Flowables (F, L)	manual and hydraulic sprayers	moderate	moderate	easy to store and transport	requires moderate agitation
Granules (G)	manually and mechanically spread	low	low	no mixing; penetrates dense foliage	not many landscape uses
Baits	manually spread	low	low	no mixing; minimal contamination	may attract nontarget organisms
Injection	injected into drilled holes in trunk	low	low	no environmental contamination	uneven chemical distribution; wounds tree
Implantation	implanted into drilled holes in trunk	low	low	requires no special equipment	can only deliver small amounts of chemical

Pesticide Application Equipment

There are several types and sizes of equipment available for applying pesticides to flowering plants, ground covers, shrubs, and trees. What kind of equipment is best to use depends upon the target plants, type of pest, and pesticide formulation. No matter how simple or sophisticated, application equipment must be in proper working order to deliver at a uniform and consistent rate. Keep a record of the maintenance schedule for all equipment. The equipment should routinely be cleaned and checked for leaks, plugged screens or lines, and worn parts. Failure to do so can result in costly accidents and breakdowns.

Pesticide residues should be removed from all application equipment, preferably after each use. Wipe off the surfaces of spray trucks, guns, and hoses. Flush out residues inside of spray guns, hoses, and the pump by running fresh water from the spray tank through the spray gun. Be sure to spray the rinse water back into the spray tank. Herbicide residues cannot be adequately washed off of application equipment. Never use herbicide application equipment for any other type of pesticide.

Manual Sprayers

Manual sprayers commonly used to spray ornamental plants are relatively inexpensive, simple to operate, maneuverable, and easy to clean and store. Their versatility makes manual sprayers an asset to almost any plant care organization.

Compressed-air sprayers are used to spray flowers, ground covers, shrubs, and small trees. These sprayers hold 1.5 to 5 gallons of spray and can be carried by hand or on a shoulder strap, or mounted on a cart. A uniform spray mixture is maintained by shaking the tank. A hand-operated pump develops a head of air pressure that forces spray material out of the tank and through a nozzle. Pressure in the tank will drop as the material is sprayed. To reduce the rate of the pressure drop, fill the tank only two-thirds full with spray material and repressurize the tank frequently. The sprayer can be fitted with interchangeable or adjustable nozzles to meet the requirements of various pesticides, ornamental plants, and spray areas. Some compressed-air sprayers use a pre-charged cylinder of air or carbon dioxide to provide pressure. A spraying pressure between 20–60 psi is maintained by a pressure valve. These units are bulky and are, therefore, mounted on wheels.

Backpack sprayers can be used for many of the same kinds of applications as compressed-air units. The weight of the backpack is supported across both of the applicator's shoulders to lessen fatigue. Pressure is supplied by a hand-operated piston or diaphragm pump. To maintain the pressure, the applicator must provide intermittent strokes every few seconds. A uniform mixture of spray is maintained by mechanical or hydraulic agitation. Hydraulic agitation mixes the spray material by bypassing some of the solution back to the tank through an agitator nozzle.

Backpack sprayers can be used for small tree, as well as shrub, applications.

Wick applicators are designed to apply systemic herbicides with precision. They are particularly useful for managing weeds growing among established ornamental plants. Herbicide flows from a reservoir down a hollow wand and saturates an applicator wick or wetting pad. The applicator then "paints" weeds with herbicide. The flow of the chemical is controlled by an on-off switch and a dripper regulator.

Power Sprayers

Power sprayers use gasoline engines, or sometimes batteries, to agitate spray solutions and provide spray pressure. Various models are available which are useful for small ornamental plants, as well as large tree applications.

Small power sprayers with about 3-horsepower gasoline engines and 15- to 30-gallon spray tanks are well suited for pesticide applications on golf course, school, park, and private landscapes. Pumps are available which can supply low pressures (up to 60 psi) or high pressures (about 300 psi). A variety of spray guns, wands, extensions, and nozzles make small power sprayers adaptable to many conditions. The versatility of small power sprayers makes them a good investment for many applicators.

Rotary nozzle sprayers are an economical means of applying pesticides to large plantings of small ornamentals. These lightweight, hand-held units

have a battery-powered, spinning cup which throws spray in a hollow cone pattern 4 to 7 feet in diameter. The cup speed controls the droplet size. Rotary nozzle sprayers are ideal for IPM programs since they require very little energy to run and apply minimal amounts of spray solution.

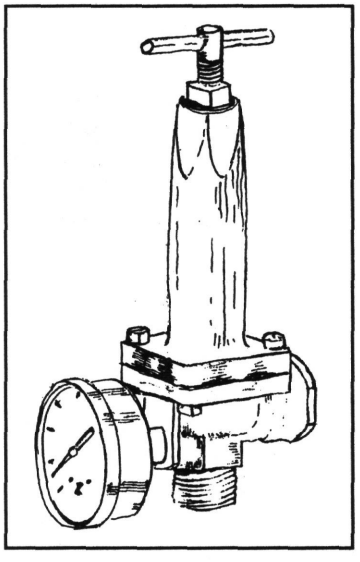
Hydraulic sprayers are traditionally used to spray ornamental and shade trees, but can be rigged for use on small ornamental plants as well. They can be equipped with a variety of sizes of tanks, pumps, hoses, and hand-held spray guns. Sprayers are available with tank capacities from 30 up to 1,500 gallons and with pumps that can supply up to 60 gallons per minute. Pressures range from 200 to 800 psi. Foundation plantings and flower beds can be treated with hydraulic sprayers of moderate pumping capacity (10 gpm at 400 psi) that are fitted with 1/4–1/2 inch hose. Tall shade trees require high pressure, high volume pumps capable of 35-60 gpm at 650 psi.

Hand-held guns are used with nearly all hydraulic sprayers. Many applicators use a variable discharge-angle gun. With a twist of the handle the spray angle can be controlled from a wide angle for shrubs and small trees, to a solid stream for tall trees. Droplet size can be altered by changing the nozzle or disc size. Smaller drops provide better coverage, but less vertical height and more drift. Spray guns fitted with a large-capacity nozzle or large-holed disk make it possible to attain spray heights of up to 100 feet. Nozzles wear with use, particularly when exposed to abrasive materials like wettable powders. As they wear, the orifice becomes larger and the nozzle output increases. To lessen this wear, use hardened stainless steel, chrome-plated brass, or ceramic nozzle components.

Spray mixtures used in hydraulic sprayers are dilute and applied until the spray solution begins to drip off of the foliage, or to the **point of runoff.** While calibration of the sprayer is not required, the applicator must obtain thorough plant coverage.

This foliage has been sprayed to the point of run-off.

A relief valve is necessary on all high-pressure hydraulic sprayers to protect the system from excessive pressure, and to regulate the pressure that is applied to the spray gun. Whatever liquid does not go to the handgun is returned to the tank through the bypass line. Relief valves must be sized to handle the desired flow rates and pressures. A pressure gauge covering the range of operating pressures should be installed in the supply line to assist in adjusting and monitoring the sprayer's operation. A damper is needed to protect the gauge from the pump pulsations. All components of the system must be designed to withstand the high pressures produced by the pump. Do not operate a pump at pressures above those recommended by the manufacturer as it will soon break down or wear out.



High-pressure sprayers should be fitted with a pressure regulator and gauge.

Hydraulic sprayer tanks must have an air inlet valve to equalize the pressure outside and inside of the tank. Large and small spray tanks can collapse during use due to the vacuum created in the tank as spray is pumped out.

Mistblowers are airblast sprayers which distribute pesticide onto the plant in a blast of air. They vary in size from small backpack blowers that move a few 100 cubic feet of air per minute (cfm) at velocities up to 200 mph, to large truck-mounted machines that move up to 60,000 cfm at velocities near 100 mph. Single or multiple nozzles inject the pesticide into the air stream. Since mistblowers are dependent on a column of air to carry the pesticide, they must be operated in *virtually no wind.* Do not spray when the wind exceeds 4 mph.

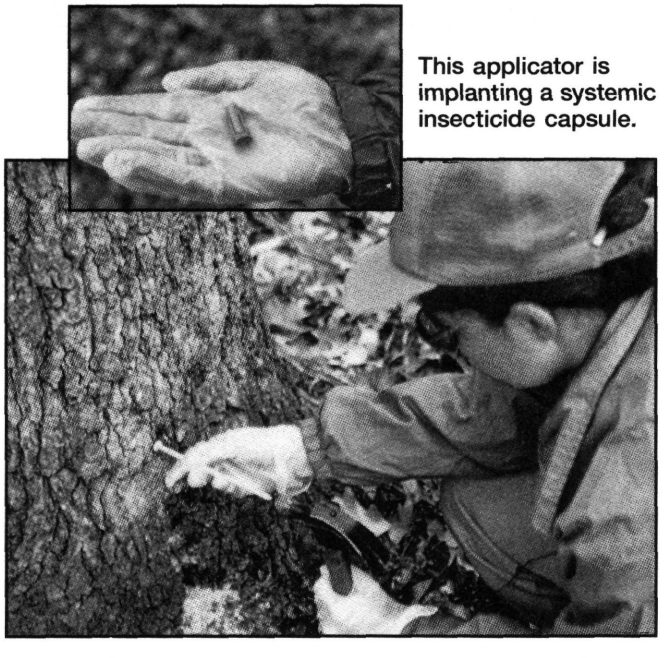
To obtain uniform coverage with mistblowers, you must direct a larger proportion of the spray material to the top of the tree. There is a difference of opinion as to what this proportion should be, but a general guideline is to apply two-thirds of the material into the top half of the tree. Various combinations of air

volume, air velocity, liquid volume, and liquid pressure are used to obtain the desired spray distribution. Calibration is particularly important with mistblowers because it is usually difficult to see the applied pesticide deposit. You must know the amount per minute of pesticide that the blower is delivering to the target and then time your application so that the right amount of spray concentrate is applied.

Compared to hydraulic sprayers, mistblowers are lighter in weight, use far less water, and are physically easier to operate. However, mistblowers have limited landscape applications because of the great potential for drift of highly-concentrated pesticide.

Injection and Implantation

Insecticides, fungicides, and fertilizers can be applied directly into shade and ornamental trees by **injection** and **implantation**. First, holes are drilled into the outer sapwood of the trunk or root buttress of the tree. To encourage rapid healing, holes should be as small in diameter as possible. An injection site can be used only once, because within several days after a hole is drilled into healthy sapwood, the tree reacts by isolating the wound from the rest of the tree. Liquids can neither move into or out of an isolated area.



This applicator is implanting a systemic insecticide capsule.

Injection solutions are injected by gravity or pressure into the drilled holes. Pressure of 10-40 psi is usually provided by a manual compressed-air sprayer. Implantations are solid chemicals, usually in water-soluble capsules, which are inserted into drilled holes. Injected or implanted chemicals are dissolved and carried up into the tree with the sap. Uptake is most efficient when sap is rapidly moving—warm, sunny days when trees are in leaf. Because injected and implanted chemicals move upward, they are not used for managing pests and diseases of roots.

Injection and implantation are efficient and safe methods of pesticide application. Practically all of the pesticide is placed within the tree. There is little waste or environmental contamination and heavy, expensive equipment is not needed. However, these methods do not guarantee uniform distribution of the chemical. Some branches may be overexposed while others receive little or no chemical. Be careful to drill holes every few inches around the tree trunk to ensure even pesticide distribution to all major branches. Implantation has two advantages over injection. Implantation is more convenient and requires less labor because a tree must only be visited once per application. Also, no specialized equipment is required. The main disadvantage of implantation is that it can be used only for applying small amounts of pesticide or fertilizer.

Spray Application Techniques

The manner in which a pesticide is applied to the plant is as important to successful pest management as the choice of pesticide and application equipment. It is the job of the pesticide applicator to apply only the amount of pesticide necessary for plant protection. Suitable plant coverage with minimal pesticide output can be achieved with the appropriate spray stream. Consider the weather conditions, plant size, and pest when adjusting the size of the spray gun orifice.

As is shown in table at the top of next page, a large orifice is only beneficial when drift must be at a minimum. Resist the temptation to fit the spray gun with a medium-sized orifice for all jobs. Much pesticide can be saved and better plant coverage achieved on shrubs and flowering plants when a small orifice is used.

It is easy for applicators to over-apply pesticide when spraying large trees. Take care to avoid over-application since pesticide exceeding the point of runoff drips off of the target tree. Use the following steps to limit this problem and attain thorough coverage:

1. Stand close to the tree trunk and direct a high-volume, tight spray stream vertically into the interior of the crown. Be sure to wear the recommended protective gear and move out from under any dripping pesticide.
2. Stand away from the tree and apply pesticide to the top of the crown. Foliage on the lower portions of the crown will catch the pesticide dripping from above.

Orifice Size and Spray Stream Characteristics			
Orifice Size	**Conditions**	**Advantages**	**Disadvantages**
moderate	normal	Produces a lot of height in addition to small droplets needed for complete coverage.	Some drift likely.
large	windy	Produces large droplets and minimizes drift.	Requires a greater amount of pesticide to achieve adequate coverage.
small	very calm	Results in excellent coverage and reduction in the amount of pesticide applied.	Great potential for drift. Little spray height possible.

3. Reduce the height and volume of the spray stream by adjusting the spray gun to a fan pattern, and apply to the upper untreated areas downward.

Much pesticide is also wasted when applied where pests are not. For example, frequently a pest infestation occurs on only one plant in the landscape, or on one section of an individual plant. It is a waste of time and material to saturate an entire juniper to manage a population of juniper scale limited to one area of the shrub. Use the monitoring techniques discussed in Chapter 1 of this manual to determine precisely where to apply pesticides.

Once a pesticide is applied, do not undermine its effectiveness through careless actions. For instance, preemergent herbicides form a chemical barrier which prevents weed seeds from germinating when applied to soil that is free of plant material and debris. Any disturbance to the treated area, including footsteps and newly-dug planting holes, breaks the barrier and greatly diminishes herbicidal action.

The pesticide application technique should reflect pests' feeding or inoculation habits. To be effective, contact insecticides must come in contact with the target insect. Lacebugs typically feed and rest on the underside of shrub leaves. Spraying a contact insecticide in a traditional manner—coating leaf surfaces to the point of runoff—will do little to limit lacebugs. The applicator must be low to the ground and direct the spray stream up into the shrub. Similarly, insects like scales and mealybugs feed on all sides of a stem. Applicators are often disappointed by rapid reinfestation of these insects after a contact insecticide application. Twig areas not thoroughly coated with insecticide harbor individual scales and mealybugs which re-populate the host. Many fungicides act as a plant protectant by preventing fungal spores from entering the plant leaf. The level of control produced by protectant fungicides is dependent upon how completely the leaf surfaces are treated.

As these examples illustrate, *it is well worth the time and effort to adjust pesticide spray output and to tailor pesticide applications to pest habits.* Refer to pest management guides and the pesticide label for application technique and protective gear recommendations. Remember to follow these guidelines when applying pesticides:

- Do not spray *with* the wind, as drift will be enhanced. Do not spray *into* the wind, because you are directly exposed to the pesticide. It is best to spray at a 90–135 degree angle to the wind.
- In windy conditions use a larger orifice to create heavier pesticide drops, and limit drift.
- Be sure to thoroughly coat the treatment area with pesticide (leaves, fruit, flowers, twigs and trunk).
- When spraying tall trees, use a thin "pencil" stream at the top, changing to a fan-pattern at the bottom of the tree. Always apply spray from the inside of the tree out, and from the top of the crown downwards.
- Do not spray directly at objects such as houses, cars, or patio areas. Unsightly residues or stains may result. To protect people and animals from pesticide exposure, do not spray into the road or through a fence. Spray plants adjacent to these areas from the side or top of the plant, or from the area out. For example, treat foundation plantings by directing the spray stream parallel to the house or from above the plants down, or by standing against the house and spraying outward.

Record Keeping

In addition to being an essential part of pest management program evaluation, Michigan law requires commercial applicators to record application information. The applicator, at the time of application, must record the following information:

- Name of applicator.
- Address or location of the pesticide application.
- Name and concentration of the pesticide applied.
- Amount of pesticide applied.
- Target pest or purpose of the application.
- Where applicable, the method and the rate of application.

These records must be maintained for at least one year after a general use pesticide application, and for at least three years after a restricted use pesticide application.

Review Questions: Chapter 3

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

1. List the four ways to categorize pesticides.

2. To use any pesticide in a manner inconsistent with its labeling is a violation of federal law. *(True or False?).*

3. Name two benefits to using pesticides in the toxicity categories III and IV (signal word caution)?

4. What type of pesticide(s) will limit mites?

5. Since they work on numerous species of pests, there is no disadvantage to using broad-spectrum pesticides. *(True or False?).*

6. Describe the difference between systemic and contact herbicides. Why are systemic herbicides more useful for managing perennial weeds?

7. Name one advantage dry pesticide formulations have over liquid formulations. Name one advantage liquid pesticide formulations have over dry formulations.

8. What is the abbreviation for wettable powders? Emulsifiable concentrates? Granules?

9. If washed thoroughly with soap and water, it is alright to use a spray tank previously holding herbicide for an insecticide application. *(True or False?).*

10. Name two types of sprayers useful for applying pesticide to small ornamental plants.

11. Systemic herbicides can be applied to weeds growing among ornamental plants with what kind of applicator?

12. Smaller spray droplet size provides better coverage, but less vertical height. *(True or False?).* Smaller droplet size produces the least amount of drift. *(True or False?).*

13. Why is it necessary to have a relief valve on high-pressure sprayers?

14. Mist blowers must only be used under what weather conditions? Why?

15. Which application method(s) poses the least risk for environmental contamination?

16. Name two reasons to adjust the spray gun orifice when switching from tall tree spraying to foundation plant applications.

17. Why should applicators avoid spraying against or directly into the wind?

18. Explain why coating leaf surfaces to the point of runoff with a contact insecticide will not limit lacebugs.

19. How should an applicator direct the spray stream when applying pesticide to plants against a fence?

20. Name all of the information concerning pesticide applications that commercial applicators are required by Michigan law to record. These records must be maintained for how long after the application of a restricted use pesticide? A general use pesticide?

CHAPTER 4

PESTICIDE SAFETY

Pesticide applicators are legally and socially responsible to safely handle pesticides. Federal and state regulations that assure pesticides are used safely are discussed in the Pesticide Laws and Regulations chapter of the core manual. It is *your responsibility* to comply with the regulations. Failure to do so could result in lawsuits, fines, and imprisonment.

By federal law, the pesticide label must include safety guidelines for use, storage and disposal of the product. Read the pesticide label *before* purchasing the product. Review the label *before* opening, mixing, or applying a pesticide.

Every pesticide applicator can improve their pesticide handling safety procedures. Experienced applicators become so familiar with equipment and materials that they may become careless or take safety shortcuts. Compare the checklist at the end of this chapter with your pesticide handling practices to see which of the common causes of accidents apply to you. Review this chapter for safety guidelines in pesticide use, storage, and disposal. The last section explains how safe practices can enhance your public relations.

Applicator Safety

Pesticide manufacturers spend much money establishing the hazards associated with the use of each product. *You must comply with the label guidelines for protective gear.* The types and use of applicator gear is outlined in the Pesticide and Human Health chapter of the core manual. Applicator gear is only effective if it fits well and is clean. Protective gear is expensive, and is essential to your physical welfare. Take care of it accordingly. Be sure to follow manufacturers' guidelines for scheduled mask filter and cartridge changes. Frequently wash or wipe-off pesticide residue from respirators, boots, gloves, and hats. Wash contaminated coveralls and other clothing separately from household laundry. Torn gloves, coveralls, and rubber boots will not adequately protect applicators from pesticide. Have on hand and clean all of the necessary gear before you mix or apply pesticides.

You may choose to wear more protective gear than is required by the label. This is an especially good idea for people who have a naturally-low cholinesterase level (see below), and those who use pesticides on a regular basis. At a minimum wear gloves, face and eye protection whenever mixing pesticides. Even pesticides of relatively low toxicity are hazardous in the concentrated form. Whenever making overhead applications, protect yourself with gloves, a respirator, goggles, and a hat.

Applicator Cholinesterase Level

Cholinesterase is an essential chemical in the nervous system of many animals including humans and insects. Carbamate and organophosphate insecticides work by fatally inhibiting cholinesterase levels in insects. Exposure to cholinesterase-inhibiting insecticides also lowers the applicator's cholinesterase level. If you are frequently exposed to carbamates (such as carbaryl, oxamyl) or organophosphates (including diazinon, dursban, malathion, acephate), you should establish a regular cholinesterase testing program with your doctor. Since everyone has a different normal level of cholinesterase in their nervous system, a base-line cholinesterase level should be established during the off-season. The base-line level can then be compared to cholinesterase levels taken during the spray season. Applicators whose cholinesterase levels have significantly dropped should avoid further exposure to carbamate and organophosphate insecticides. For more information, contact your doctor.

Pesticide Poisoning and Symptoms

Most pesticide poisonings result from accidents, or careless and ignorant use. However, even cautious applicators who follow the label, maintain equipment, and apply pesticides with safety in mind may experience overexposure to pesticides. Should an accident occur, the best defense against serious harm to yourself and others is to *be prepared.* You should know at all times what chemical, formulation, and rate you are transporting and applying. Have on hand and know how to use clean-up and first-aid materials. Use the checklist provided in this section as a guide to pesticide first-aid and safety materials for the truck or work station. Being prepared requires that you are familiar with the common pesticide poisoning symptoms.

Checklist of First Aid and Safety Materials for Operations

- ☐ pesticide product labels
- ☐ pesticide Material Safety Data Sheets (MSDS)
- ☐ Syrup of Ipecac
- ☐ first aid kit
- ☐ eye wash
- ☐ detergent soap
- ☐ source of clean water
- ☐ extra pair of rubber gloves
- ☐ change of clothing
- ☐ pesticide spill absorbent material (kitty litter)
- ☐ fire extinguisher
- ☐ Human Pesticide Poisoning or Poison Control telephone number
- ☐ name, address, and phone number of the physician or hospital which provides emergency poisoning care

Poisoning symptoms vary with the type of pesticide, where exposed, the amount absorbed, and the general health of the individual. The most common symptoms are discussed in the Pesticides and Human Health chapter of the core manual, and are reviewed in the accompanying table. While some symptoms begin immediately upon exposure, others are delayed for several hours or even days. The symptoms of pesticide poisoning are similar to those of other ailments including heat exhaustion, asthma, and food poisoning. Remember, alcohol intensifies the effects of pesticide poisoning and should be avoided whenever pesticide over-exposure is suspected.

An applicator who is ill after handling pesticides is not necessarily poisoned. If you suffer from any of the mentioned symptoms and believe the cause may be from pesticide exposure, call your doctor. *Let your doctor decide whether pesticide poisoning has occurred.*

Symptoms of Pesticide Poisoning

Herbicides and Fungicides

- headache
- skin irritation (drying, cracking, itching); skin discoloration
- sweating
- muscle twitching, weakness, or fatigue
- nausea, diarrhea
- coughing, hoarseness and congestion
- burning sinuses, throat and lungs
- chest pains

Insecticides

- headache
- visual disturbances (blurred vision)
- abnormal eye pupils (primarily pin-point pupils, but rarely dilated pupils)
- greatly increased sweating, salivation, tearing or respiratory secretions

Severe Poisoning

- nausea and vomiting
- intense thirst
- fever
- increased rate of breathing, or
- respiratory paralysis
- muscle twitching, or
- muscle weakness
- confusion
- convulsions
- unconsciousness
- death

Pinpoint pupils are a symptom of pesticide posioning.

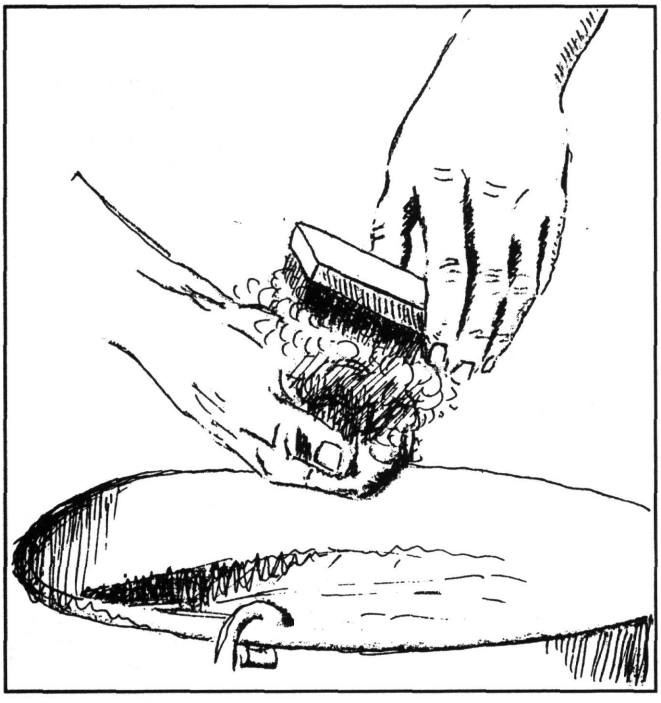
First Aid Procedures

First aid treatment varies according to the type of exposure. Be familiar with the appropriate first aid measures before beginning applications. There will be little time or opportunity to look up first aid recommendations should you ever need them. Remember, pesticide poisoning symptoms may not be immediately evident. After exposure to pesticides, *do not put off first aid until you feel bad.* If you

fear that severe exposure has occurred, first call a doctor. First aid is just that—the initial effort to help a victim while medical help is on the way.

Dermal Exposure:

- Remove contaminated clothing.
- Drench skin with water.
- Wash thoroughly (including hair and nails) with a detergent or commercial cleanser.
- Rinse completely.
- Wash again and rinse.
- Dry off and wrap in a blanket.



Inhalation Exposure:

- Immediately get to fresh air.
- Do not attempt to rescue someone in an enclosed area without the proper respiratory equipment.
- Loosen all tight clothing.
- If breathing has stopped or is irregular, give mouth-to-mouth resuscitation.
- Keep the victim as quiet as possible.
- Prevent chilling, but do not overheat.
- If you are with a victim who is having convulsions, watch their breathing and protect them from falling and striking their head. Keep their chin up to keep air passages clear.
- Do *not* give alcohol in any form to the victim.

Eye Exposure:

- Hold eyelids open and wash eyes with a gentle stream of clean running water. Use large amounts of water. Act immediately; delay of even a few seconds may result in injury. Continue washing for 15 minutes or more.
- Do not use medications in the wash water—use pure water.

Oral Exposure:

- If a pesticide has gotten into your mouth, but has not been swallowed, rinse your mouth with large amounts of water.
- If the pesticide has been swallowed, determine quickly whether or not to induce vomiting. Always follow label directions.

Never induce vomiting if:

1. the victim is unconscious or is having convulsions.
2. the pesticide is corrosive
3. the pesticide is formulated with petroleum products (such as ECs and solutions)
4. the pesticide label specifies not to induce vomiting

If the label directs you to induce vomiting, use one of the following methods:

- Induce vomiting for an adult with two tablespoons (one ounce) of Syrup of Ipecac and two glasses of water.
- Induce vomiting for a child with one tablespoon (one-half ounce) of Ipecac and one glass of water.
- Induce vomiting by drinking one or two glasses of water and then touching the back of the throat with your finger. Salt water should not be used to induce vomiting.

The victim should be lying face down or kneeling forward while vomiting to prevent vomitus from entering the lungs. Collect some of the vomitus so that the doctor can run chemical tests. *Do not waste much time inducing vomiting; get to the hospital as soon as possible. Do not attempt to administer antidotes.* If taken improperly, antidotes can be more harmful than the pesticide itself.

Safe Pesticide Handling

Preventing mishaps when applying pesticides is the most effective way to protect the applicator, nontarget organisms, and the environment.

Applicators rely heavily upon application equipment to accurately and safely apply pesticides. Do not neglect to properly maintain all application equipment. Many of the common pesticide accidents, such as blown hoses and leaking tanks and guns, can be avoided by routine equipment inspection and maintenance. Once a problem is detected, do not put off repairs nor take repair "short cuts."

Use an equipment safety checklist, such as the sample in this chapter, to determine needed equipment maintenance throughout the spray season.

Mechanical Equipment Safety Checklist

Inspect equipment for any of the following problems:

- ☐ Worn hoses.
- ☐ Poor hose to reel attachment (leaking).
- ☐ Poor spray gun to hose attachment (leaking).
- ☐ Leaking spray gun.
- ☐ Poor adjustment of spray gun output.
- ☐ Worn seal in pump (leaking).
- ☐ Poor seal of pump to spray tank (leaking).
- ☐ Leaking spray tank.
- ☐ Worn pressure-regulator valve.
- ☐ Poorly-functioning pressure relief valve.
- ☐ Spray-tank trucks or trailers with worn tires, or malfunctioning brakes, lights, etc.

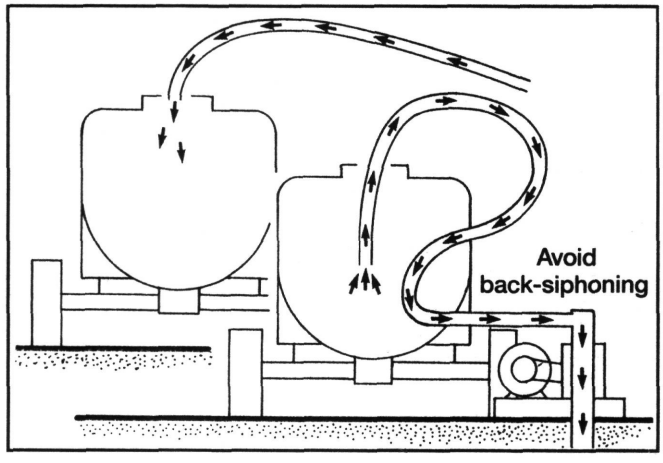
Mixing and Loading Pesticides Safely

Mixing and loading concentrates are some of the most hazardous activities involving pesticides.

Chemical residues from unwashed hands can easily get into the mouth when eating, smoking, or touching the face.

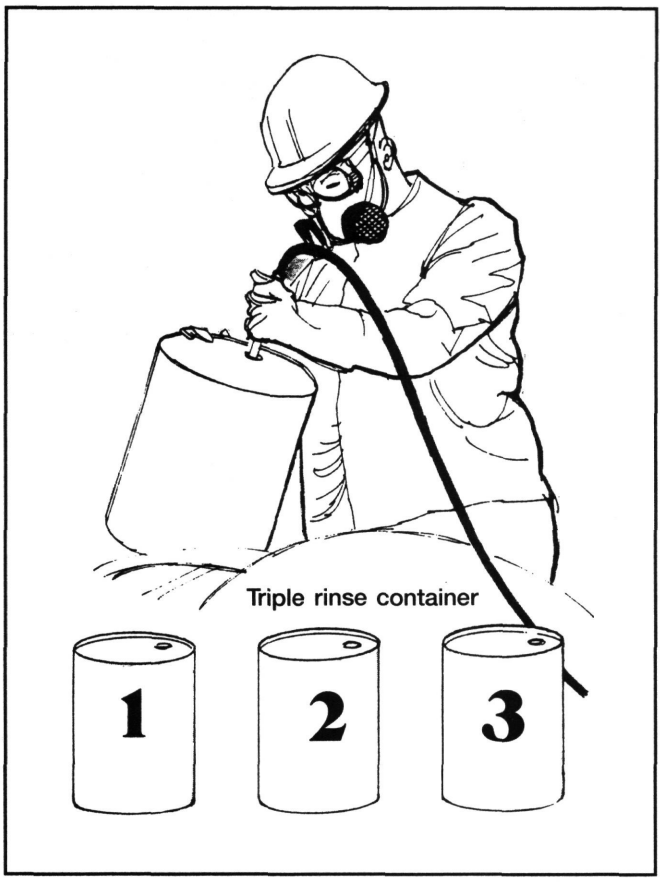
Follow these safety guidelines when mixing:

- *Do not leave the spray tank unattended while it is being filled.*
- *Do not mix above the recommended rate.*
- Before opening the container, review the pesticide label to be familiar with mixing and usage directions.
- Put on protective clothing and gear (gloves, respirator, goggles, coveralls, etc.) before handling pesticides. Never eat, smoke, or chew gum when handling pesticide concentrates.
- Mix in an area which has plenty of light and ventilation and is sheltered from the wind
- To prevent contamination and back-siphoning when filling the spray tank, do not allow the water pipe or hose to come in contact with the spray solution. All fill station water pipes should be fitted with a valve to prevent back-siphoning of the spray solution into the water source.



- Pour concentrates from the container below eye level and avoid splashing or spilling.
- Measure accurately and mix only what can be used during that application.
- Rinse all measuring devices and put rinse water into the spray tank. Store these utensils in the pesticide storage area.
- Triple rinse pesticide containers as you empty them.

Triple rinsing renders containers non-hazardous by removing pesticide residues. Refer to the Pesticide Storage, Handling and Disposal chapter of the core manual for the triple rinsing procedure. Studies have shown that at least 14.2 grams of active ingredient remains in an empty, but un-rinsed five-gallon container of a liquid pesticide formulation (see graph at bottom of page 31). While 14.2 grams of concentrated pesticide may seem insignificant, 25,000 of these un-rinsed containers would contain



780 pounds of active ingredient! Landfill operators are justifiably concerned about the health risks posed by large quantities of unrinsed containers.

Applying Pesticides Safely

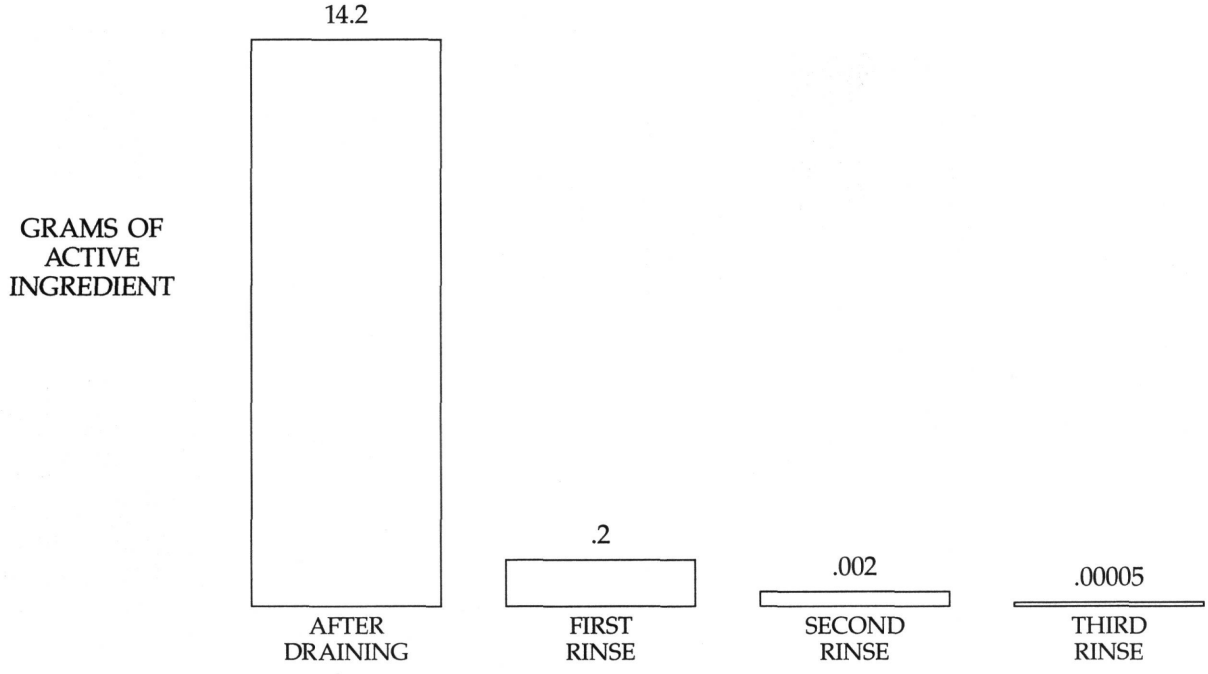
Since ornamental landscape plants are in areas frequented by people, it is especially important for Category 3B applicators to be safety conscious. People depend upon you to protect them, their children, and pets from pesticide spray and residues. Before applying pesticides, carefully inspect the area surrounding target plants. Remove from the area, cover, or wash off the following objects:

- toys
- large play equipment
- sandboxes
- pet dishes
- swim gear
- small swimming pools
- hanging laundry
- lawn furniture
- bird baths
- bird feeders
- ornamental fish ponds

Have clients close house windows and move cars that are in the vicinity of the application area. *Beware of food plants near target plants.* Should you inadvertently apply pesticide to a food plant, it is best to remove set fruit or vegetables. As a part of your inspection, be sure to *check over fences* in the target area for these items.

Triple Rinse and Pesticide Removal

Grams of active ingredient of a liquid formulation remaining in one 5-gallon container.



It is up to you to inform people when it is safe to return to the area after a pesticide application. Check the product label for **reentry periods,** but generally it is safe for people and pets to enter an area after pesticide sprays have dried and dusts have settled.

Application equipment is attractive, and highly dangerous, to children. Equipment that is not in use must be stored in a safe and secure manner. To prevent the accidental release of pesticide from a spray gun during an application, turn off and release the pressure to the gun whenever it is not being used. The serious harm that could come to curious children would be your responsibility. Operating application equipment likewise should not be left unattended. Do not take even short breaks away from the site without first securing all equipment.

Storage and Disposal

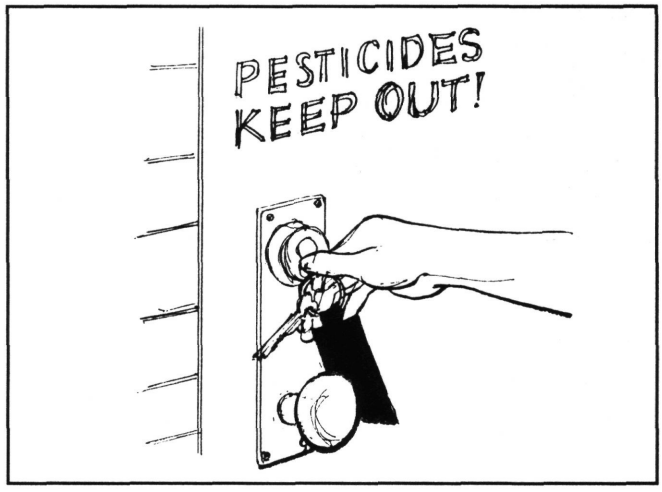
Storing hazardous materials poses a great potential for liability. Also, stored pesticides degrade or are banned for use, and packaging and labels deteriorate. Strive to limit the amount of materials requiring storage through careful planning and application.

It is a good policy to inform your local fire department about your storage facility. Chemical fires require special handling and produce extremely toxic smoke. You may be required by federal law to report when storing certain chemicals. To determine whether or not you are storing reportable chemicals, call the Michigan Department of Natural Resources SARA Title III Office at 517-373-8481 or refer to the Cooperative Extension Service Bulletin #E2173, "SARA Title III".

There are numerous guidelines for establishing a safe, secure pesticide storage area. The following is a summary of the guidelines provided in the Pesticide Handling, Storage, and Disposal chapter of the core manual.

Exterior Pesticide Storage Area

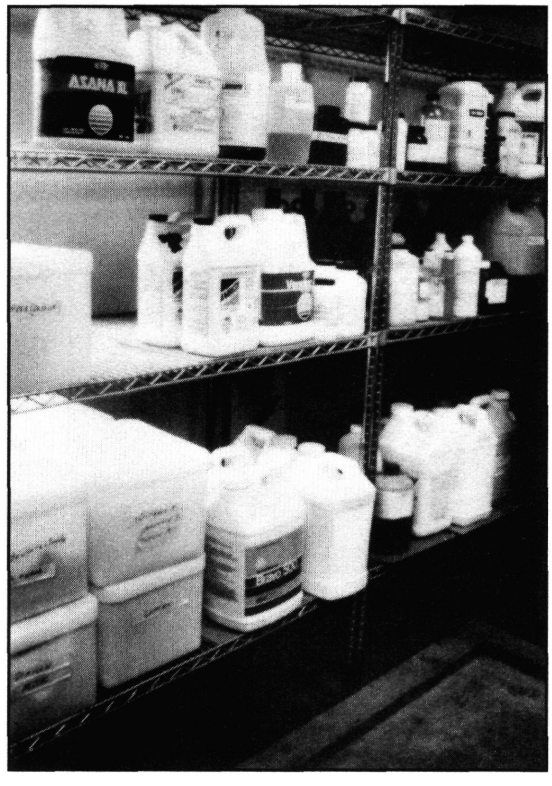
- If possible, have a separate building used only to store pesticides. This building should not be located close to a well.
- Secure the area with fences and locks. Bar any windows.
- Provide good ventilation.
- Post the area with highly-visible signs that warn that pesticides are stored there.
- Use fire-proof construction materials.
- Install a secondary containment structure to prevent groundwater contamination in case of a large spill or fire.
- Provide separate storage areas for volatile herbicides.



Secure the storage area.

Interior Pesticide Storage Area

- Keep an updated inventory sheet.
- Keep temperatures moderate to prevent explosions or degradation of pesticides.
- Post NO SMOKING signs.
- Post fire department and poison control center telephone numbers.
- Have a working fire extinguisher rated for chemical fires.
- Provide chemical spill absorbent material such as kitty litter.
- Keep a supply of soap and water near the storage site.
- Place containers on metal shelving; place drums on wooden palates.



Pesticide Containers

- If possible, keep pesticides in the original container.
- Protect labels with lacquer.
- Attach the label to any other container used to carry pesticide.
- Do not use anything resembling food containers to carry pesticides.
- Securely reseal or bag opened pesticide containers.
- Use old or damaged containers first.
- Mark mixing containers and utensils with the words poison or danger.

Improperly disposing of pesticides may contaminate groundwater, poison wildlife, and cause other environmental damage. Chemical wastes can be interesting to children. Prevent unfortunate events by limiting the amount of waste you create, and by practicing safe pesticide waste disposal. The best way to dispose of a pesticide is to use it in a manner consistent with its label. Adopt these practices to reduce the need for disposal:

- Do not stock up on pesticides. Purchase pesticides in small quantities throughout the season.
- Mix only what can be used per application.
- Apply any leftover pesticide solutions in accordance with the product label.
- Near the end of the season, make an effort to use all opened containers of pesticides.

If there are leftover pesticides, return products to the dealer or manufacturer, or offer it to another qualified applicator. If these disposal options are not possible, consult with the MDNR Waste Management Division at (517) 373-2730. Prior to disposing of pesticide wastes, commercial applicators should consider the current hazardous waste guidelines established under the Resource Conservation and Recovery Act (RCRA) and state hazardous waste statutes. Pesticide wastes classified as hazardous require special disposal and record-keeping practices. MDNR Waste Management Division can provide more information on the RCRA and other legal responsibilities associated with pesticide waste disposal.

Pesticide Spills

Pesticide spills include the small amount of concentrate that escapes as you mix, a leaking container, or an overturned spray tank. Your goal is to promptly and effectively stop the spill, contain it, and clean it up.

Stop the Spill. Stop the leak at once if possible. If a hose is broken, turn off the sprayer and wrap the torn area to prevent leaking as you travel back to the shop. A leaky spray tank should be emptied as soon as possible into another tank, or sprayed to manage labeled pests. Repair leaking tanks immediately and completely. Since spray guns frequently develop leaks during use, have on hand an extra spray gun during application jobs. Leaking pesticide containers also demand immediate action. Place the faulty container into a larger container and use the material as quickly as possible.

Contain the Spill. Pesticide spills must be contained to avoid contaminating groundwater, sewers, and surface water. In the case of flowing pesticides, construct a dam to prevent the chemical from spreading, or catch it with a suitable container. Thoroughly soak up puddles with absorbent material such as clay cat litter or commercially-marketed products. Handle the saturated absorbent material as you would the pesticide itself.

Clean Up the Spill. Do not attempt to clean pesticides off of porous materials such as brooms, or leather shoes or gloves. Dispose of these items once they are contaminated. Vehicles, application equipment, and rubber protective gear exposed to spilled pesticide should be carefully washed with an alkali cleanser such as dish soap. Be sure to wear protective gear when cleaning items.

If the spill is minor, it can be cleaned up by promptly applying activated charcoal to the surface. Activated charcoal will absorb or chemically tie-up the pesticide and prevent plant injury and long-term environmental contamination.

It may be necessary to decontaminate or neutralize the spill, especially if the pesticide is a carbamate or organophosphate insecticide. First refer to the label for decontamination recommendations. Full-strength household bleach and hydrated lime are effective decontamination solutions. Work the solution into the contaminated area with a coarse broom, then pick up the residue with fresh absorbent material. Repeat this procedure as necessary. Finally, cover the area with at least two inches of lime and then topsoil. Be cautious to properly dispose of contaminated absorbent material and soil.

Report the Spill. Large spills which have the potential to reach surface or groundwater must be reported immediately. To determine if spills are of reportable quantities, refer to Extension Bulletin #E2173, "SARA Title III", or contact the MDNR SARA Title III Office at 517-373-8481. Should a reportable spill happen to you, contact:

1. Pollution Emergency Alerting System (1-800-292-4706)
2. the local Emergency Planning Coordinator
3. the State Police Emergency Management Division (517-334-5113)
4. the local fire department

Public Relations

People are increasingly concerned about the use of pesticides and the possibility for exposure to these toxic materials. Those who use pesticides must recognize that their neighbors and other community members feel they have a legitimate concern about pesticide applications. Citizens pressure community leaders and legislators to regulate pesticide use on urban landscapes. There will no doubt be increased regulations and restrictions imposed upon pesticide applicators. The result is greater liability when regulations are disobeyed. The wise applicator is wary of the legal aggressiveness shown by people attempting to recover damages. Applicators are expected to conduct themselves professionally and with safety consciousness.

Much of the potential criticism can be avoided if the applicator is considerate of public concerns, is knowledgeable and informative, and uses extra care in pesticide applications. This chapter discusses ways to work effectively with the public.

The Professional Applicator

Uneducated or inexperienced applicators commonly over-apply pesticide with the misconception that "more is better." Too few applicators regularly inspect plants to determine if pest levels are at the action threshold, or evaluate the effectiveness of applied tactics. Flagrant errors, such as using herbicide application equipment for an insecticide application and making an application at the wrong address, have been known to occur. Because most pesticide application problems are within the control of the applicator, they are best resolved by improving operational practices.

Merely being an experienced, or even certified, applicator does not make you a professional pesticide applicator. It is not enough to know how to safely and effectively use pesticides. Professional applicators apply that information on a daily basis.

Look professional. People equate professional ability and integrity with the appearance of you and your equipment. Keep equipment new-looking, and free from dirt and pesticide residues. Wear clean, neat clothing. Company uniforms can be easily created by affixing company logo patches to color-coordinated coveralls, jackets, and hats.

Communication. Landscape ornamental applicators must be able to communicate with the general public. Clients often want to know what is wrong with their plant and what is to be done about it. Client neighbors and visitors of public landscapes may also be curious or concerned. View questions as an opportunity to improve public understanding of pest management. People do not appreciate glib responses such as "I know what I'm doing" or "Don't worry, it's not your property." The best way to deal with the majority of the concerns addressed by the public before or during applications is to answer their questions and respond to their concerns as clearly and directly as possible. If you are asked a question that you cannot answer, refer the person to a resource, or investigate the matter yourself. Never improvise an answer to "save face."

Keeping up. Pest management does not end with the completion of the spray season. Professional plant managers take advantage of every opportunity to learn more about non-pest plant disorders and treatments, as well as insect, disease, and weed identification and management. Stay informed about new detection and management methods, and available application equipment. Belong to professional organizations and participate in workshops and trade shows to learn about new developments in pest management. You can receive pesticide applicator recertification credits for attending approved workshops. Reading industry journals and taking evening courses are two other methods of keeping up to date. Do not hesitate to think through and apply new techniques. Your monitoring and application records will help you determine the usefulness of new detection and management methods.

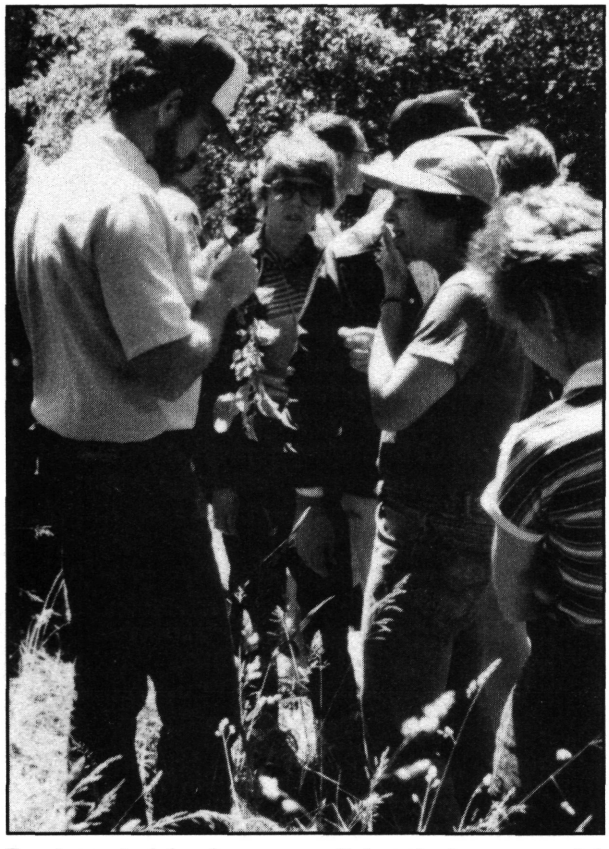
Professional organizations will also help you to understand and keep current on the industry requirements of state regulatory agencies such as the

Michigan Department of Agriculture, Michigan Department of Natural Resources, and Michigan Department of Transportation. Make sure that you know the latest regulations for conducting your business. Ignorance of the law is no defense.

Some of the sources for information include:

- labels and material safety data sheets (MSDS).
- Cooperative Extension Service
- field demonstrations
- chemical company staff
- industry publications
- applicator training seminars

Training Employees. There is a direct relationship between the experience and training of an applicator and the number of problems that can be expected on the job. Some of the problems associated with an inexperienced or poorly-trained employee may simply cost you money, but others may cost you your reputation. If you are a supervisor, it is important to educate employees about target plants, pests, and application techniques. They too must be well-versed in all areas of pesticide safety. Review with employees the appropriate responses to common client concerns. Such training should be mandatory for all new employees, and be part of a refresher course for experience employees.



Employee training is an essential part of a successful pest management program.

Remember, persons who are not certified and are applying general use pesticides under the supervision of a certified applicator are required by Michigan law to be a registered technician. The Michigan Department of Agriculture is responsible to give examinations and regulate both certified applicators and registered technicians.

Establish policies for applicators that outline exactly what is expected of them when they are on the job. Be sure to periodically inspect employee pesticide handling and application habits and evaluate their pest management successes. *Direct supervision by a certified applicator is required when using restricted use pesticides.* Develop a standardized system for dealing with any employee who does not conform to the policies. You are responsible should an accident occur.

Remember, employees are representing your company. Choose your employees carefully and train them with equal care.

Applicators as Consultants

As public sensitivity to urban pesticide applications and interest in alternative methods increases, applicators will be in demand for consulting and educational services. This role strongly contrasts to the traditional function of the pesticide applicator, but parallels the recent shift in plant care needs. As previously mentioned, educating the public about IPM practices such as monitoring, setting injury levels, and timing tactics with susceptible pest life stages can be difficult, but is vitally important to the success of management programs.

Promote plant care practices as an effective method of keeping plants vigorous, and better able to defend against pests. Properly-implemented installation, watering, fertilizing, pruning, and winter protection are lucrative services which are crucial to limit the stress experienced by urban plants. Some applicator businesses could benefit by expanding to offer these services.

Experienced applicators who are educated about pest and plant disorder diagnosis, and IPM will easily meet the requirements of a plant care consultant.

Educate the Client

Many applicators find that the greatest challenge in implementing an urban IPM program is the demand from some clients for a "bugfree" landscape. Because most people are ignorant about pest management, they distrust monitoring for injury levels and readily turn to chemical controls. Clients often equate gallons of pesticide sprayed with the degree of pest control and the value of your service. As a plant care provider, you must educate the client or public so that reasonable injury levels can be

established and alternative methods of managing pests can be used. Help the client to realize that your knowledge and monitoring skills are valuable services.

The client/public should understand that:

1. *Not all insects, fungi, etc. are pests.*
2. A landscape cannot be simultaneously pest-free and benefit from natural controls.
3. Aesthetic injury is not necessarily health-threatening to the plant.
4. There are specific times to implement pest management tactics. Outside of this window management efforts are wasted.
5. Plants must be regularly inspected for damage and timing of management tactics.
6. Tactics should be implemented selectively. Most plants will not require treatment.
7. Pesticides are by no means the only and best method of pest management.

Pesticide Safety Checklist

Store Pesticides Safely

- ☐ Do you have a separate, vented space to store pesticides?
- ☐ Do you keep it locked and the windows barred or boarded up?
- ☐ Do you keep all of the pesticides in this storage area rather than in the garage, basement, yard, or porch?
- ☐ Do you store herbicides separately from other pesticides?
- ☐ Are there signs on your storage area so firemen and others are warned?
- ☐ Do you check periodically for leaking containers?
- ☐ Are the pesticides resting off of the floor on washable (steel) shelves?

Keep Pesticides in Their Original Containers

- ☐ Do you always keep pesticides in the original container with an intact label?
- ☐ Do you refuse to put pesticides into bottles, cans, or jars which resemble food containers?
- ☐ Do you protect pesticide labels by lacquering or covering them?
- ☐ Do you safely dispose of unlabeled pesticides, rather than take a chance that you will remember the directions for use, safety precautions, and antidotes?

Use the Recommended Protective Gear

- ☐ Do you read the label to see what protective gear you must wear?
- ☐ Do you start each application day with clean spray clothing?
- ☐ Do you check the signal words and precautions for use on the label before handling the pesticide?
- ☐ Do you clean and maintain your protective equipment regularly and often?
- ☐ Do you throw away rubber gloves with only tiny holes in them?

Spills and Splashes of Concentrates are Very Hazardous

- ☐ Do you know what to do if you should spill pesticide on yourself while mixing?
- ☐ Do you wear protective footgear with your pant cuffs on the outside so pesticides won't run into your footgear?
- ☐ Do you have kitty litter or a manufactured pesticide absorbent on hand to soak up spills?
- ☐ Do you always watch your sprayer tank when filling so that pesiticide won't run over and spill on the ground?
- ☐ Do you have a check valve or other device on your equipment to prevent back-siphoning into the water supply?
- ☐ Is your application equipment well maintained so it doesn't leak and leave toxic puddles or piles of pesticide on the ground or on equipment?
- ☐ Do you never drain leftover spray mix on the ground or into the sewer?
- ☐ Do you discard old high pressure hose instead of patching it and hoping no one will be nearby when it bursts?
- ☐ Do you clean nozzles with a brush, or by rinsing instead of blowing them out with your mouth?

Poor Container Disposal May Result in Contamination

- ☐ Do you triple rinse each container as you empty them?
- ☐ Do you dump the rinse water into the mixing tank?
- ☐ Do you recycle triple-rinsed containers whenever possible?
- ☐ Do you puncture, break, or crush containers so they cannot be reused?
- ☐ Do you return to the manufacturer 30 and 55 gallon pesticide drums rather than giving them away for floats, trash barrels etc.?

Children Are Attracted to Equipment

- ☐ Do you keep your spray equipment where children cannot play on it?
- ☐ Do you keep your spray equipment clean so that those touching it will not be contaminated?
- ☐ Do you always release pressure on your equipment so spray guns won't be accidentally triggered?

Review Questions: Chapter 4

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

1. Failure to comply with state and federal pesticide use regulations could result in lawsuits, fines, and imprisonment. *(True or False?).*

2. You may, but are not required by law to, wear the protective gear recommended on product labels. *(True or False?).*

3. In what form are pesticides the most hazardous to handle?

4. What is cholinesterase and why should applicators be concerned with their cholinesterase level?

5. Name the two chemical classes of insecticides that inhibit cholinesterase. Give four specific examples.

6. Why should alcohol never be given to or taken by a person exposed to pesticides?

7. If you suspect that a severe exposure to pesticides has occurred, what should you do **first?**

8. First aid for dermal pesticide exposure includes removing contaminated clothing, and washing with detergent and water. *(True or False?).*

9. What should be done when eyes are contaminated with pesticide?

10. Name four instances when vomiting should not be induced in the case of oral pesticide exposure.

11. Equipment that is not routinely inspected and maintained is the cause of many accidents with pesticides. *(True or False?).*

12. List five safety guidelines to follow when mixing and loading pesticides.

13. Why should applicators check over fences before applying pesticide to adjacent areas?

14. Where can an applicator find the reentry period of a pesticide? Generally, what is the reentry period for pesticide sprays?

15. Name four reasons to limit the amount of pesticide you store.

16. What are three safety guidelines for the exterior of the pesticide storage area? The interior pesticide storage area?

17. What is the best way to dispose of pesticides?

18. What should be done with leftover, unopened pesticides?

19. Should a pesticide spill occur, what are the three steps to prevent contamination?

20. If you do not know the answer to a client's question, you should make one up to appear educated. *(True or False?).*

21. Why is it important for you to maintain neat, clean equipment and applicator gear?

22. Name three ways professional plant managers can keep up to date with plant disorders and management methods.

23. Why should applicators stay current on the industry requirements of state regulatory agencies such as the MDNR and MDA?

24. There is a direct relationship between the experience and training of an applicator and the number of problems that can be expected on the job. *(True or False?).*

CHAPTER 5

NON-PEST DISORDERS AND LANDSCAPE WEEDS

Environmental and cultural disorders may kill landscape plants, but more often physically weaken them. Weeds, through competition, injure plants in a similar way. Weakened ornamental plants are more susceptible to attack by pests, and more likely to be damaged by normally harmless diseases and insects. This chapter examines how non-pest plant stresses contribute to the decline of landscape plants.

Environmental and Cultural Disorders

Ornamental plants are subject to numerous stresses imposed by the artificial conditions of a landscape. *The majority of landscape plant injury is caused by poor growing conditions.* Plants harmed by environmental and cultural disorders are more susceptible to attack by pests. Creating as hospitable a landscape for plants as possible is a crucial part of plant care and pest management.

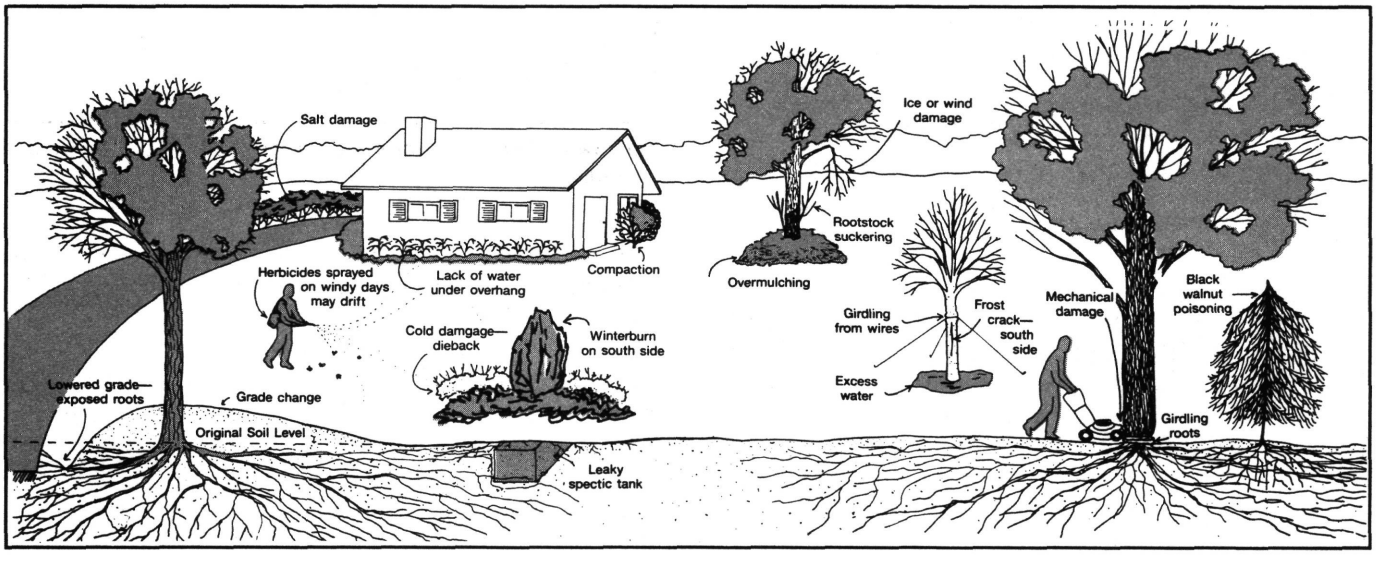
The environmental conditions of a landscape, such as the soil type and pH, temperature ranges, amount of moisture, and sun exposure fundamentally affect the welfare of plants. Most plant care providers are familiar with hopelessly thin, poor-flowering shrubs in too shady sites. In Michigan several species of plants, most notably pin oak, suffer from iron chlorosis due to the alkalinity and soil composition.

The landscape environment is difficult to modify on a large scale and therefore should be considered when selecting plants for a particular site. However, while the environment a plant is growing in cannot be changed, it is possible to alter the conditions a plant experiences. For example, inadequate soil fertility or pH can be buffered through regular fertilizer applications. Burlap wraps and antitranspirants prevent winter damage due to excessive drying by wind and fluctuating winter temperatures. Moderately dry areas can be irrigated to support a greater variety of ornamental plant species.

Be familiar with the common environmental problems in your area, since the symptoms of injured plants may be easily confused with those resulting from pest activity.

Pesticides will not benefit plants suffering from cultural problems. Cultural plant disorders can

Environmental and cultural stresses of the landscape.



result from growing, planting, and plant care practices. For instance, the use of a herbicide that is incompatible with bedding plants may kill ornamentals as well as weeds. People who are careless with weed whackers and lawn mowers can girdle and kill trees. This injury is so common it has been termed "lawn mower blight."

Plant care practices beneficial to one plant may injure another. Most irrigation systems provide frequent, light watering. While this is beneficial to turf, shallow watering discourages deep rooting in shrubs and trees. Standard bed preparation includes loosening the soil to increase aeration and water penetration. However, this practice often harms the roots of nearby ornamental trees and shrubs. There are numerous sources of information regarding the proper way to plant, water, fertilize, and prune ornamental plants (see Resources).

Landscape Weeds

A weed is defined in the core manual as any plant that grows where it is not wanted. Whether or not a plant is considered a weed, as the definition reveals, depends more upon where the weed is growing than its species. Fescue grass, a valuable turf plant, is an undesirable weed when growing in flower beds. Unlike other landscape pests, weeds do not directly attack plants. Although the injury is often less noticeable than that caused by insects and diseases, ornamental plant health and appearance can be significantly diminished by weeds.

Weeds directly compete with ornamentals for growing space, water, nutrients, and sunlight. Many weeds are plant species that readily spread to newly-disturbed environments. Weeds are often especially aggressive growers and prolific reproducers. Some thrive in poor growing conditions and are indicators of such sites in the landscape:

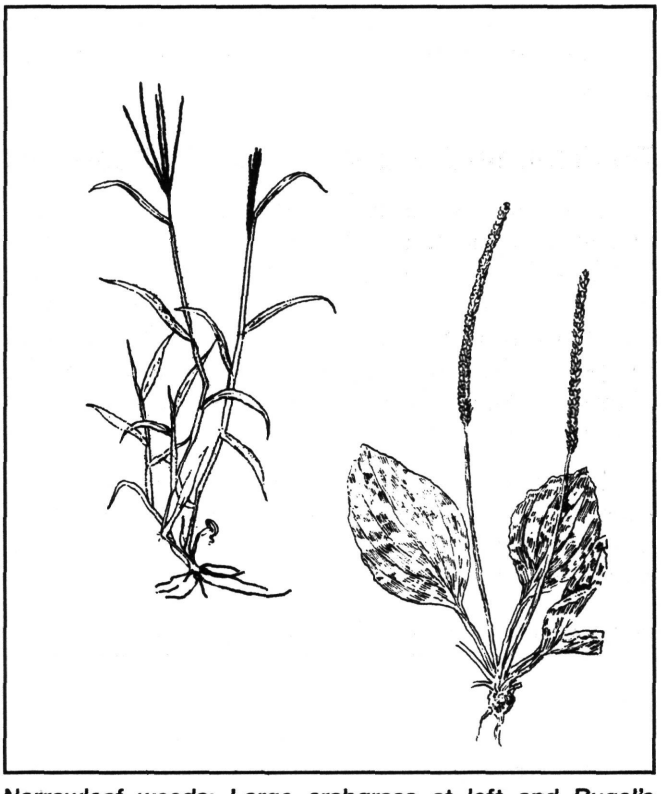
- hot soil (milk purslane, prostrate spurge)
- compacted, wet soils (annual bluegrass)
- wet, shady areas (rough bluegrass, horsetail)
- deep shade (ground ivy, chickweed)

It is not surprising that weeds commonly overcome ornamental plants in the landscape. Weeds are often a result, not a cause of, poor landscape plant performance.

A large part of flower bed management is preventing competition between weeds and developing flower plants. Large, established trees and shrubs can also be crowded by weeds (hedge bindweed, Virginia creeper), or girdled by vines (common trumpetcreeper, American bittersweet). Certain weeds indirectly harm ornamentals by harboring pests. Red, Scotch, and Jack pines are the primary hosts of pine needle rust. This disease will not develop on pines without the presence of its alternate host, aster or goldenrod. Weeds can be directly troublesome to people. They increase costs by interfering with landscape care practices. Poison ivy and rag weed cause irritating skin rashes and allergies.

Weed Biology

Basic physiological differences divide weed plants into two groups: monocots and dicots. **Monocots,** or narrowleaf plants, include weeds in the grass (crabgrass, foxtail), sedge (yellow nutsedge), and lily (wild garlic) families. These plants are reliably recognizable by their parallel leaf veins. Because the growing points of most monocots is at or below ground level, they are difficult weeds to manage. Only non-woody, or **herbaceous,** monocots are found in temperate regions.



Narrowleaf weeds: Large crabgrass at left and Rugel's plantain.

Both herbaceous and woody **dicots** grow in Michigan. Dicot, or broadleaf, weeds have a net-like pattern of leaf veins. There are many families of dicot weed species: composite (thistles, dandelions); mustard (shepard's purse); carrot (wild carrot); and morning glory (field bindweed). All broadleaf plants have aboveground growing points, and some also have underground growing points. The action of some herbicides is based on the physiological differences between monocots and dicots.

Dicot (or broadleaf) weed: Poison ivy.

After germination or sprouting, all plants have four stages of development:

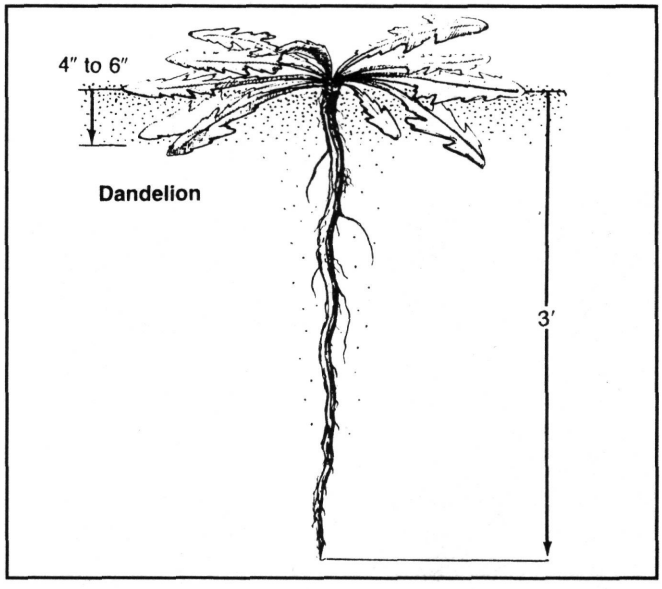
1. **Seedling Stage**—the newly emerged, immature plant. Seedlings are tender and vulnerable to all stresses.
2. **Vegetative Stage**—the plant rapidly produces stems, roots, and foliage. There is great uptake of water and nutrients during this period of growth.
3. **Seed Production**—the plant's energy is directed towards the production of seed. Uptake of water and nutrients is relatively slow and is directed mainly to flower, fruit or seed structures.
4. **Maturity Stage**—the plant has little or no movement of water and nutrients or energy production.

The developmental stage of a weed affects how it responds to weed management measures. For example, a seedling is not yet established and is easily eliminated through cultural or chemical methods. A plant in the vegetative stage will take up a herbicide more quickly than a mature plant.

There are three distinctive types of weeds, based on the number of years required to complete their life cycle. **Annual weeds** of both monocot and dicot species live for only one year. **Summer annuals,** such as pigweed, lambsquarter, and crabgrass, germinate from seed in the spring, mature, seed and die by winter. Chickweed and pennycress are **winter annuals** which germinate from seed in late summer, overwinter, then produce seed the following spring.

All **biennial weeds** are broadleaf plants with a two-year life cycle. Examples of biennial weeds are Queen Anne's lace and bull thistle. These weeds generally germinate from seed in the spring. A thick, fleshy root and compact cluster of leaves **(rosette)** develop the first summer. During the second year, biennials mature, produce seed, and die.

Perennial weeds live for three or more years and are the most persistent and difficult weeds to manage. Seed is usually first produced during the second year of growth. While a few perennials reproduce only by seed, most species have specialized structures at or below the soil surface with the capacity to produce new plants. These structures, called **propagules,** include rhizomes, stolons, bulbs, and tubers (see the Pest Identification chapter of the core manual). Each year during the fall, food reserves are moved from the dying plant crown into the roots and propagules. When they suffer crown loss due to winter dieback or cutting, perennials regenerate via the extensive network of underground structures. Successful perennial weed management requires destroying underground plant parts.



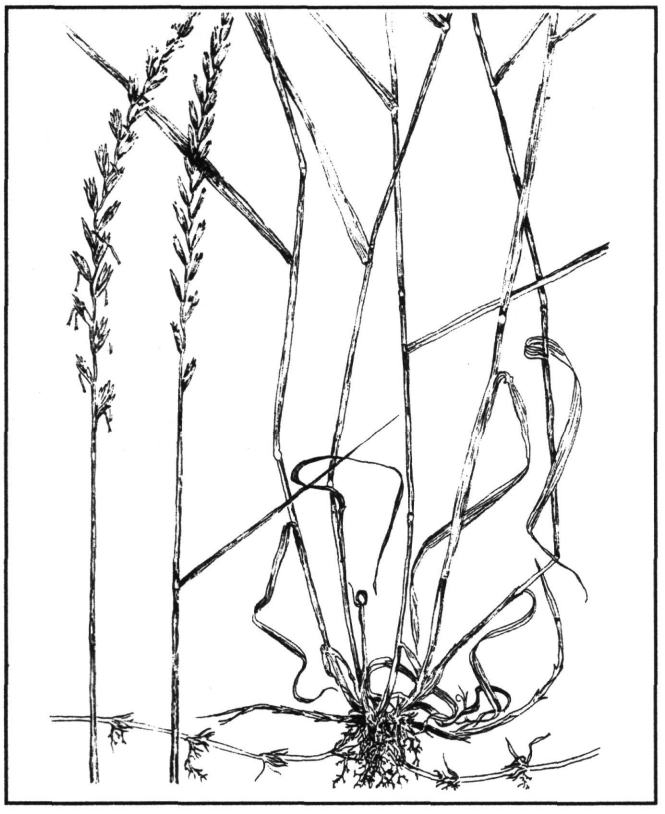
The fleshy root of a dandelion can regenerate top growth.

Managing Landscape Weeds

The methods implemented in a successful weed management program will vary with specific site conditions and the type of weed. You must accurately identify species of weed plants. The Pest Identification chapter of the core manual discusses plant characteristics used in species diagnosis. There are many publications available to aid you in determining weed species (see Resources). Difficult samples may be brought to the MSU Plant and Pest Diagnostic Clinic (517-355-4536).

The standardized common names of weeds are used in references and on herbicide labels. However, you may encounter more than one common name

for a species of plant. The weed *Agropyron repens* is called couchgrass and quackgrass. To eliminate any possibility of confusion, refer to the scientific species name.

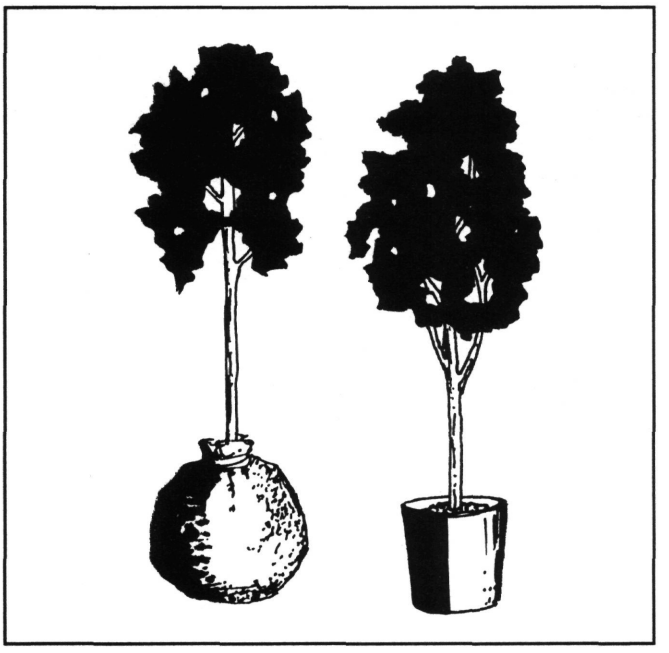


Agropyron repens.

Keep an inventory and regularly monitor the activity of weed problems in the landscapes you manage. A weed inventory aids plant managers in coordinating tactics and implementing them during susceptible weed growth stages.

There are five strategies that are used to manage landscape weeds. Keep in mind that most weed problems require the coordinated use of multiple techniques.

1. **Create vigorous ornamental plants.** Healthy landscape plants are better able to compete with and eliminate all types of weeds. A vigorous, dense ornamental planting is the first step in weed management. Appropriate species selection, installation and plant care practices will provide an environment in which ornamentals thrive.
2. **Prevent seed production.** Weed plants are capable of producing a great number of seeds which may be viable for years. One pigweed plant can release 100,000 seeds in one season. Management efforts should concentrate on eliminating weeds before the seed production stage. Whenever possible, eliminate sources of weed seed in areas adjacent to the landscape. Take caution not to spread seeds around the landscape on tools, soil, or plants. Beware of introducing weed seed-infested compost, mulches, top-soil, or plant material.



Plant only weed-free stock.

3. **Prevent seed germination.** It is impossible to completely eliminate weed seeds from the landscape. There are several ways to prevent seed from developing into weeds. Many dormant seeds exist deep in the soil. Take care not to disturb soil deeper than two inches to avoid bringing dormant weed seeds into soil where conditions are right for germination. Use a mulch in landscape beds to prevent sunlight from reaching weed seeds. Germinating seeds can be suppressed by applying a preemergent herbicide to a clean, prepared soil bed. Be cautious not to disturb the soil surface or otherwise break the preemergent chemical barrier.
4. **Limit emerged weeds early.** Every type of weed is most susceptible to management tactics when young. Small plants with immature root systems are easily removed or destroyed by mechanical means. Seedlings are tender and more easily injured by chemicals. During the rapid growth stage, plants absorb and move herbicides more effectively.
5. **Limit susceptible stages of developed weed plants.** Managing developed weeds requires much effort. Ideally, weeds should be eliminated before they become established. The efficacy of many tactics will be enhanced if applied when the weeds have depleted food reserves and are physically weakened. This occurs in woody perennials in the late spring after the new leaves

have fully-expanded. Herbaceous perennials are weakest during the bud-to-bloom stage. Repeated cutting of perennials and second-year biennials induces stress as the plant is forced to produce new top growth.

Alternative Weed Controls

All applicators should be aware of the potential for ornamental plant damage when using herbicides. Drift, run-off, and incorrectly applied herbicides can outright kill desirable plants. Properly applied herbicides, when used over a number of seasons, will weaken ornamentals and may create colonies of herbicide-resistant weed species. Because of ornamental and weed plant proximity in most landscape situations, and because weeds are particularly persistent pest problems, successful weed management programs usually incorporate both non-chemical and herbicide tactics. The following is a description of some of the alternative methods for managing landscape weeds.

Sanitation. This tactic eliminates weed seeds by maintaining seed-free mulches, tools, and planting stock.

Tillage. Working the soil disrupts root systems and buries weeds. Tillage will kill annual and most biennial weeds, but will not eliminate perennial weeds which have developed extensive underground parts. This technique cannot be used near ornamental plant roots.

Cultivation. Persistently removing weeds by pulling, digging or hoeing is an effective and selective means of limiting many seedling weeds. Most annuals germinate within the top two inches of the soil. To prevent damage to desirable plants and minimize the amount of weed seeds brought to the surface, do not cultivate deeper than necessary.

Cutting. This technique can be used to limit seed production, or to weaken or kill weed plants. Only weeds with growing points above ground level such as annual broadleaf weeds can be managed by cutting. Repeated cutting changes the species composition from tall-growing to low-growing weeds.

Reduce weed seed production by mowing

Mulching. Mulching effectively prevents weeds in the landscape, but is not appropriate for all plantings. Be wary of straw and hay mulches as they often contain weed seeds. Black plastic film is one of the better mulches for limiting weeds, but can injure landscape plants by blocking the filtration of water, air, and nutrients into the soil. As a solution to the filtration problems of plastic, landscape fabric has been developed and is an effective landscape mulch.

Some alternative tactics will seriously inhibit perennials and temporarily eliminate annual weeds. Other practices may be used with chemicals to enhance the efficacy of the herbicide.

Herbicides

There is a great variety of herbicides marketed for use for landscape weed management. Plant, soil, and weather conditions influence herbicidal action, and must be considered when choosing a herbicide. Remember that the label defines the legal uses and applications of the product.

Herbicide Characteristics. How a particular herbicide works on a plant will determine if it will successfully eliminate a weed. For instance, **contact herbicides** are effective on annual and biennial weeds. Since only the portion of the plant that the herbicide directly contacts is killed, perennials are only temporarily suppressed. **Systemic herbicides** move throughout the plant and are therefore useful for perennial weed management.

In contrast to **nonpersistent herbicides, persistent herbicides** remain active in the environment for an extended period of time. Persistent herbicides are useful for some situations, but would be inappropriate for use on a bed scheduled for immediate planting.

Nonselective herbicides kill most or all vegetation. Be careful to protect nearby ornamentals. **Selective herbicides** are effective on only specific species of weeds and have many landscape uses. Be sure to check the label not only for weed species controlled, but also for susceptible ornamental plants.

Herbicides can be categorized by when they are used. **Preplant herbicides** are applied or injected into the soil. They are extremely toxic to all plant material and to humans. Preplant herbicides are often used in nurseries to rid new planting areas of weeds. Because of their toxicity, however, they are seldom used in landscape weed management.

The most common type of herbicide used for landscape weed management is **preemergence herbicide.** This herbicide is applied to the soil as a preplant treatment or in established beds to kill germinating seedlings. Selective preemergence herbicides are useful for eliminating weeds growing among ornamental plants. Carefully follow label instructions to avoid a poor level of weed control or injury to desirable plants.

Postemergence herbicides are applied directly to the weed and are available as contacts and systemics. These contact herbicides are effective for eliminating annuals and biennials, and temporary suppression of perennials. Perennials are best managed with systemic postemergence herbicides.

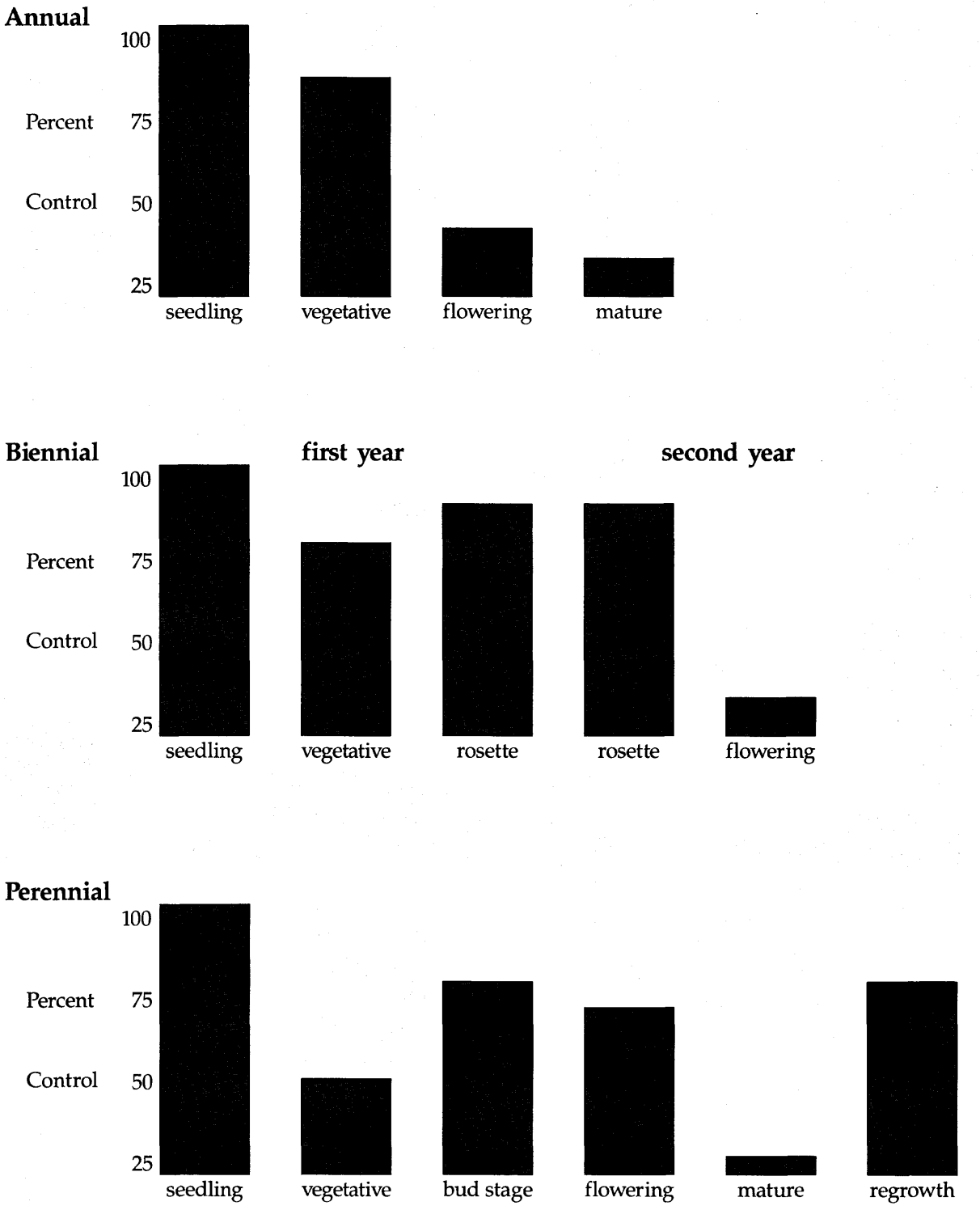
Plant Characteristics. Knowledge of plant biology and life cycles will help you understand how plant characteristics of a weed can impact the herbicidal action. Several of these plant characteristics are listed below:

- **Growing Points.** Growing points that are sheathed or located below the soil surface will not be reached by contact herbicide sprays.
- **Leaf Shape.** Herbicides tend to bounce or runoff narrow, upright leaves; broad, flat leaves tend to hold the herbicide longer.
- **Wax and Cuticle.** Foliar sprays may be prevented from entering plant leaves by a thick wax and cuticle layer. The cuticle is the top layer or "skin" of a leaf and is covered by wax.
- **Leaf Hairs.** A dense layer of leaf hairs holds herbicide droplets away from the leaf surface, allowing less chemical to be absorbed into the plant. In contrast, a thin layer of hairs holds the chemical onto the leaf surface, allowing more chemical to be absorbed.
- **Deactivation.** Certain plants can deactivate herbicides and are therefore less susceptible to chemical injury.
- **Life Cycle Stage.** Seedlings are vulnerable to most management practices. Plants in vegetative and early bud stages are susceptible to systemic herbicides. Mature plants are the least damaged by herbicides (see graph on next page).

Climatic Factors. The climate where you are applying the herbicide can have considerable impact on its effectiveness. Consider the factors listed here:

- **Relative Humidity.** A foliar-applied herbicide enters leaves more easily and rapidly at higher relative humidity. Under such conditions, the weed leaf is more succulent, may have less of a wax layer and thinner cuticle, and the cuticle is hydrated with water. Herbicides work best when plants are actively growing: high relative humidity usually enhances active growth.
- **Light.** The presence or absence of light can affect how fast the herbicide acts. Light breaks down some herbicides if they remain on the soil or plant surface for a long time.
- **Precipitation.** Soil moisture and rain affect the way herbicides work and how long they stay on the soil and plants. Too much soil moisture may keep the herbicide from contacting and being absorbed by soil particles. Heavy downpours or large amounts of rain can cause soluble herbicides to leach through the soil or run-off the site. However, light rain can be beneficial after root-absorbed herbicides have been applied as it carries them down into the soil surface where they can be absorbed by plant roots.
- **Temperature.** Because soil-applied herbicides become volatile at high temperatures, it is important to quickly incorporate them into the soil after a warm-weather application. Evaporating herbicide will not effectively eliminate target weeds, and may drift and damage valuable plant material.

Percentage of Herbicide Effectiveness on Various Stages of Weed Development



Review Questions: Chapter 5

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

1. The majority of landscape plant injury is caused by insects. *(True or False?).*

2. Iron chlorosis on Michigan pin oaks is an example of what type of plant disorder?

3. Give two examples of cultural plant disorders caused by poorly-implemented landscape care practices.

4. What is the definition of a weed?

5. Weeds are often a result, not a cause of, poor landscape plant performance. *(True or False?).*

6. What is the difference between summer and winter annual weeds? Between biennial and perennial weeds?

7. Define propagule. Why does possessing propagules make perennials so difficult to manage?

8. List the five strategies that are used to manage landscape weeds. Name some methods that can be used for each strategy?

9. What is the difference between selective and nonselective herbicides? For what uses are they appropriate?

10. Which part of a weed life cycle is the most susceptible to cultural and chemical controls?

11. Describe how rain can inhibit or enhance herbicidal action.

CHAPTER 6

BIOLOGY AND MANAGEMENT OF PESTS

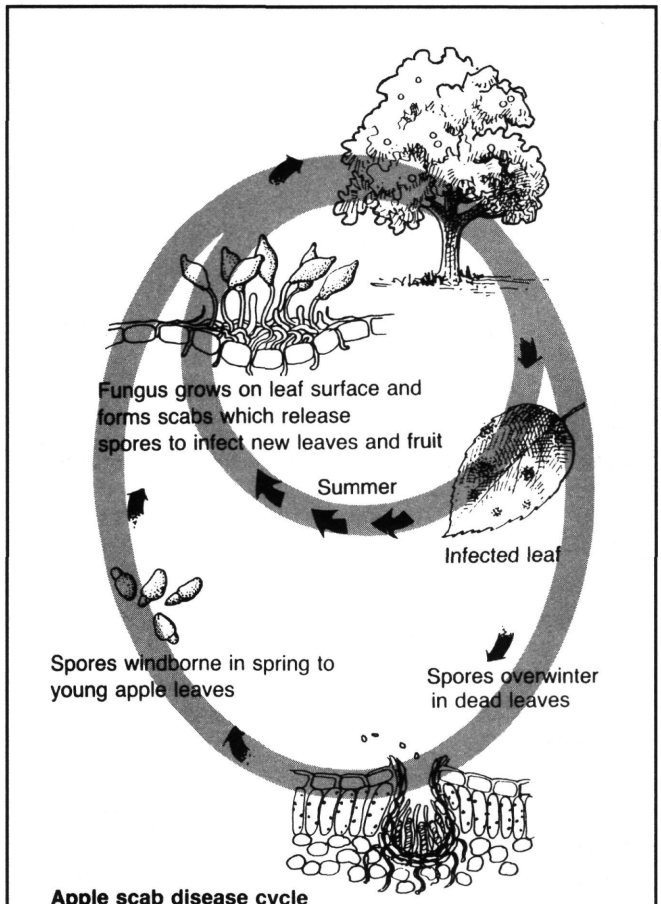
Natural and applied controls are used to manage pests. As has been emphasized in this manual, seldom will a "stab-in-the-dark" approach to pest management adequately protect plants from damage. Inappropriate pesticide applications at best do not limit pests, and at worst destroy non-target organisms including the natural enemies of pests. Knowledge of the pest life cycle, feeding habits, and reproductive behavior allows applicators to make informed choices to create an economical and effective pest management program. In this chapter you will learn the biology, damage, and management techniques of major pest groups.

Diseases of Ornamental Plants

Diseases are the most difficult plant injury agents to diagnose and manage. Broadly defined, a disease is a continual disturbance of normal plant function. **Noninfectious diseases** are caused by nonliving agents such as drought, salt exposure, air pollution, and nutrient deficiency. These factors are types of cultural and environmental damage. Fungi, bacteria, viruses, mycoplasmas, and other microorganisms cause **infectious diseases.** Only infectious disease can be spread between plants. The characteristics of these pathogens are described in the Pest Identification chapter of the core manual.

The biology of pathogens is quite different from the biology of most other pests. Viruses are not even considered by some to be life forms, since they do not "live" when outside of the host. The life cycles of various disease pathogens follow a common pattern called the Disease Cycle (see the Pest Identification chapter of the core manual). Infectious diseases spread through direct plant contact or by seed-like spores carried by wind, water, animals, and humans. The diagram on this page represents the life cycle of a typical wind-dispersed disease.

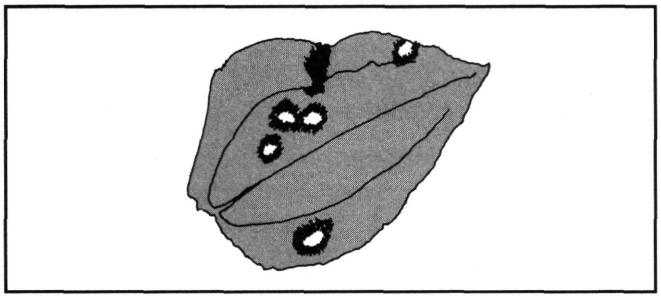
The first phase in the disease cycle requires the presence of disease inoculum, which are spores for the disease scab. If inoculum contacts a host plant, and when moisture and temperature conditions are favorable, infection occurs as the pathogen enters the host. Infection is followed by a period of pathogen growth within the host. Disease symptoms usually begin to appear during this phase. Once the disease is established, reproduction follows. Fungi produce spores, and viruses and bacteria duplicate themselves into more pathogens. Pathogen reproduction creates more inoculum. This inoculum may reinfect the same host (for example, other leaves and fruits of a scab-infected apple tree), spread to other hosts, or remain in the soil to infect plants at some later date. The disease management techniques discussed in a later section of this chapter are designed to interrupt some part of the disease cycle.



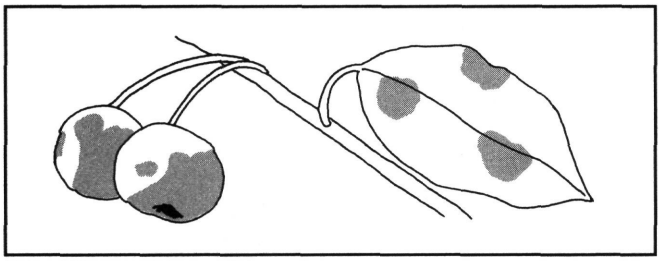
Apple scab disease cycle

Disease Identification

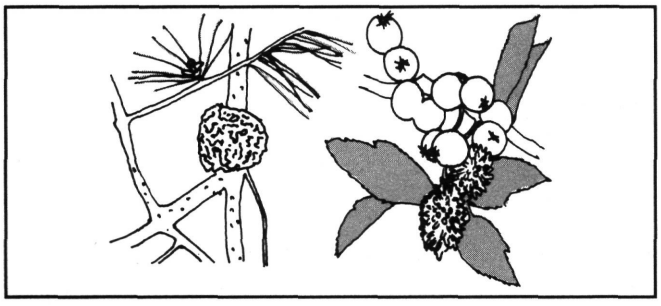
Plant diseases are grouped according to the causal agents, as in the core manual, or by the symptoms they produce. Because they are more easily detected and diagnosed than the microscopic pathogens, most disease references are organized by disease symptoms. As you diagnose plant diseases, keep in mind that a particular disease often produces a number of symptoms, and one symptom can result from different non-infectious disorders or pathogens. The following is a description of some ornamental plant disease symptoms.



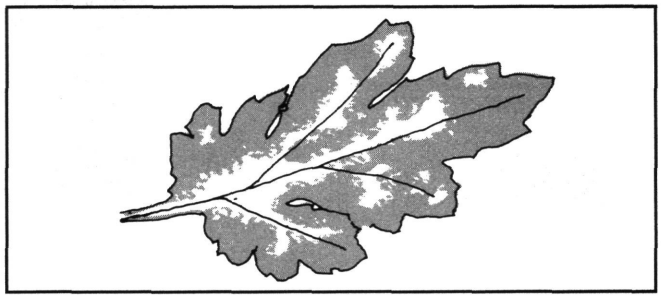
Leaf spots—caused by fungi, bacteria, nematodes, air pollutants. Develop as a discolored (orange, green, yellow, brown) spot on the leaf which eventually turns black or brown. Spots may look like a target with rings of different colors. Examples: bacterial leaf spot of ivy; fungal leaf spots of geranium; tar spot of maple.



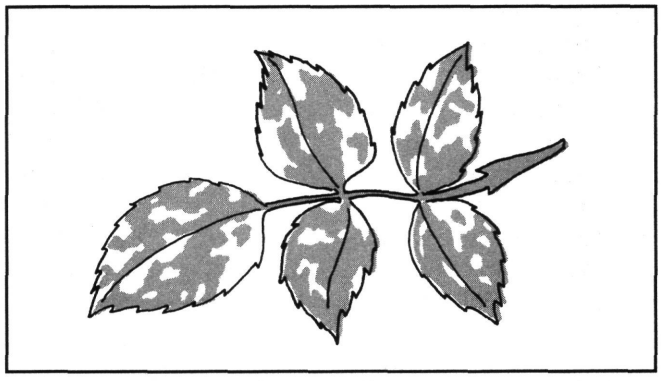
Scab—caused by fungi. A rough, olive-green area on leaf and fruit surfaces. May cause defoliation and fruit disfigurement. Example: apple scab.



Rusts—caused by fungi. Orange to reddish-brown spots or lesions on leaves, twigs, or fruit. May cause galling or disfigurement. Rust diseases produce several different types of spores which may infect a different species of plant. Examples: white pine blister rust; rust of garden phlox.

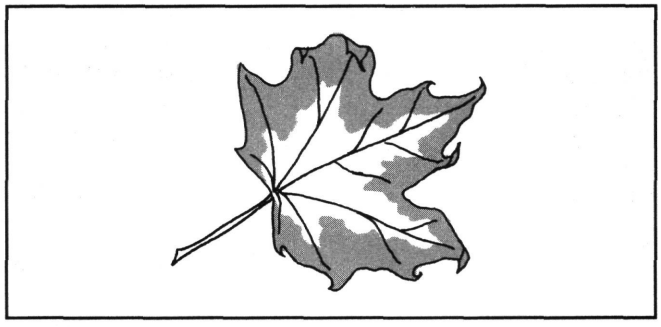


Powdery mildew—caused by fungi. Fungus grows on the surface of plants causing a grayish, cottony layer on leaves, stems, buds, and flowers. Heavily-infested leaves will dry out and drop. Examples: powdery mildew of lilac, black-eyed Susan, and coreopsis.

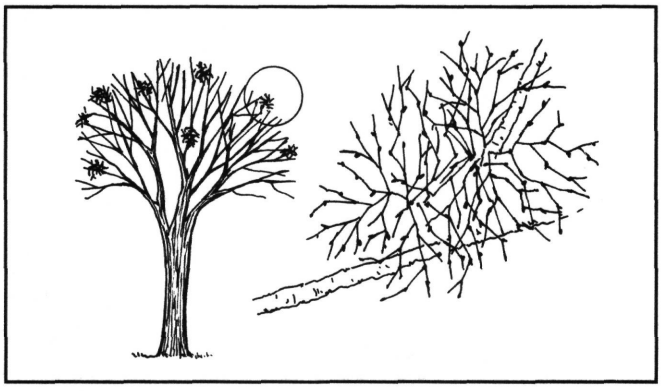


Mosaics—caused by viruses. Mosaic infection results in less vigorous growth. Noticeable symptoms occur as a pattern of light and dark green areas on the foliage. May be associated with leaf curling or other growth abnormalities. Example: iris mosaic virus.

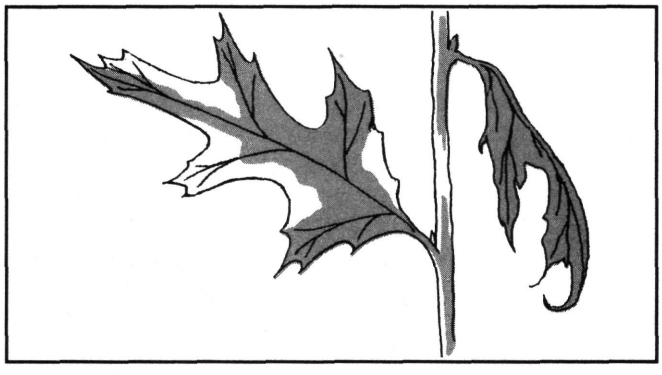
Chlorosis—caused by viruses or poor soil drainage or fertility, and high pH. Yellowing of normally green tissues on part of or the entire leaf. May show up on only one branch or on the entire plant. Examples: iron chlorosis of sweetgum and pin oak; chlorosis of bleeding-heart.



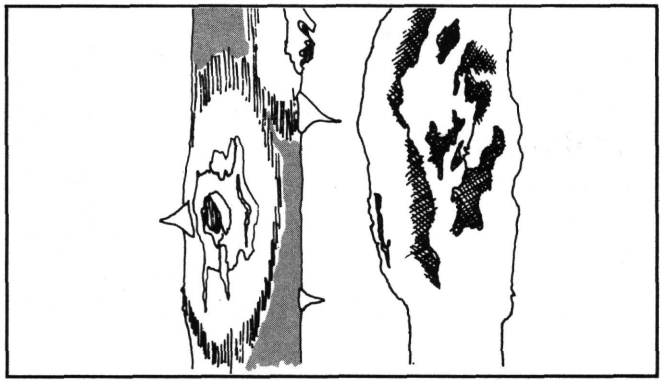
Scorch—caused by lack of soil moisture, long periods of high winds, and transplant shock. Yellowing and death of leaf margins and the areas between veins. Scorch often results in early leaf drop. Examples: scorch of Japanese maple and dogwood.



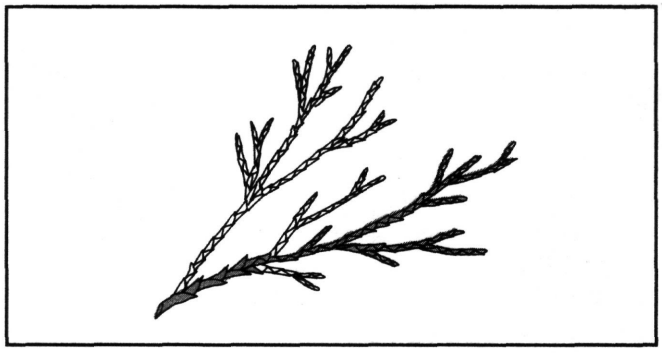
Witches' Brooms—caused by mycoplasma-like organisms, viruses, fungi, or environmental problems such as deicing salt. Also caused by mites and insects. Results in compact clusters of shoots that grow densely from a common point on the branch. The brooms have a bush-like or bird's nest appearance. Examples: aster yellow of china aster; lilac witches' broom.



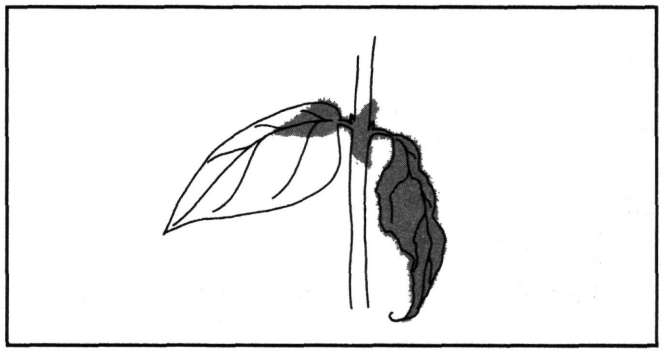
Anthracnose—caused by fungi. Dead areas form on leaves along veins and on fruit causing deformation and early drop. May form cankers on plant twigs. Infections which kill buds deform plants and produce witches' brooms. Example: sycamore anthracnose; anthracnose of viola.



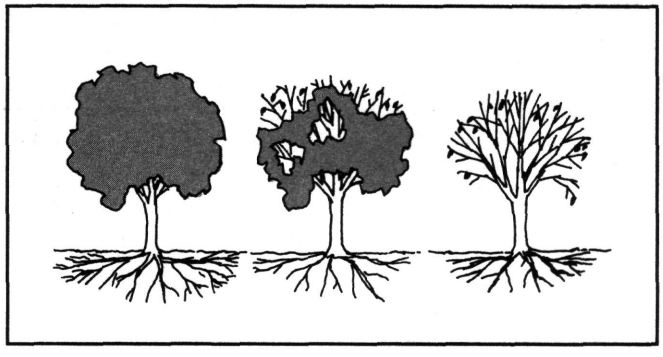
Cankers—caused by bacteria and fungi. Cankers are dead, often sunken areas on twigs, trunks, branches, or roots that are surrounded by callus and living tissue. Over time, cankers may girdle a branch. Examples: apple nectria canker; phomopsis canker of delphinium; cytospora canker of poplar.



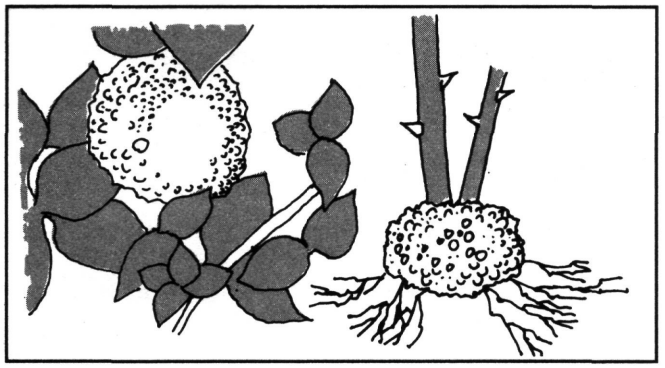
Blights—caused by fungi and bacteria. Blights kill young, growing tissues, especially leaves and twigs. Blighted areas are black and shriveled and remain clinging to drooping shoots. Tip dieback of young shoots results in brown, dead, or curled new growth. Examples: juniper twig blight; botrytis blights; bacterial blight of gladiolus.



Wilts—caused by water deficiency in stems and leaves due to a lack of soil moisture, root system injury, or pathogens. Vascular wilts are caused by fungi which plug up the water- and food-conduction vessels resulting in wilting, withering, and death of foliage, shoots, or the entire plant. Discolored sapwood (dark green to brown streaking) is associated with vascular wilts. Examples: oak wilt; Dutch elm disease; verticillium wilt.



Decline—caused by a combination of urban and other environmental stresses, and pathogens. Trees and shrubs develop thin areas of foliage adjacent to apparently healthy branches. Dieback usually begins at the top of the canopy of deciduous trees and on the lower branches of evergreens. Example: maple decline.



Galls—caused by bacteria and fungi. Also caused by insects, mites, and nematodes. Galls are an overgrowth or swelling of unorganized plant cells induced by pest activity. Infected plants generally suffer from a loss of vigor and a decline in appearance. Examples: crown gall on euonymus; gall rusts of pine.

Rots—caused by fungi and bacteria. Disintegrates, discolors, and decomposes plant tissue. A dry, or hard rot is firm and dry; a wet or soft rot is watery and foul smelling. Crown and stem rots cause severe dieback or death of the plants. Root rots result in a decline in vigor followed by wilting and death. Examples: crown and rhizome rot of delphinium and iris, phytophthora root rot; crown rot of ajuga.

As is evident by the long list of disease symptoms and the overlap of agents producing them, disease diagnosis is a difficult task. Use resources such as bulletins, books and the Cooperative Extension Service (see Resources). Because most disease forms are microscopic, reliable diagnosis of a suspected pathogen must be left to the trained diagnostician. Samples of damaged plant material and soil can be sent or brought to:

MSU Plant and Pest Diagnostic Clinic
138 Plant Biology Building
Michigan State University
East Lansing, MI 48824-1312
(517) 355-4536

Monitoring Disease Activity

There are several indicators in the landscape that aid plant managers in predicting disease outbreaks with reasonable accuracy. To capitalize on these indicators you must be familiar with the biology of host plants and pathogens.

Host Susceptibility

It is widely known that some species of plants are more disease-prone then others. Plant varieties and cultivars also differ in disease susceptibility. As a part of your pest management program, keep an inventory of the disease-prone plant species and varieties present in the landscapes you manage.

Plants are usually only attacked during part of their development. For instance, blackspot infects only the older foliage of roses. Powdery mildew of roses, however, attacks buds and new foliage and rarely infects older leaves. Cytospora canker of spruce is a disease that generally appears only on mature plants. While only young spruces that are in weak condition contract cytospora canker, it is almost rare to see a 20-year-old Colorado spruce without the disease.

Many diseases attack specific plant parts. Anthracnose on privet results in leaf and twig blight as well as cankers. Flower blight, however, only attacks privet blossoms. Applicators must be aware of the site of disease infection. It is useless to apply a foliar fungicide to manage root rot.

Weather Conditions

From year to year, plant disease development is sporadic largely due to variability in weather conditions. Rainfall, duration and frequency of dew, air and soil temperatures, and soil moisture are all factors influencing pathogen activity. Most plant care providers can recall a particularly bad year for one disease or another. When weather conditions are optimal, susceptible plants suffer from severe disease infection.

Although most benefit from moist conditions, species of pathogens vary in their preference for air and soil temperatures. For example, botrytis blight, anthracnose, and rust generally do best in wet, cool weather and sites, while fungal root, stem, and crown rots thrive in soil with high temperatures.

Just as they promote disease development, weather conditions will also thwart an outbreak. Dry spells during midsummer can interrupt foliar disease attacks, eliminating the need for treating diseases like scab, rose blackspot, and anthracnose. Irrigation or high humidity, however, encourage development of diseases.

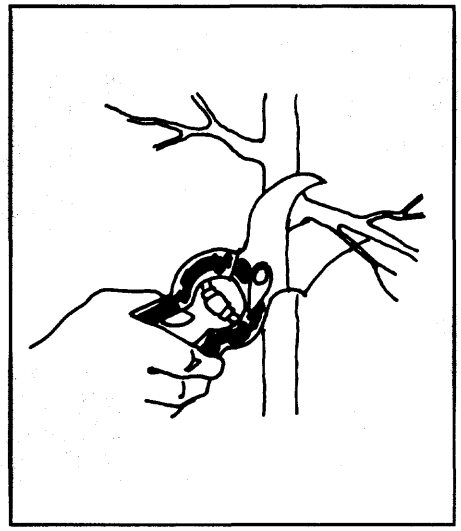
Microclimate

A microclimate is a relatively small area with growing conditions different from those of the surrounding land. Search for microclimates when determining disease-prone plants. Examples of microclimates include low-lying areas with heavy dew or fog, the southern exposure of buildings, and the borders of roadways exposed to wind, salt, and pollution. Tightly-planted ornamentals such as hedges, screens, and flower beds experience disease-loving microclimates. Dense plant crowns and plantings do not allow for rapid moisture evaporation, creating the damp environment preferred by most disease pathogens. Subtle differences in the landscape can result in dramatic variation in the degree of disease infection among plants. This explains why lilac plants in sites lacking sun or air movement are heavily infected year after year with powdery mildew, while lilacs in other areas are not.

Infectious Disease Management

There is no way as yet to entirely eliminate disease inoculum from the landscape or reliably eradicate pathogens infecting ornamental plants. Disease management efforts therefore focus on preventing disease from occurring or lessening the effects of disease. There are four categories of tactics to protect landscape plants from disease injury:

1. **Resistance.** This tactic focuses on the host plant rather than the pathogen. Select plant species, cultivars, and varieties that exhibit resistance to disease infection or damage.
2. **Avoidance.** Manipulate the landscape environment or microclimate through cultural controls to avoid conditions favorable to disease development.
3. **Elimination.** This method eliminates existing pathogen inoculum through sanitation practices such as removing infected plants or limbs, and raking and destroying diseased leaves. There are some chemicals designed to eradicate disease.



Pruning off a disease limb will prevent the spread of vascular disease.

4. **Protection.** This method renders the pathogen ineffective before it can infect the plant. Most fungicides are protectants.

Because of the difficulty in managing most plant diseases, applicators must by necessity employ IPM techniques such as sanitation and careful timing of pesticide applications. Alternative methods for some of the most important landscape diseases in Michigan are listed in table on page 53. Refer to the Extension bulletin E-2022, "1987 Disease Control Guide" for recommendations of pesticides to manage diseases of ornamental ground covers, shrubs and trees. Remember that no matter what reference manuals recommend, *you are responsible for checking the product label for the legal uses of the pesticide.*

Insects of Ornamental Plants

Anyone who frequents the outdoors is aware of the great number and diversity of insects. We are fortunate that of the known 800,000 insect species, less than 3% are considered plant pests. However, these pests vary greatly in the way they feed, develop, and reproduce. As described in the Pest Identification chapter of the core manual, insects feed on plant foliage, flowers, fruits, twigs, and roots. They injure plants by sucking sap, consuming plant parts, and boring through stems and wood. Some insects feed on plants only during one stage of their life cycle, while others are destructive to plants during most of their life stages.

Insect pests can be grouped by physical characteristics as in scientific taxonomy, or by their feeding habits and resulting plant injury. For instance, the order *Hymenoptera* groups together bees, wasps, ants, and sawflies based upon their physical similarity. This is a widely-diverse group of insects, however, in terms of their behavior. Plant managers are often called upon to manage some hymenopterans (sawflies, leaf miners, gall-forming wasps), but should encourage others (parasitic wasps, honey bees.) Pest identification sources use both methods of categorizing insects. Familiarity with both the physical and behavioral characteristics of insects will greatly aid in pest identification and management.

Because insects exhibit great diversity in feeding habits, you must tailor insect management tactics to specific pest-host biological relationships. The following is a brief description of the biology of and plant injury caused by insect pests of ornamental plants.

Piercing-sucking Insects

All sucking insect pests undergo gradual metamorphosis. Both the immature and adult forms feed on the sap of plants by puncturing stems, foliage,

Diseases of Michigan Ornamental Plants and Non-chemical Controls

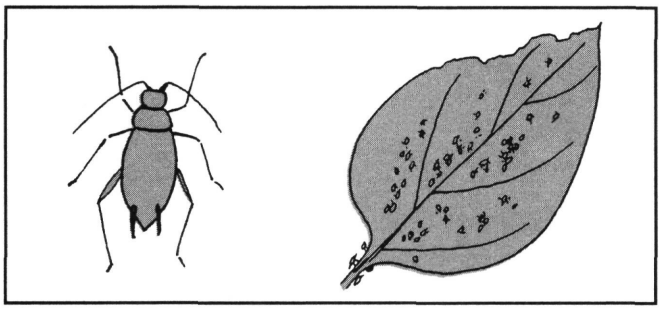
Disease	Hosts	Pathogens	Symptoms	Nonchemical Control
Blackspot	rose	Fungus	Circular black spots; infected leaves yellow and drop	Provide good aeration; avoid overhead irrigation; remove and destroy infected leaves.
Scab	apple, flowering crab, pyracantha	Fungus	Black/brown blotches and distortion; possible early leaf drop. Prefers wet weather.	Use resistant varieties. Rake and burn diseased leaves and fruit to reduce inoculum.
Powdery Mildews	lilac, phlox, rose, zinnia and many more	Fungi	White powdery growth on leaf and fruit surfaces. Advanced cases cause leaf curling and early drop. Prefers shady, moist areas.	Provide plenty of sun and crown aeration. Use resistant varieties.
Black Knot	ornamental plum, cherry, and peach	Fungus	Large, hard, black knots on twigs. Knots of ½" diameter may encircle twigs. Infected twigs usually die within a year.	Remove infected branches and burn to prevent the spread of the disease.
Cedar-apple Rusts	HOSTS: quince, hawthorn, apple, flowering crab, mountain ash	Fungi	Yellow to orange leaf spots form in late summer. Brown fungal threads develop on lower leaf surfaces.	Avoid planting hosts near alternate host species. When practical, remove and destroy infected twigs and galls. Rake infected leaves.
	ALTERNATE HOSTS: Eastern red cedar and other junipers		Rust-colored galls exuding a jelly-like mass of spores in the spring. Twig cankers may be present on junipers.	
Botrytis Blights	periwinkle, peony, petunia, rose, geranium and many others	Fungi	Gray moldy growth over infected leaf, flower, and fruit surfaces. Also causes twig and flower blights, and stem cankers. Prefers very moist conditions.	Maintain aeration. Remove and destroy infected plant parts or plants.
Diplodia Tip Blight	Scotch, Austrian, and mugo pines	Fungus	Dieback of expanding new growth (candles), particularly on lower branches. Dying, brown candles exuded excessive resin.	Use native pines (Eastern white, red, or Norway). Maintain tree vigor.

continued on next page

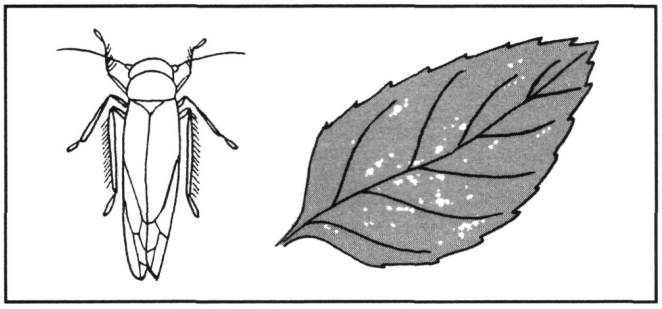
Diseases of Michigan Ornamental Plants and Non-chemical Controls *continued*

Disease	Hosts	Pathogens	Symptoms	Nonchemical Control
Fireblight	amelanchier, apple, flowering crab, pear, hawthorn, cotoneaster	Bacteria	Sudden death of flowers, buds, leaves, or young fruits and shoots. Blighted parts turn black and shrivel. Twig cankers may be produced. Prefers spring wet weather.	Use resistant varieties. Remove infected parts with disinfected tools. Avoid using high-nitrogen fertilizers on susceptible plants.
Verticillium Wilt	redbud, magnolia, maples, elm, lilac, barberry	Fungus	Infects roots plugging the water and food-conducting tissues, causing wilt and dieback in section of the crown.	Water and fertilize declining trees. Remove and burn severely infected plants.
Anthracnose	sycamore, white oak, maple, ash, dogwood	Fungus	Dead areas of leaf; dead buds and expanding leaves; stem cankers. Affected branches grow asymmetrically, often producing witches' brooms. Prefers cool, wet springs.	Use resistent plants. Maintain vigor of infected plants. Rake and destroy infected leaves and twigs.
Crown Gall	clematis, lilac, viburnum, privet, euonymus, dogwood, cherry	Bacterium	Abnormal plant growth up to several inches in diameter at the soil line or on roots. Infected plants grow slowly and decline.	Avoid creating entry sites (wounds) on plant roots and trunks. Dig up and destroy infected plants. Remove contaminated soil. Do not replant with susceptible species.
Tomato Spotted Wilt Virus	over 200 species of herbaceous plants	Virus; spread through thrip mouthparts	A wide range of symptoms include the absence of plant injury to wilting, stunting, leaf spots, cankers, and death.	Remove and destroy infected plants. Do not introduce infected plant material. Reduce spread of infection through thrip control.
Aster Yellows	aster, petunia, zinnia, and others	Mycoplasm-like organisms.	Growing tips yellow and are twisted or stunted. Spread by feeding leafhoppers.	Remove and destroy infected plants.
Root Rots	arborvitae, boxwood, cotoneaster, English, ivy, euonymus, elm, privet, redbud, pyracantha	Pythium, rhizoctonia, and fusarium fungi	Impairs ability of roots to absorb water and nutrients, symptoms include wilt and nutrient deficiencies. Kills herbaceous ornamental seedlings.	Avoid over watering and sites with poor drainage. Do not introduce contaminated plant material.

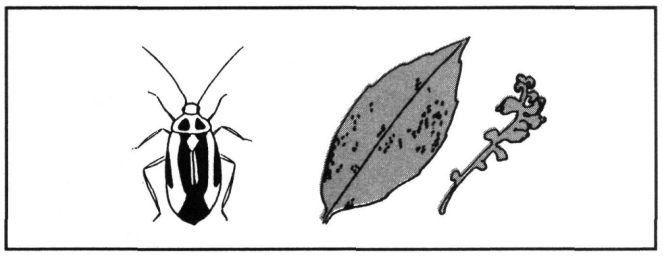
flowers, or fruit with piercing-sucking mouthparts. The resulting damage includes stippling or curling of foliage, loss of plant vigor, or even death. Many piercing-sucking insects are vectors of disease, injecting pathogens into plants as they feed.



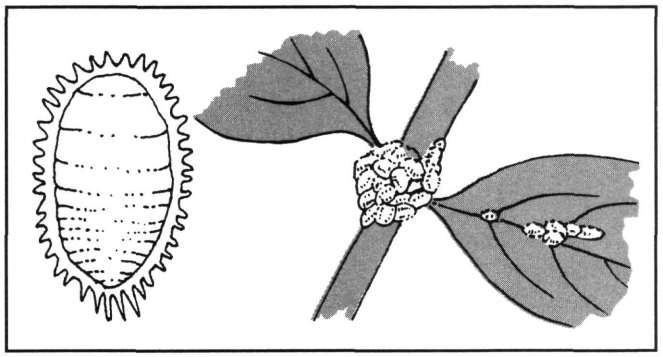
Aphids. Aphids are pear-shaped, soft-bodied insects that are usually less than 1/4" in size. There are many colors of aphids including brown, black, green, yellow, and white. They reproduce either by eggs which hatch in the spring or by giving birth to live young. Depending upon the temperature there may be multiple generations per year. They usually attack new, tender stems and leaves, which results in abnormal curling. Root aphids attack the roots of many ornamentals including aster, buttercup, dahlia, and primrose. Plants heavily infested with aphids lack vigor. Aphids secrete honeydew which drips onto the plants, furniture, and cars. Unsightly sooty mold and ants feed on the honeydew. A wide variety of predators and parasitoids usually suppress aphid populations below damaging levels. Examples: tuliptree aphid; tulip bulb aphid; spirea aphid.



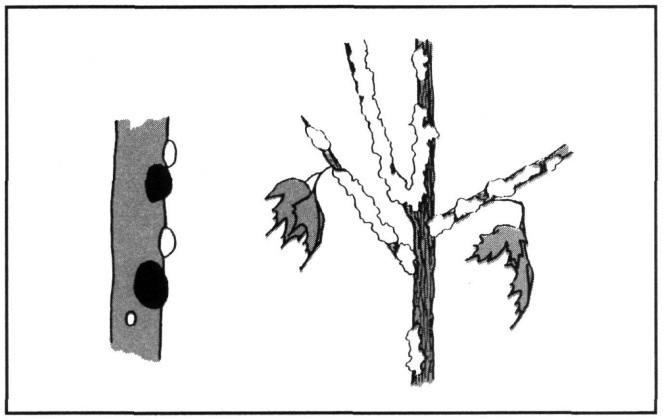
Leafhoppers. The leafhopper family is a large (over 2000 ornamental-feeding species) and diverse group of insects. They range in size from 3 to 15 mm and come in a great variety of colors. Feeding damage appears as white stippling or browning of foliage, or cupping and withering of leaves. Browning and death of plant tissue is caused by the toxic saliva injected by feeding leafhoppers. The greenish-yellow immature leafhoppers run sideways along the underside of leaves when disturbed. Adults look like tiny, green moths darting from branch to branch. Examples: aster leafhopper of flowering plants; Japanese maple leafhopper.



Plant bugs. Adult plant bugs are 2 to 7 mm long, and green, yellow, or bronze in color. Plant bugs feed on a large variety of ornamental plants. As they feed, plant bugs inject a small amount of saliva into plant tissues. This results in bronze leaf spots characteristic of the four-lined plant bug, or in distortion of new growth and dead patches. The tarnished plant bug punctures terminal shoots and flower buds of many ornamentals, causing the flowers to wilt and die. Example: honey locust plant bug.

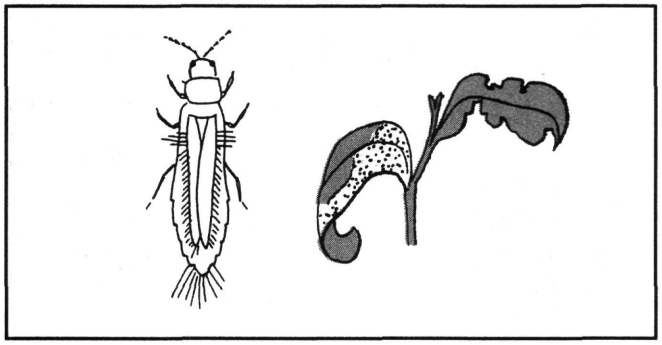


Mealybugs. Mealybugs are soft-bodied insects with a waxy covering that makes them appear white, grey, or pink. They range in size from 4 to 12 mm long. Mealybugs can be found creeping and feeding on stems, shoots, or leaves. Mealybugs produce honeydew and sooty mold when feeding. They have many natural enemies that keep most populations in control, but outbreaks can significantly weaken or kill plants. Examples: taxus mealybug, longtailed mealybug of foliage plants.



Scales. Adult scales produce a thick, protective coating of wax. They are seldom recognized as insects by untrained persons. Most scales overwinter

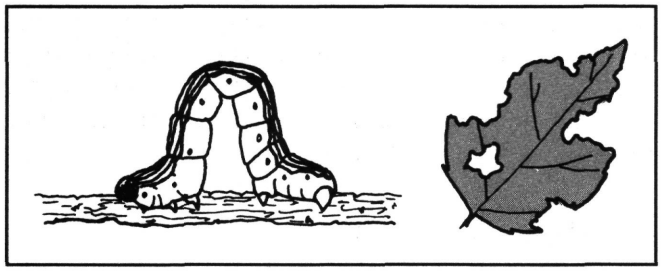
on the plants as eggs underneath the female scale covering. Newly-hatched scale "crawlers" move about the plant in search of a feeding site. Once they insert their mouthparts, crawlers become immobile and develop the waxy covering. Feeding damage results in branch dieback, and loss of vigor. Some species produce honeydew. Death of heavily-infested plants is not uncommon. Examples: euonymus scale, oyster-shell scale; pine needle scale.



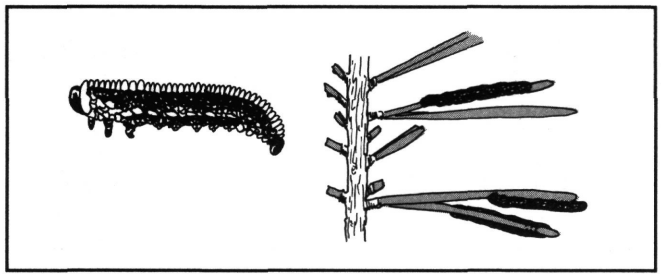
Thrips. Thrips are small (1 to 4 mm) cigar-shaped insects which are commonly found on flowers, flower buds and dense leaf buds. Thrips are not technically piercing-sucking insects, since they scrape leaf surfaces to suck sap. The resulting damage can give foliage a grayish, dusty appearance. Feeding on unfolded leaves often causes distortion. Some thrips feed on flower petals leaving unsightly patches or streaks. The Western flower thrip transmits the tomato spotted wilt virus as it feeds. Heavy infestations of thrips can be diagnosed by the dark, shiny drops of excrement. Examples: flower thrip; privet thrip.

Leaf-chewing Insects

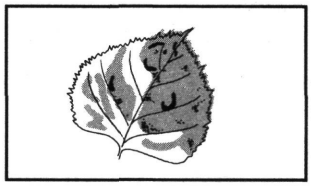
Leaf chewers are a diverse group of insects including adult beetles and immature moths, butterflies, beetles, and sawflies. These insects can be diagnosed by their characteristic pattern of foliage feeding.



Caterpillars. Butterfly and moth larvae, or caterpillars, are soft-bodied except for a hard head capsule. They have from five to seven pairs of "legs" and come in a variety of sizes, shapes, and colors. Some caterpillars are covered with thick, long hair, while others have smooth bodies and mimic twigs. They may chew holes in leaves or chew inward from the leaf edge. Caterpillars which gather on plants in large numbers (i.e. morning cloaks and gypsy moths), may heavily defoliate their host plants. However, trees are tolerant of leaf injury and little harm is realized unless the defoliation level exceeds more than half of the tree crown. A species of caterpillar which is a problem during the present season often is not a pest the following year. With growth, a caterpillar's appetite increases. The great majority of feeding damage occurs just before pupation. Often caterpillar problems are not detected until feeding is nearly over and treatments no longer benefit infested plants. Prevent this situation by monitoring for small caterpillar activity. Examples: spring and fall cankerworm, tussock moth.

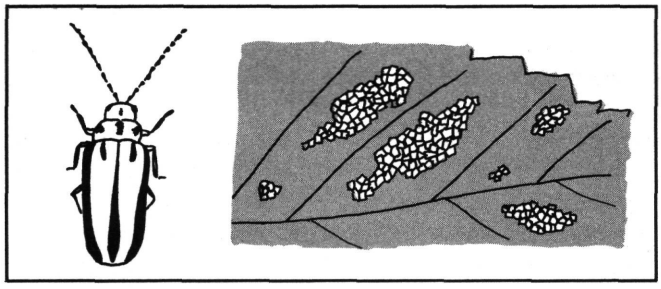


Sawflies. Sawfly larvae look like caterpillars, but are the immature form of small (8 to 25 mm), fly-like wasps. Like caterpillars, sawflies consume foliage and cause the most damage just before pupation. Most sawflies of ornamental concern are those that attack evergreens. Because they usually occur in groups, sawfly infestations causes disfigurement or defoliation. Examples: pine sawfly; mountain ash sawfly.

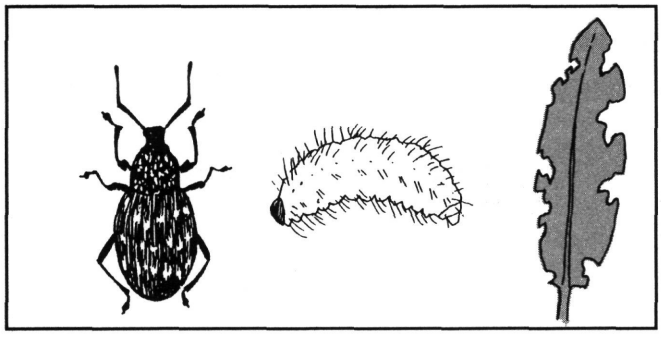


Leafminers. Leafminers are maggot-like immature forms of species of wasps, beetles, moths, and flies. Leafminer eggs are laid inside of leaves. Hatched larvae consume the inner layer of the leaf leaving characteristic "mines." Larvae inside of mines are protected by the leaf exterior and therefore are less susceptible to insecticides. Leafminers pupate and emerge as adults from the leaf. Examples: birch leafminer (sawfly wasp); columbine leafminer (moth); boxwood leafminer (fly); black locust leafminer (beetle).

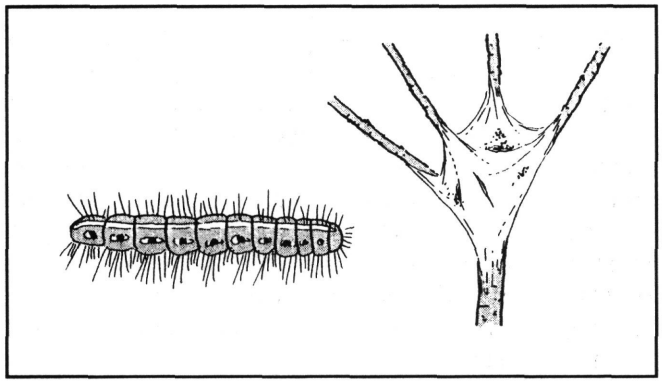
Leaf beetles. Leaf beetles make up one of the largest plant-feeding families of beetles with more then 2,000 species found in North America. The adult beetles are often brightly- or metallic-colored and range in length from 3 to 12 mm. Leaf beetle larvae are soft-bodied and usually feed on foliage with the adults. Some leaf beetle larvae live in the soil and feed on plant roots. Feeding damage of many leaf beetle pests is skeletonizing of leaves. The beetles consume all but the upper leaf epidermis,



leaving tiny "windows" on leaf surfaces. Defoliation can occur when plants are heavily infested. Examples: imported willow leaf beetle; elm leaf beetle.

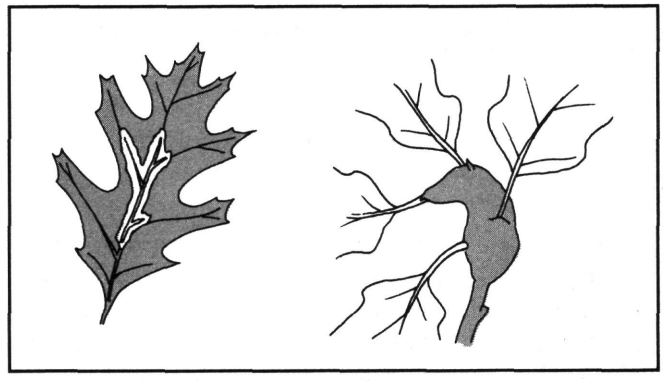


Weevils. Weevils are another large family of beetles containing more than 2,500 species in North America. Adult weevils are characterized by a broad, beak-like snout. Most are 4 to 10mm long, slow-moving, and darkly-colored. The feeding damage of adults can be diagnosed by the crescent-shaped notching of leaf edges. Some weevil larvae (white pine weevil, root collar weevil) develop under the bark of shoots or trunks. The larvae of root weevils feed on plant roots. These larvae are white, legless, and C-shaped. Examples: black vine weevil; strawberry root weevil.



Tent and Case-making Insects

Some insects gather leaves and twigs or produce silk to construct a protective tent or case. Case-making insects which are rarely injurious include leaf rollers, leaf tiers, and casebearers. Casebearers are moth or leaf beetle larvae which construct tubular cases from foliage, soil particles or other debris. Species of casebearers attack a large variety of ornamentals, occasionally causing serious damage. Bagworms are moth caterpillars that, shortly after hatching, build cases out of host leaf materials. Since bagworm larvae remain on the host on which they hatch, the isolated infestations often build to damaging levels. Webworms and tent caterpillars are moth larvae who feed at night and gather inside of unsightly silken tents during the day. Large infestations may result in defoliation. When chemical control is necessary, apply insecticide to the foliage where caterpillars feed. Examples: bagworm of Eastern red cedar, Japanese maples, and arborvitae; Eastern tent caterpillar and fall webworm.

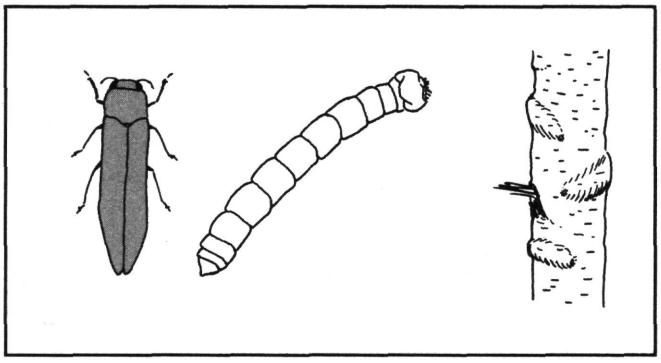


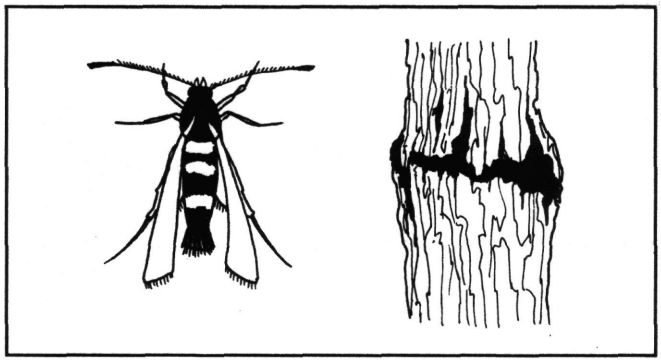
Gall-forming Insects

Galls affect the growth of developing plant tissues. Consequently, most galls are produced solely during late spring on new plant growth. Formed galls cannot be eliminated; the injury is irreversible. Though the galls are often conspicuous and may be unattractive, they rarely cause more than aesthetic damage. Gall wasps are small, black insects which insert eggs into plant tissue. Hatched larvae produce chemicals which result in spherical stem galls, star-like leaf galls, or horny twig galls. Oak trees are host to a large number of gall wasps. Gall midges are flies that attack oak, willow, elm, maple, walnut, pine, and honey locust. Gall midges induce ridged vein galls or rounded stem and leaf galls. Adelgids are related to aphids. Several important species induce plant gall formation. The pineapple-shaped gall common on ornamental spruces is caused by spruce gall adelgids. Some adelgids are free-living and do not induce galls. Examples: Cooley spruce gall adelgid; pine bark adelgid.

Root-feeding Insects

Scarab beetle larvae and weevils (see leaf-feeding beetles) are the two most important groups of insects that feed on landscape plant and turf roots. These immature soil insects are often referred to as white grubs. The adult insects of many species consume ornamental plant foliage. Injury can be serious and management difficult as the grubs are protected by soil. Examples: Japanese beetle; European chaffer; June beetle.





Boring Insects

Boring insects feed inside of plant roots, trunks, branches, or twigs. Since most borers only attack plants that are in a weakened state, proper plant care is the best defense against boring insects. Borers represent beetles (flat- and roundheaded borers), and moths (clearwing borers.) Adults of some borer species mimic wasps in appearance. In most cases, it is the larvae that cause plant damage as they tunnel under the bark and, in some cases, into the wood. Eggs are laid on the bark; tiny larvae hatch and penetrate the bark to begin feeding. Coating the bark with a residual insecticide to prevent egg laying and hatching is one method of borer management. Once they are underneath the bark, boring larvae are protected from most insecticides. Barriers placed over the trunks of newly-planted or otherwise weakened trees lessens the occurrence of borer entry. Twig and root borer management consists of removing and destroying infested plants and plant parts. Established borer larvae may be crushed with flexible wire inserted into the stem, or by some insecticides. Examples: iris borer; lilac borer; peach tree borer.

Insect Management

Most insects are resistant to insecticides during part of their life cycle. During this time the insect is either inactive or is protected by a physical barrier to insecticide. Examples include:

- **pupal cases** of moths and butterflies
- **waxy coating** covering adult scales
- **galls** formed by adelgids and wasps
- **host plant bark** covering bark beetles and wood borers
- **leaf tissue** covering deposited eggs or leaf-miner larvae
- **soil** covering beetle grubs and various overwintering insects

All insects have life stages that are vulnerable to controls. Insect management activities and susceptible life-stages must coincide. The timing of and need for insect suppression is influenced by several other biological factors. Weather conditions, for example, may slow or accelerate the growth of pest populations and therefore influence pest management decisions. Consider the following biological properties of insects when assessing the need for and timing of tactics:

- Life stage susceptible to management tactics.
- Damaging life stage(s).
- Length of time feeding damage occurs.
- Reproduction rate.
- Number of generations per year.
- Weather conditions.
- Presence of natural enemies.

Alternative Insect Controls

Managers of landscapes, who are primarily concerned with maintaining plant health and appearance rather than obtaining "pest-free" plant material, set higher pest damage thresholds than nursery operators. Because a reasonable amount of aesthetic plant damage can be tolerated, alternative control methods should be widely incorporated into IPM programs for established landscape plants. Although there are fewer options available to plant producers which result in an acceptable level of control, nonchemical methods should be a part of all insect management programs. Remember, insecticides may be the most effective "manufactured" management tool, but they are ranked a distant second to the natural enemies of insect pests. Before carrying out any insect management measures, always consider the negative impact on beneficial organisms.

Insect pests search for preferred egg-laying, feeding, and shelter sites. Features, such as foliar hair, leaf shape or form, or fruit structure affect a plant's attractiveness to insect pests. Many plants produce chemicals which render them undesirable to insects. For example, the gypsy moth caterpillar will consume over 500 species of trees, shrubs, and vines. However, for some reason they will not consume ash, honey locust or Callery pear.

Plants have a limited ability to outgrow, repair, or withstand insect damage. There are varieties of marigolds, for instance, which have a greater capacity to survive leafhopper damage than other varieties. Not surprisingly, plant resistance to insect damage is most effective in healthy, vigorous plants. Recognize that even the most tolerant plant variety will be damaged if an insect pest population is great enough or is present for a long period of time.

Many cultural and mechanical control methods are appropriate for insect management programs. Any measure to increase plant health and vigor (watering, fertilizing, aeration, etc.) and decrease insect habitat (tilling, weed control, plant species diversity) will greatly aid in insect damage prevention. Refer to Chapter 3 of this manual and the table on the next page for examples of alternative means of insect control.

Insecticides

Despite the controversy, concern, and criticism over insecticides, chemical control continues to be a useful tool in IPM programs.

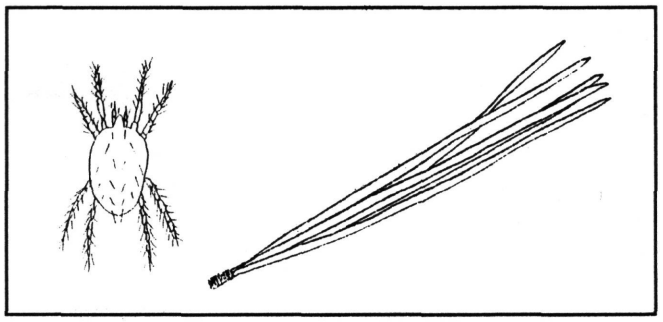
Avoid problems from improper insecticide use by:

1. Monitoring plants frequently. Apply pesticides only when and where needed.
2. Protecting beneficial insects and mites. Eradication of insect pests is not necessary to prevent landscape injury, and a residual insect pest population is needed to maintain beneficial insects.
3. Carefully timing insecticide applications to attack insects at the weakest point of their life cycle. Frequently monitor pest activity to time the applications.
4. Avoiding preventive treatments except when intolerable damage is certain to occur.
5. Taking advantage of non-toxic and systemic insecticides to limit pests while minimizing the effect on nontarget organisms.

Specific product recommendations for insect problems are made on product labels and in reference publications such as "Insect and Mite Management on Landscape Plants", Extension bulletin E-2088. Remember, *it is your responsibility* to be certain that any pesticide you use is registered for use in Michigan and is applied as specified by the label.

Mites

Mites are closely related to insects, but are in the same class, Arachnida, as spiders and ticks. Most insecticides are not effective on mites. Mites are minute in size—some species cannot be seen with the unaided eye.



Spider mite and injury.

There are many species of mites that cause significant injury to bedding plants, ground covers, shrubs, and trees. The most frequently encountered mite pest in the landscape is the two-spotted, or red-spider, mite. This mite attacks deciduous ornamentals (dahlia, elm, flowering crab, hawthorn, pansy, phlox, rose), as well as evergreens (English ivy, juniper, hemlock). The nymphs and adults of the two-spotted mite, as well as many other damaging species, feed via piercing-sucking mouthparts on the foliage, buds, stems, and fruit of all types of ornamental plants. The damaged plant parts are very finely speckled and may have an overall cast of red, bronze, yellow, white, or brown. Off-color foliage of junipers, spruces, false cypress, and firs is a sign of the spruce spider mite. Spider mites spin light, delicate webs where they feed. Eggs and mites which are covered with webbing are more or less protected from sprays.

Gall mite feeding damage includes rusting of foliage or distortion of leaves and buds. As their name suggests, some gall mite species produce leaf spindle or bladder galls, such as are formed by the maple bladder gall mite. Rarely do gall mites cause significant landscape injury. This is fortunate since mites who produce protective galls are particularly difficult to manage.

Mite populations can build rapidly because they have many generations per year. Mites develop and reproduce quickly during the cool periods of early and late summer. The most severe injury, however, occurs on plants in hot, dry locations. Watch for landscape "hot spots" in areas mulched with stone, and those near pavement and buildings. Like most pests, mites do best and cause the most damage on plants in a weakened condition. Use of insecticides to manage insect pests often encourages mite outbreaks due to the sudden drop in mite natural enemy populations.

Despite their small size, the presence of mites on ornamental plants can readily be determined. Tap the suspected infested branch over a white piece of paper. Dislodged mites will appear as tiny specks moving on the paper. Careful monitoring of mite-

Insects of Michigan Ornamental Plants and Alternate Controls

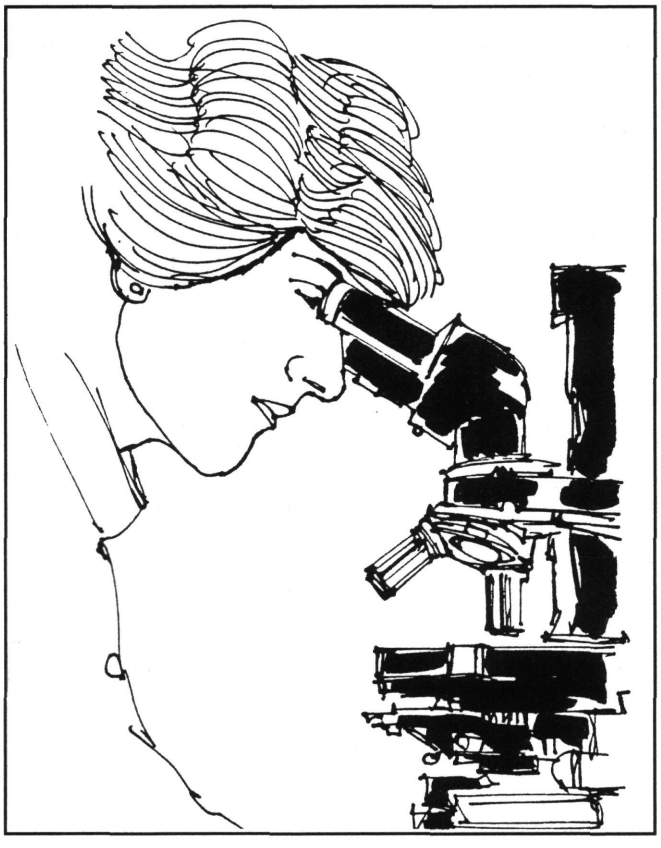
Insect Pest	Location on Host	Alternative Controls
Aphids	Nymphs and adults feed on tender foliage of all kinds of ornamental plants.	Remove aphids from plant with a hard stream of water.
Whiteflies	Feed on the underside of leaves of azalea and many flowering plants.	Encourage natural enemies. Maintain plant vigor.
Lacebugs	Found on the underside of leaves and on stems of sycamore, oak, hawthorn, andromeda, azalea, and cotoneaster.	Encourage natural enemies.
Mealybugs	Nymphs and adults feed on host foliage, trunks, and stems of all types of ornamental plants.	Remove with a hard stream of water or scrape off with a scrub brush.
Scales	Found on leaf and twig surfaces of many shrubs, trees and flowering plants.	Use a scrub brush to remove waxy coating to increase predation and insecticide efficacy. Scrape off scales from twigs, or prune off infected twigs.
Boxelder Bug	Nymphs feed on foliage. All stages are found in great numbers on boxelder, poplar, and birch trees in the fall.	Trap adults under boards or folded newspaper and destroy.
Plantbugs	Nymphs and adults feed on leaves, causing brown spots. Defoliation can occur with heavy infestations. Some species inject a toxin which deforms or kills stem tips, buds, flowers, and fruits.	Encourage natural enemies. Maintain plant vigor.
Spruce gall adelgids	Adults and young nymphs found on crevices of twig tips and in buds of Norway, white and blue spruces, and Douglas fir. Other stages inside of galls.	Prune out galls occupied by insects. Burn removed galls.
Borers	Adults found on bark and branches of hosts including ornamental fruits, dogwood, birch, rhododendron, lilac, arborvitae, and many flowering plants. Larvae feed on the inside of the plant.	Trap borer adults with sex-lure traps. Wrap host trunk with heavy tree wrap to help prevent egg laying or entry by boring larvae. Grow healthy trees free of mechanical injury and water stress.
Leafminers	Larvae feed on the inside of leaves. Often a problem on black locust, American holly, birch, delphinium, chrysanthemum, and many other plants.	Remove and destroy infested leaves of herbaceous plants.
Cankerworms	Larvae are found on the foliage of elm, linden, oak, beech, crabs and many other trees and shrubs.	Spray with Bt or insect-parasitic nematodes.
Tent Caterpillars & Webworms	In protective structure in crotches or around branch tips. Common in cherry, crab, mountain ash as well as shade trees.	Prune out caterpillars and webworms inside of web or tent. Spray with Bt or insect-parasitic nematodes.
Sawflies	Larvae are clustered in large numbers on the new growth of pine, Mountain ash, dogwood, ash, viola, and others.	On small trees, blow off sawflies with a stream or water or remove by hand.
Chaffers	Adults are found on the foliage of flowering plants and shrubs, including rose, grapes, elms, peony and hollyhock.	Protect susceptible plants with gauze netting. Avoid water stress.
Black Vine Weevil	Adults chew on foliage and larvae feed on the roots of taxus, euonymus, rhodedendrons and many low-lying ornamentals.	Encourage natural enemies.

prone plants provides information necessary to manage mite populations at low levels and prevent outbreaks.

Properly watering and fertilizing plants is a primary means of limiting mite injury. Forceful hosing of infested plant foliage and stems will dislodge and crush mites and their eggs. There are also miticides or acaricides available to manage mite pests. Remember however, there are numerous mite predators, such as ladybird beetles, lacewings, and predaceous mites, that are also "controlled" by chemical sprays. Also recognize that repeated use of a miticide often results in mite populations that are resistent to the chemical control. For these reasons, it is wise to incorporate as many non-chemical and preventive mite management methods as possible.

Nematodes

Nematodes are microscopic, worm-like animals living in soil, water, and other organisms. Plant-parasitic nematodes feed most commonly on roots, but also on stems and foliage. They use needle-like mouthparts, or stylets, to puncture plant cells. After injecting digestive juices, nematodes consume plant cell contents. The pinewood nematode occupies the resin ducts and cambium of ornamental pines. Leaf-feeding nematodes attack chrysanthemums, begonias, dahlias, and many other ornamentals, causing brown or blackish areas between the veins. Fungal and bacterial diseases often enter through nematode feeding wounds.



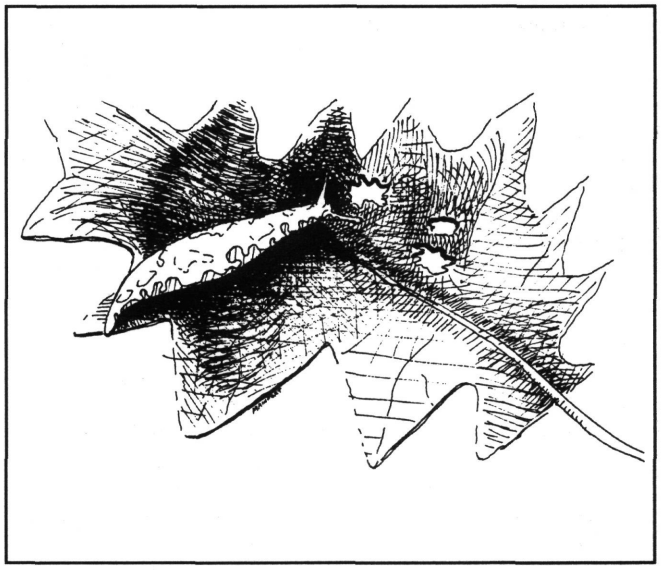
Nematodes typically injure roots by forming galls and lesions, or by rotting them. Above-ground symptoms of root-feeding nematodes are like those caused by a failing root system and include wilting, stunting, dieback, and lack of vigor. Infected plants may have galls, decay, and rough, stubby, or black and discolored roots. These symptoms are usually thought to be caused by poor soil or lack of water and fertilizer. The Northern root knot nematode attacks many ornamental plants including Japanese barberry, clematis, dahlia, forsythia, gladiolas, hydrangea, pachysandra, peony, rose, periwinkle, verbena, and weigela.

Because of their small size and nondescript top injury, laboratory analysis may be necessary to diagnose nematode problems. Plant and soil samples can be sent to the MSU Plant and Pest Diagnostic Clinic. The address is listed in the Resources section of this manual.

Most nematicides are extremely hazardous soil fumigants and therefore cannot be utilized to manage nematodes in the landscape. Plants suffering from nematodes must be removed and destroyed. Choose replacement plants that are not susceptible to infection by the damaging nematode. Great care must be taken when using nematicides to prevent plant injury in the nursery.

Snails and Slugs

Snails and slugs are soft-bodied animals which leave large, irregular holes as they feed on the foliage of young and succulent plants such as hosta, marigold, and delphinium. The spotted garden slug and tawny garden slug are common landscape pests. Snails and slugs are mostly active at night, and



A slug feeds on foliage.

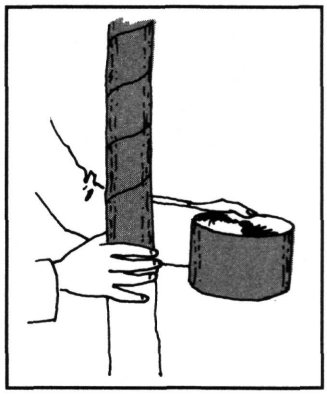
prefer moist areas. A shiny slime trail on plants and soil indicate movement of these pests. Slugs differ from snails in that they have no shell. Young snails and slugs, which resemble the adults, hatch from eggs in the spring. They generally mature, reproduce, and die by the winter.

Dusting the soil and susceptible plants with diatomaceous earth will effectively limit snails and slugs. Diatomaceous earth is a dust made from the ground-up shells of fossilized microorganisms. As snails and slugs travel over and ingest the dust, they are mortally cut. Snails and slugs require moist, shaded areas and can be discouraged by garden sanitation. Thinning plant crowns to improve ventilation and air movement also reduces snail habitat. Snails and slugs can be trapped and drowned in small containers of stale beer, or trapped under and removed from boards placed on moist garden soil. Baits treated with molluscicide are also available.

Vertebrates

Several types of large animals harm ornamental plants. While vertebrate injury in the landscape mostly occurs as isolated cases, the damage is often serious. For instance, by boring numerous holes in the trunks of trees, sapsuckers disrupt food and water transport systems and introduce disease and decay organisms. The injury caused by these birds can be recognized by the neat rows and columns of trunk holes. There is no effective way to eliminate sapsucker damage.

In the winter mice, rabbits, meadow voles, and deer feed on the bark of ornamental trees and shrubs. If feeding injury extends all the way around the stem, the portion of the plant above the injury will die. Beavers feed on or outright kill and remove small landscape trees. Winter- and beaver-feeding damage can be prevented on susceptible plants by using physical barriers, such as plastic or wire wraps, or chemical repellents. When applying the protection to plant stems, be sure to consider the probable depth of the snow during the winter. A thick layer of snow will allow feeding animals to reach the stems above zone protected by wraps or repellents.



Tree wrap helps prevent bark feeding by animals.

When considering management options remember that nontarget wildlife must not be endangered. Physical barriers, live traps, wildlife repellents, and removal of pest habitat should be implemented before poisonous baits. Remember that the trapping of wildlife, excepting rats, mice, voles, moles, and chipmunks, is regulated by the Michigan Department of Natural Resources (see traps section, Chapter 2).

Review Questions: Chapter 6

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

1. Define infectious disease. How does it differ from noninfectious disease?

2. Name the part of the disease cycle in which inoculum enters the host.

3. A particular disease often produces a number of symptoms, and one symptom can result from different non-infectious disorders and pathogens. *(True or False?).*

4. Describe the plant injury and causal agents of: leafspots, chlorosis, cankers, blights, and decline.

5. What is a microclimate in the landscape? How does it relate to disease development on ornamentals?

6. Honey dew and sooty mold is produced by what kind of insect feeding? Name a group of insects that produces honeydew.

7. Adult caterpillars are: a) bees b) aphids c) butterflies or moths d) nymphs.

8. Describe how leafminer larvae feed.

9. Give three examples of protective structures insects construct which protect them from pesticide sprays.

10. Describe how plants can be resistent to insect damage.

11. Whenever possible it is best to eradicate insect pests from the landscape. *(True or False?).*

12. Name the most frequently encountered landscape mite pest. What are the plant injury symptoms?

13. Describe the method to confirm that mites are infesting a plant.

14. Name two natural enemies of mites.

15. Describe how nematodes feed on plants. What is the resulting injury produced by foliage- and root-feeding nematodes?

16. Because of their distinct appearance, nematodes are easily diagnosed in the field. *(True or False?).*

17. Galls are produced by species of fungi, insects, mites and nematodes. *(True or False?).*

18. Since snails and slugs are generally not active during the day, how can you determine where they have travelled?

19. Describe how the feeding damage caused by mice can kill a tree or shrub.

Resources

You may wish to purchase some of these resources to use as a reference for your work. Those identified as Extension Bulletins may be ordered from the Michigan State University Extension Bulletin Office (517-355-0240).

MSU Cooperative Extension Service (CES) publishes the Crop Advisory Team (CAT) Alert, Landscape Edition each growing season. CES campus specialists and field staff from across the state meet once a week through a conference phone call to discuss and compile information on current and predicted plant growth, pest status, management recommendations, pesticide registration status, and market developments. The weekly publication developed from these meetings is called the "Landscape Alert." To subscribe to the Alerts, call 517-355-0117 or write: Pest Management Programs, Room 11, Agricultural Hall, MSU, East Lansing, MI 48824-1039

Pesticide Product Information

Agricultural Chemicals Book I—Insecticides, Acaricides and Ovicides. W. T. Thomson.

Agricultural Chemicals Book II—Herbicides. W. T. Thomson.

Agricultural Chemicals Book III—Fungicides. W. T. Thomson.

Tree, Turf and Ornamental Pesticide Guide. W. T. Thomson.

The Insecticide, Herbicide, Fungicide Quick Guide. B. G. Page and W. T. Thomson.

Herbicide Handbook of the Weed Science Society of America.

The 1987 Pesticide Directory: A Guide to Producers and Products, Regulators, Researchers and Associations in the United States. Lori Thompson Harvey and W. T. Thomson.

Farm Chemicals Handbook. Richard T. Meister, editor.

Pesticide Use and Safety

Fundamentals of Pesticides—A Self Instruction Guide. Dr. George W. Ware.

Pesticides: How They Work, Human Poisoning Treatments. Extension bulletin #E0789.

Pesticide Emergency Information. Extension bulletin #AM37.

SARA Title III. Extension bulletin #E2173.

Insecticide User's Survey. Oakland County Cooperative Extension Service (313) 858-0887

Spartan Ornamental Network.
MSU Department of Horticulture
A240 Plant and Soil Sciences Building
East Lansing, MI 48824-1325
(517) 355-9741

Plant Identification

Manual of Herbaceous Ornamental Plants. Stephen M. Stills

Manual of Woody Landscape Plants. Michael A. Dirr.

Fruit Key and Twig Key to Trees and Shrubs. W. M. Harlow

MSU Plant and Pest Diagnostic Clinic
138 Plant Biology Building
Michigan State University
East Lansing, MI 48824-1312
(517) 355-4536

Pest Management—General

Diseases and Pests of Ornamental Plants, 5th edition. Pascal P. Pirone.

The Ortho Problem Solver. Ortho Division of Chevron Chemical company.

The Complete Guide to Pest Control—With and Without Chemicals. Dr. George W. Ware.

Rodale's Landscape Problem Solver. Jeff and Liz Ball.

Rodale's Flower Garden Problem Solver. Jeff and Liz Ball.

Coincide: The Orton System of Pest Management. Donald Orton and Thomas L. Green.

Diagnosing Problems of Ornamental Landscape Plants. Extension bulletin #E2024.

Production of Ground Covers as Bedding Plants. Extension bulletin #E2127.

Crop Advisory Team (CAT)
Alert, Landscape Edition
Cooperative Extension Service
Room 11, Agricultural Hall
Michigan State University
East Lansing, MI 48824-1039

MSU Plant and Pest Diagnostic Clinic
138 Plant Biology Building
Michigan State University
East Lansing, MI 48824
(517) 355-4536

Landscape Weeds

Nursery and Landscape Weed Control Manual. Robert P. Rice, Jr.

Problem Perennial Weeds of Michigan. Extension bulletin #E0791.

Weeds of the North Central States. Extension bulletin #NCR281.

Annual Broadleaf Weed Identification. Extension bulletin #NCR090.

Annual Grass and Perennial Weed Identification. Extension bulletin #NCR092.

Factors Affecting Foliar-Applied Herbicides. Extension bulletin #NCR250.

Weed Control in Nurseries and Landscaped Areas. Extension bulletin #E1677.

Ornamental Plant Diseases

Diseases of Trees and Shrubs. Sinclair, Johnson, and Lyon.

A Guide to Identifying Plant Disease Symptoms. Extension bulletin #E1592.

1987 Disease Control Guide—Broadleaf Trees, Shrubs, Ground Covers, and Vines. Extension bulletin #E2022.

1987 Disease Control Guide—Conifer and Christmas Trees. Extension bulletin #E2023.

Winter Injuries to Trees and Shrubs in Michigan. Extension bulletin #E1343.

Insects of Ornamental Plants

Insects That Feed on Trees and Shrubs. Warren T. Johnson and Howard H. Lyon.

Insect and Mite Management on Landscape Plants. Extension bulletin #E2088.

Plant Care and Maintenance

Herbicide Injury to Trees and Shrubs: A Pictorial Guide to Symptom Diagnosis. Jeffrey Derr and B. L. Appleton.

Landscape Management, Planting and Maintenance of Trees, Shrubs, and Turfgrasses. James R. Feucht and Jack D. Butler.

Arboriculture—Care of Tree, Shrubs, and Vines in the Landscape. Richard W. Harris.

Tree Maintenance. Pascal P. Pirone.

Tree Pruning. Alex Shigo.

New Tree Biology. Alex Shigo.

Planting and Care of Ornamental Landscape Plants. Extension bulletin #E1947.

How to Keep Your Trees Healthy. Extension bulletin #E1076.

Fertilizing Shade and Ornamental Trees. Extension bulletin #E0786.

Pruning Shade and Ornamental Trees. Extension bulletin #E0804.

State Master Gardener Program
240 Plant and Soil Science Building
Michigan State University
East Lansing, MI 48824
(517) 353-3774

Natural Controls

The Encyclopedia of Natural Insect and Disease Control. Roger Yepsen, editor.

Bio Integral Resource Center (BIRC)
P.O. Box 7414
Berkeley, CA 94707

Praxis (distributor of biocontrols)
Box 134
Allegan, MI 49010
(616) 673-2793

Professional Publications

Grounds Maintenance
9221 Quivira Rd.
P.O. Box 12901
Overland Park, KS 66216-0901

Landscape Management
7500 Old Oak Blvd.
Cleveland, OH 44130

Arbor Age
P.O. Box 8420
Van Nuys, CA 91409

Professional Organizations

Professional Plant Growers Association
P.O. Box 27517
Lansing, MI 48909
(517) 694-7700

Michigan Nursery and Landscape Association
819 N. Washington Ave., Suite 2
Lansing, MI 48906
(517) 487-1282

American Association of Nurserymen
1250 I. Street, N.W., Suite 500
Washington, DC 20005

National Arborists Association, Inc.
The Meeting Place Mall
Route 101
P.O. Box 1094
Amherst, NH 03031-1094
(603) 673-3311

International Society of Arboriculture
Leal Park
303 West University Ave.
P.O. Box 71
Urbana, IL 61801
(217) 328-2032

Michigan Forestry and Park Association
1117 Blake Street
Lansing, MI 48912

Answers to Chapter Review Questions

Chapter 1
Principles of Pest Management

1. IPM is the use of *all available strategies* to manage pests so that an acceptable yield and quality can be achieved economically with the least disruption to the environment.
2. True.
3. (1) Detection of Agents Injuring Plants; (2) Identification of Agents Injuring Plants; (3) Economic Significance; (4) Selection of Methods; (5) Evaluation.
4. Action can be taken before the plant is seriously damaged, and low-level pest populations are often more easily managed than those at outbreak levels.
5. Weather and therefore pest development varies a great deal between years. Degree days precisely measure the occurrence of temperatures necessary for pest development.
6. True.
7. (1) Evergreen fall leaf drop; (2) Yellow leaves of some plant cultivars; (3) Fruiting, such as the production of cones.
8. False.
9. Hand and pole pruners, trowel, soil probe, knife, binoculars, hand lens, and specimen bags.
10. False.
11. Injury threatening the health, and aesthetic quality of the plant. See page 9.
12. Pests easily spread from plant to plant and may have increased reproduction when preferred hosts are close together.
13. Were plants protected from injury? Did excessive environmental contamination result? Were secondary (other) pest problems created? Was the program impractical or too expensive?

Chapter 2
Pest Control Techniques

1. Short-term suppression techniques provide immediate pest control to prevent further plant damage. Long-term maintenance controls help to create a landscape which can by itself maintain pest populations below injury threshold levels.
2. True.
3. See page 12-13.
4. Raking and disposing of infected leaves before spores are released.
5. Dutch elm disease and fire blight; tent caterpillars and web worms.
6. Mice, rats, moles, voles, and chipmunks.
7. Prevent pests from coming in contact with ornamental plants.
8. False. Natural enemies require some pest individuals to live on. Their survival and population growth is directly related to the availability of pests.
9. Minute pirate bug, ladybird beetle, green lacewing.
10. Provide alternative hosts and favorable habitat. Limit the destruction of beneficials by applying pesticides only when and where necessary. Use systemic pesticides and avoid broadspectrum pesticides.
11. Bt. Armyworm, Eastern tent caterpillars, gypsy moth, and fall webworm.

Chapter 3
Application of Pesticides

1. Type of pest controlled, pesticide chemistry, mode of action, and pesticide formulation.
2. True.
3. Less toxic pesticides have fewer regulations governing their use and less liability associated with pesticide accidents.
4. Miticides and acaricides (some insecticides are labeled for mites).
5. False. Broad-spectrum pesticides kill beneficial as well as pest organisms.
6. Systemic herbicides are absorbed into and travel within the host plant. Contact herbicides kill only the plant portions the spray touches. Systemic herbicides are used to control established perennial weeds because they will kill the underground plant portions.
7. Dry formulations are easily transported and stored. Unmixed dry formulations are not as affected by temperature extremes. Liquid formulations are more easily measured in the field.
8. Wettable powder = WP; emulsifiable concentrate = EC or E; granules = G.
9. False.
10. Compressed-air, backpack, small power sprayers and rotary nozzle sprayers are all useful for spraying small plants. Properly fitted hydraulic sprayers are also useful for spraying small plants.
11. Wick applicator.
12. True. False. The smaller the droplet, the more drift is produced.
13. High pressure sprayers need a relief valve to prevent excessive pressure and to regulate the pressure going to the spray gun.
14. Very calm (under 4 mph) conditions. Mist blowers produce a great deal of drift.
15. Injection and implantation (see "Pesticide Formulations" table on page 19).
16. Tall tree spraying requires a medium orifice for height. Better coverage with less spray solution output can be obtained with a small orifice.
17. See page 23.
18. Lacebugs live on the underside of leaves.
19. Spray from the side into the plant, down into the top of the plant, or from against the fence outward.
20. See page 24. Three years. One year.

Chapter 4
Pesticide Safety

1. True.
2. False. You must comply with label recommendations.
3. The unmixed, or concentrated form, of pesticides is the most hazardous to handle.
4. Cholinesterase is an essential chemical in the nervous system. Exposure to cholinesterase-inhibiting insecticides can lower an applicator's cholinesterase below a healthy level.
5. The chemical class carbamates (including carbaryl and oxamyl) and organophosphates (including diazinon, dursban, malathion, acephate).

6. Alcohol intensifies the effects of pesticide poisoning.
7. Call a doctor.
8. True.
9. See page 29.
10. (1) The victim is unconscious or is having convulsions; (2) The pesticide is corrosive; (3) The pesticide is formulated with petroleum products; (4) The pesticide label specifies not to induce vomiting.
11. True.
12. (1) Do not leave a filling tank unattended;
(2) Do not mix pesticides above the recommended rate;
(3) Review the pesticide label before opening and mixing; (4) Wear protective clothing and gear;
(5) Triple rinse pesticide containers as you empty them. See page 30 for more safety guidelines.
13. A small amount of pesticide may drift over fences. When applying pesticides near a fence, the applicator must take the same precautions for the adjacent property as for the client's property (see page 31).
14. Check the product label for the reentry period. It is generally safe for people and pets to enter an area after pesticide sprays have dried and dusts have settled.
15. (1) There is a great potential for liability; (2) Stored pesticides degrade; (3) Pesticides can be banned from use; (4) Pesticide packaging and labels deteriorate.
16. See page 32.
17. The best way to dispose of a pesticide is to use it in a manner consistent with its label.
18. Unopened pesticides should be returned to the dealer or manufacturer, or offered to another qualified applicator.
19. Stop the spill, contain the spill, and clean up the spill.
20. False.
21. People equate professional ability and integrity with the appearance of you and your equipment.
22. (1) Membership in professional organizations;
(2) Workshops; (3) Trade shows;
(4) Industry journals;
(5) Evening college courses.
23. To keep up to date with the latest requirements for conducting your business.
24. True. Thorough employee training is well worth your time and money.

Chapter 5
Non-pest Disorders and Landscape Weeds

1. False. The majority of landscape plant injury is caused by poor growing conditions.
2. Environmental.
3. Lawn mower blight and herbicide injury.
4. Any plant that grows where it is not wanted.
5. True.
6. Summer annual weeds germinate from seed in the spring and die by winter. Winter annuals germinate from seed in late summer, overwinter, and produce seed the following spring. Biennial weeds complete their life cycle in two years. Perennial weeds live for three or more years.
7. A propagule is a specialized plant structure at or below the soil surface which produces new shoots. Stolons, bulbs, rhizomes, and tubers are all propagules.
8. (1) Create vigorous ornamental plants. Plant resistance and proper plant maintenance; (2) Prevent seed production. Sanitation, cultivation, cutting and chemical controls; (3) Prevent seed germination. Mulching and preemergent herbicides; 4) Control emerged weeds early. Tillage, cultivation, cutting and herbicides; (5) Control susceptible stages of developed weed plants. Tillage, cultivation, and cutting in addition to herbicides.
9. See page 44.
10. All weeds are most easily controlled as seedlings (see the graph on page 46).
11. Large amounts of rain can cause soluble herbicides to leach through the soil or run-off the site. Light rain can carry root-absorbed herbicides down into the soil where they can be taken in by roots.

Chapter 6
Biology and Control of Pests

1. Infectious disease is caused by living things, or pathogens, such as fungi, bacteria, viruses, and mycoplasmas. Noninfectious disease is caused by non-living agents such as drought, salt exposure, and nutrient deficiency. Only infectious disease can spread between plants.
2. Infection.
3. True.
4. See pages 49 and 50.
5. A microclimate is a relatively small area with growing conditions different from those of the surrounding land. Plants growing in microclimates favorable to disease development, such as wet areas, will be more heavily and consistently infected.
6. Piercing-sucking insect feeding produces honeydew. Aphids, mealybugs and some scales.
7. Butterflies and moths.
8. Leafminer larvae eat the plant tissue between leaf surfaces, leaving hollow areas, or mines, in the leaf.
9. See page 57.
10. Some plants are able to outgrow, repair, or tolerate insect damage.
11. False. Natural enemies depend upon pests to survive.
12. Two-spotted, or red spider, mite. Mite feeding results in fine speckling of foliage, stems and fruit. Plants may appear off-color. Fine webbing may be seen on the plant.
13. Tap an infested plant part over a white piece of paper. Dislodged mites will appear as tiny specks moving on the paper.
14. Ladybird beetles, lacewings, and predacious mites.
15. Nematodes puncture plant parts with a needle-like stylet. After injecting digestive juices, nematodes consume plant cell contents. They may spread bacterial diseases. Leaf-feeding nematode feeding results in blackish areas between the veins. Root-feeding nematodes cause wilting, stunting, dieback, and lack of vigor.
16. False.
17. True.
18. Look for the shiny slime trail on plants and soil.
19. Mice feed on the bark of trees. If the feeding injury extends all the way around and girdles the main stem, the plant will die.

PESTICIDE EMERGENCY INFORMATION

(Please post in an appropriate place)

For any type of emergency involving a pesticide, the following Emergency Information Centers should be contacted immediately for assistance.

Current as of August 1989

HUMAN PESTICIDE POISONING

Eastern Half of Michigan

within the Detroit city proper:
***(313) 745-5711**

within the 313 area code:
***1-800-462-6642**

Poison Control Center

Children's Hospital of Michigan
3901 Beaubien
Detroit, MI 48201

Western Half of Michigan

within the Grand Rapids city proper:
***(616) 774-7854**

Statewide
***1-800-632-2727**

Blodgett Regional Poison Center

Blodgett Memorial Medical Center
1840 Wealthy, S.E.
Grand Rapids, MI 49506

Upper Peninsula of Michigan

within the Marquette city proper:
***(906) 225-3497**

Upper Peninsula only:
***1-800-562-9781**

U.P. Poison Control Center

Marquette General Hospital
420 West Magnetic Street
Marquette, MI 48955

Michigan State University
Cooperative Extension Service

PESTICIDE EMERGENCY INFORMATION:
Revised by Larry G. Olsen, Pesticide Education Coordinator, Michigan State University.
Current as of August 1989—**destroy previous editions**

SPECIAL PESTICIDE EMERGENCIES

Animal Poisoning

Your personal veterinarian:

and/or

Animal Health Diagnostic Laboratory,
Michigan State University:
(517) 353-1683

Pesticide Fire

Local fire department:

and

Fire Marshal Division, Michigan State Police:
(517) 322-1924

Traffic Accident

Local police department or sheriff's department:

and

Operations Division, Michigan State Police:
***(517) 337-6102**

Environmental Pollution

Pollution Emergency Alerting System (PEAS)
Michigan Department of Natural Resources:
****1-800-292-4706***
(Toll free for environmental emergencies)

For information on pesticide disposal and local pick-up days:

Michigan Department of Natural Resources
Waste Management Division:
(517) 373-2730

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

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