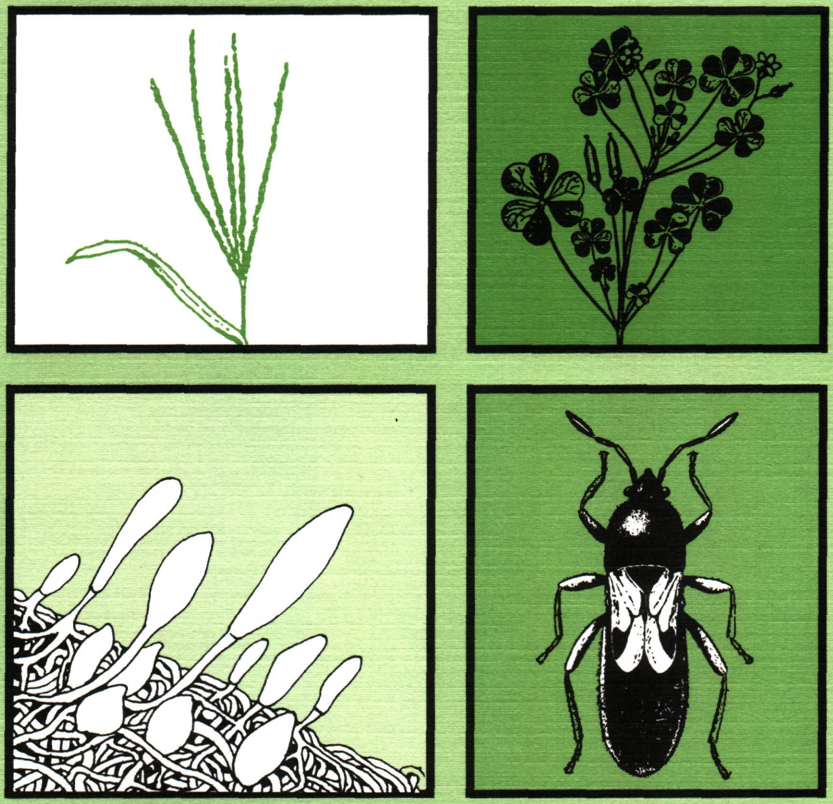
Turfgrass Pest Management

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



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Turfgrass Pest Management

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

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Preface

This manual is intended to prepare pesticide applicators in Category 3A, turf pest management, for certification under the Michigan Pesticide Control Act of 1976, as amended. This category includes the management of turf pests of landscape, recreational, and athletic turf. Included in this category are commercial applicators managing pests of golf courses, schools, parks, athletic fields, and private lawns. The "Commercial and Private Pesticide Applicator Manual: Certification and Registered Technician Training" (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), to become initially certified as a commercial pesticide applicator for ornamental pest management, take the core exam and Category 3A exam. To become **recertified** take the 3B recertification exam and recertification core exam. These exams are administered by the Michigan Department of Agriculture.

Acknowledgements

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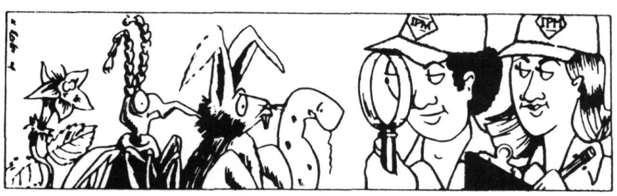
CHAPTER 1

PRINCIPLES OF PEST MANAGEMENT

A pesticide applicator is not merely a person who applies pesticides. Much social and legal responsibility accompanies the use of these 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 turfgrass with control activities.

Integrated Pest Management



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. Not only is turf pest eradication an unrealistic goal, but also this strategy often leads to additional pest problems and environmental contamination. Therefore, the goal of IPM is to reduce and maintain pest populations at levels where aesthetic and economic losses are tolerable. Practices which help prevent or reduce plant injury are used. Integrated pest management is not "anti-pesticide," but rather incorporates a wide range of pest controls such as resistant turf varieties, cultural practices, natural enemies, mechanical controls, and pesticides.

IPM was initially developed for agricultural systems based on the ideas 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 ideas were learned as hard lessons by the agricultural community in the 1960's. Before the introduction of the pesticide 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 oversimplifying plant problems and relying too heavily upon one method of control is unacceptable pest injury to plants.*

Golf course superintendents have traditionally used IPM techniques to manage pests. Golf course turf is stressed a great deal, due to wear and because it is intensively managed. Also, superintendents have limited opportunity to apply pesticides because golfers are on the courses during all daylight hours. In Michigan, commercial turf IPM programs have also successfully managed pests with a minimal amount of pesticides. Some lawn care companies that implement IPM report a 40-60% reduction in pesticide usage. Companies that market turf care rather than merely pesticide applications provide a valuable service to clients as well as earn respectable company profits.

Since 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. As the public becomes aware of the benefits of turf IPM, they are less resistant to such activities. The steps of IPM for turfgrass are:

1. Detection of Agents Injuring Turf
2. Identification of Agents Injuring Turf
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 turf grass.

Detection

There are several IPM goals accomplished by regularly monitoring turfgrass for signs of stress and pest activity. Primarily, you must know what is injuring turfgrass plants before management decisions can be made. A stab-in-the-dark approach will not economically or adequately protect turf. Another objective is to spot pest populations at non-damaging levels. Then you can take action to manage pests before the turf has suffered serious injury. In addition, pest populations are more easy to maintain at, than reduce to, non-damaging levels. Low-level pest populations can often be managed with less toxic controls. Regular monitoring is also necessary to determine if the pest is in the life stage that is susceptible to controls.

Management recommendations for the bluegrass billbug illustrate the importance of detection to IPM. Bluegrass billbugs overwinter as adult weevils. Around late March or early April, the adults become active and lay eggs in the stems of grass. Eggs hatch and the larvae feed down grass stems and into grass crowns. Billbug damage is easiest to see in late July at the height of larval feeding. In mid-summer, mature larvae move into the soil to pupate. Adults feed at the base of plants in late July and August. Insecticides are not effective when applied to larvae feeding on grass plant crowns. While the mature, soil-inhabiting larvae can be killed with insecticides used for grubs, controlling billbug larvae after injury has occurred is useless except for revenge! Monitor and perform control measures in the spring, as limiting egg-laying billbug adults provides the most turf protection.

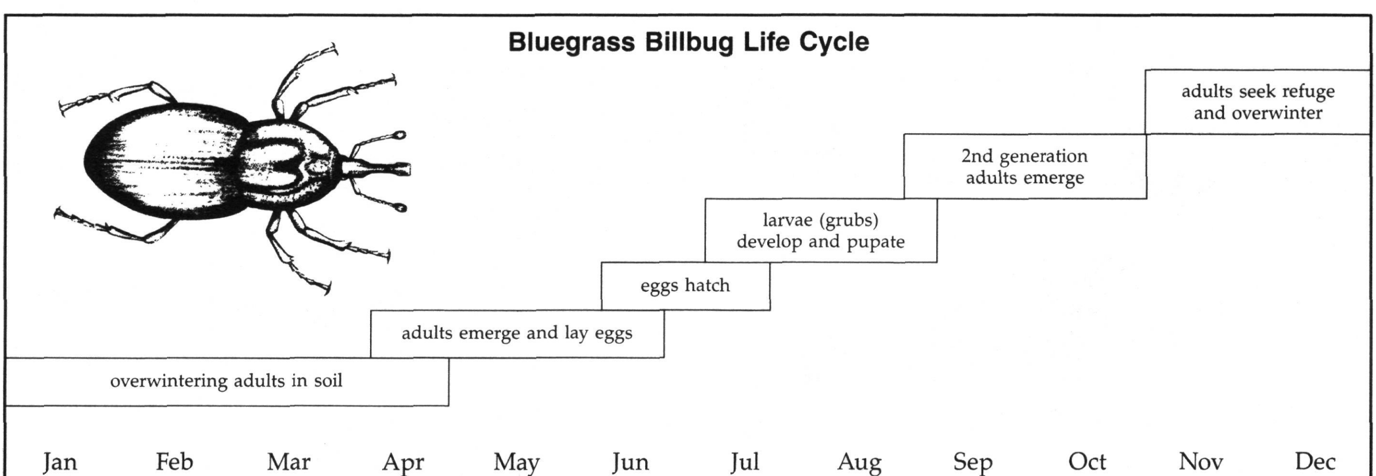
Monitoring Techniques

There are a number of ways to monitor turfgrass for information used in a pest management program. One of the most common detection methods is the actual sighting of pests and their damage. The following describes turf pest detection methods.

1. **Visual inspection.** Get down on your hands and knees and part the grass with your fingers. Concentrate on the edge of the damaged area where fungal disease and insects are likely to be abundant. Watch for insect movement and check grass blades and thatch for insect cases or excrement (frass), or for fungal fruiting bodies.
2. **Coffee can technique.** Use this technique to flush turf insects out of grass crowns and thatch. First cut both ends out of a 2-pound coffee can. Drive one end a couple of inches into the turf, then fill the can with water. Wait a few minutes for insects to float to the surface.

Monitor insects by flushing them out of turf.

3. **White paper test.** Use a sod lifter, cup cutter, sturdy knife, or a trowel to remove a small piece of sod. Slowly peel the sample including soil,



thatch, and grass plants apart over a sheet of white paper. Against the white background, living organisms will be easily detected.

4. **Turf roll-back.** Cut a section of turf one foot square and roll it back to expose root-feeding grubs.

Roll back turf to monitor root-feeding pests.

5. **Disclosing solutions.** A disclosing solution is an irritant which causes turf organisms to move to the surface of turf where they can readily be detected and counted. An effective irritant consists of pyrethrin products mixed at one-half the recommended application rate. Disclosing solution can also be made by mixing 2 tablespoons of liquid detergent with one gallon of water. Apply one gallon of disclosing solution per square foot of turf.

To be useful in turf management, detection information should include detailed information such as the specific area of turf showing injury, level of injury, or number of pests present per sample area. To keep detection information uniform, develop a system to rank turf condition. Use a standardized monitoring sheet such as the sample included at the end of this chapter.

Watch the physical development of pests to know when they are susceptible to management tactics. The rate of pest development varies from year to year depending upon weather conditions. For this reason, timing pest management activities based on calendar dates often gives unsatisfactory results. Pest activity is predicted more accurately by monitoring weather conditions which influence pest development. For instance, temperature greatly affects when disease will occur. Hot-weather diseases such as melting-out and anthracnose become active and damaging when temperatures are over 75°F. Other environmental conditions such as dew, rainfall, and wind are also good indicators of disease development. Insect pests also respond to environmental conditions. For instance, cool, wet springs favor the development of armyworm and slows that of their natural enemies.

Both plant growth and pest development depend on the amount of heat that surrounds the organism. Turf pest development and their activity is best predicted with **degree days.** Degree days are figured in several ways, but are all based on a common principle: the development of plants and pests begins when the air temperature reaches a certain level, and usually continues until the temperature falls below that threshold. Degree days precisely measure the occurrence of above-threshold temperatures. The threshold is called the base temperature and is between 40° and 50°F for most organisms. The Crop Advisory Team of Michigan State University reports degree days with base temperatures of 42° and 50°F for several areas in Michigan. Pest management references, such as *Coincide: The Orton System of Pest Management* and the *Crop Advisory Team (CAT) Alert, Landscape Edition* (see Resources), identify what stage of pest development occurs at specific degree day totals.

There are commercially-available weather monitoring devices and computer programs to help you predict pest development. These devices can be expensive and are therefore suited for use on large, highly-valuable turf areas. But, there are also many inexpensive ways to measure or obtain information about the environmental predictors. When selecting equipment keep in mind that climatic information that most accurately measures the conditions affecting turf is gathered at the crown level of turfgrass.

Identification

An organism should not be classified and treated as a pest until it is proven to be one. There are species of insects, fungi, nematodes, and bacteria that are harmless or beneficial to turf. Mistaking harmless and beneficial organisms for pests and eliminating them with unnecessary pesticide applications often causes greater or additional pest problems. Understanding pest life cycles and behavior allows applicators to effectively target pest control activities.

Many turfgrass disorders are directly associated with a specific species or variety of grass. For instance, necrotic ring spot is a devastating fungal disease which attacks Kentucky bluegrass. Even within this species of grass, certain varieties are more prone to the disease than others. Knowing the variety of injured turfgrass will help you diagnose the disorder.

Similarly, turf pests frequently prefer, and therefore are a greater problem, on sites with certain environmental characteristics. Most diseases benefit from moist conditions, but powdery mildew and Rhizoctonia brown patch do particularly well in shady areas with poor air circulation. Ground ivy *(Nepeta hedracea)* is a lawn weed which prefers shady areas with poor drainage. Crabgrass, a weed which outcompetes turf in sunny, compacted areas, can be expected to become established around drives and walks.

Diagnosing Turf Disorders

Turf disorder diagnosis is often complicated. Frequently, clients do not recognize and respond to injured turf until long after pest activity is complete. Then, the only obvious visual evidence is brown spots in the lawn. In addition, it is common to find more than one disorder occurring simultaneously on turf.

Brown spots are the obvious sign of many turf disorders.

You must be familiar with various injury agents and their damage, and understand how growing conditions influence pest activity on turf. A collection of good turf disorder reference materials is an essential diagnostic tool. Inspecting injured turf with someone experienced in turf disorder diagnosis is the best way to learn. Attending turf educational programs sponsored by the Cooperative Extension and turf organizations is also helpful. Adopt the following diagnostic techniques:

- Ask the client about maintenance practices (e.g. mowing height/frequency) and unusual use of the turf in the past.
- Bring along the necessary tools for thorough investigation and root, soil, and grass sample collection. These may include trowel, soil probe, sharp knife, cut coffee can, hand lens, and specimen bags.
- Have ready access to turf disorder references such as Extension bulletins, books, your records, and fellow diagnosticians.
- Remember that there is often more than one disorder injuring turf at the same time.

Brief descriptions of causal agents of turf injury which help in turf disorder diagnosis are listed in the accompanying table. Remember, evidence of insects, diseases, and nematodes is often within the turf stand and not obvious. You must closely examine the turf, thatch, and soil.

Economic Significance

All pest management activities have costs in terms of materials, time, or environmental contamination. The costs of management tactics must be justified by an equal or greater benefit. This cost-benefit principle is an important component of integrated pest management and is the basis for 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 was developed for IPM of cash crops, where pest injury is easily converted into monetary losses. For turfgrass management, replacing killed turf is an obvious cost of pest activity. Managers must also consider losses in terms of the aesthetic quality or use of the turf. In addition, pests can interfere with, and therefore increase the cost of, maintenance practices.

The **action threshold** is the pest density at which action must be taken to prevent the pest from reaching the economic injury level. Action thresholds are usually set based on the judgement of the applicator. Michigan State University researchers have determined quantitative action thresholds as the number of insects found using specific detection techniques (see Insect Pests, Chapter 9.) Remember, take *action* before *injury* occurs.

Setting Injury Levels and Thresholds

Most pest species are not a problem unless the population increases to a certain density. Turf pest populations may never reach damaging levels because of plant resistance, unfavorable weather conditions, and the natural enemies of pests. Therefore, the presence of a pest does not necessarily mean that management measures must be taken. Indeed, it is not practical to eradicate a turf pest and rarely is it necessary to prevent turf injury.

Turfgrass is more prone to serious pest problems when unnatural conditions exist such as an unsuit-

"Brown Spot" Turf Disorder Diagnosis

Injury Agent(s)	Injury Process	Symptoms	Diagnostic Tips
Mower injury due to dull blades or improper blade adjustment.	Crimps or tears grass blades — ends dry out and turn brown.	Grass blades show a white cast and browning tips.	Examine grass blades for bending, ripping, or fraying.
Dry spots caused by non-uniform irrigation, poor soil condition, thatch, or fungal growth in the soil.	Lack of water causes browning of turf.	Localized dry (brown) spots.	Punch affected spots and the adjacent green area with a knifeblade or other sharp instrument to determine if soil is moist.
Summer dieback.	Natural dieback (dormancy) or turf during hot periods.	Turf may appear brown after mowing. Where concentrated, dieback occurs as brown spots.	Annual bluegrass *(Poa annua)* is prone to dying back. Determine if browning shown only by *P. annua* grass.
Chemical burn due to gasoline or other petroleum products.	Kills grass wherever it is spilled.	Pattern of dead turf depends upon the spill: small spots result from leaking mower gas tanks; large spills result in large dead areas; etc.	All types of grasses, as well as other plants, will be affected. Is damage near mower filling area?
Fertilizer burn.	Product is phytotoxic to turf due to improper application rate or method.	Brown spots or streaks on turf where spreader turned or around obstacles. Uniform brown cast results when fertilizer applied to and left on wet grass.	Check fertilizer history; when applied, how applied, rate, analysis.
Dog injury.	Dogs urinate on turf.	Green or brown spots result depending upon the size of the dog, soil moisture, and temperature. Grass not killed in or around the affected spot turns greener because of nitrogen in the urine.	Will affect all types of grasses.
Insect injury.	Insects feed on grass blades or roots.	Depending upon insect species, injury includes yellowing, wilting, and death of plants.	Check for the damaging insect or its evidence on turf plants or in thatch. Pull up turf to find grubs. Presence of insect-feeding vertebrates such as skunks, birds, and moles indicate a significant insect population.
Infectious diseases.	Disease pathogens infect and injure grass plants. Maximum disease growth and spread differs among diseases and grass types, and is dependent on weather conditions.	Symptoms vary depending upon the disease (see Diseases of Turfgrass, Chapter 8). Injury includes discoloring of turf and death of blades and grass plants.	Usually damage is localized or confined to areas with the preferred site conditions. Many pathogens prefer certain species or cultivars of grass. Check plants and thatch for evidence of pathogens or fruiting bodies.

able growing environment and large plantings of the same species or variety. Unfortunately, turf managers commonly encounter such situations. When setting injury levels for turf stands, consider factors such as turf vigor and quality, turf use, and the pest population size.

The economic injury level is based on the potential for serious injury and the use of the turf area. These factors are listed below.

Factors Affecting Injury Levels

1. Client's (or other important person's) tolerance of pest damage.
2. Visibility or use of the turf stand.
3. Level of maintenance.
4. Health and vigor of the turf stand.
5. The greatest possible pest injury to host plant.
6. Expected pest reduction by natural controls.

The following examples illustrate how these factors influence the injury level. Residential lawn applicators are familiar with differences in clients' tolerance level depending upon the visual impact of a weed. A homeowner may complain about a single flowering dandelion, but not even notice that their lawn is 10% nimblewill. Similarly, golf course superintendents set lower economic injury levels for greens and tees than for roughs. These areas are the turf focal points of the course. Besides the visual impact, greens and tees sustain a great amount of wear and mowing, and must be dense and uniform to provide the appropriate surface for golfing.

The health and vigor of a turf stand in large part determines the impact of a pest infestation, and how rapidly and effectively the turf will recover from pest injury. If turf is stressed the action threshold will be much lower than that of a healthy, vigorous lawn that can resist and recover from pest attack.

The action threshold also depends upon how seriously the pest can affect a particular grass stand. Leafspot is an example of a disease that is so damaging that action must be taken at the first sign of it, or to prevent it. This disease, however, is not likely to develop into a serious problem if the stand does not consist of susceptible Kentucky bluegrass varieties.

Finally, turf managers may set a higher threshold when natural control is expected. The fungal disease powdery mildew prefers very moist conditions. Even a mildew infestation considered damaging may not warrant chemical control during a dry spell.

Personal experience, and references will help you set initial economic injury levels and action thresholds. Injury levels should be modified to reflect the pest damage tolerance of the consumer. Commonly, turf 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 turfgrass situation. *Setting economic injury levels which reflect specific pest and turf conditions is the cornerstone of IPM.*

Selection of Methods

Many factors limit pest populations including weather, plant defenses, natural enemies of pests, 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 grass plants, and use of the turf. Consider all available management tactics and evaluate the benefits and risks of each for every pest problem.

Choose methods that:

- are most likely to permanently limit the pest.
- are the least toxic to nontarget organisms and the environment.
- are most likely to stay on the target area.
- enhance natural controls.
- are the least hazardous for the applicator to handle.
- are least likely to injure grass plants (the least phytotoxic).

Chapter 3 explains alternative management tactics. Pesticide use is further discussed in Chapter 4.

A combination of methods should 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. Factors which limit the number of appropriate management options are:

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

Although often overlooked, evaluating your management tactics is essential for successful pest management. Examining your management program should answer several questions. Did the methods adequately protect turf from injury? Were there negative consequences of the tactics such as environmental contamination, or promotion of other pest problems (secondary pests) because natural enemies were eliminated? Were the methods impractical or too expensive? You can assess your pest management efforts by using the monitoring techniques described in this chapter. Remember, the management value of your evaluation directly depends upon how complete and accurate your records are.

Turfgrass pests cannot be maintained below threshold levels over long periods of time solely through the use of pesticides. Turf managers seeking practical, economical, and environmentally-sound pest management will use all of the five IPM steps outlined in this chapter.

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. What pest control methods are used in IPM programs? Are pesticides a part of IPM?

3. List the five steps of IPM for turf.

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

5. What type of pest can be detected by the "coffee can" method? Which method should be used to detect fungal diseases? grubs?

6. Explain why degree days are more useful for monitoring pest activity than calendar dates.

7. Name five non-pest conditions which affect the health and appearance of turf. Why should these conditions be recorded during monitoring?

8. There are thousands of species of insects, fungi, nematodes, and bacteria that are harmless or beneficial to turf. (True or False?)

9. Explain how knowing the species or variety of turfgrass can help in pest diagnosis.

10. Brown spots in turf can be caused by a dull mower. What do the grass blades mowed with a dull mower look like, and why do brown spots result?

11. What is the cause of summer dieback?

12. What is one indication that the dead brown spots in a lawn are caused by chemical burn?

13. Name three costs resulting from pest activity on turf.

14. What is the difference between the economic injury level and the action threshold?

15. Name three factors influencing the economic injury level. Give examples for each.

16. The selection of pest management tactics will be limited by one or more of six factors which have nothing to do with the actual pest problem. Name these factors.

17. List 3 questions that should be answered by the evaluation of your IPM program.

Lawn Monitoring Sheet

Client name: Property address:	Client phone number:	Date:
Turf species, variety, mix?	Specific location of injured turf:	
Soil type, pH, fertility:	Compaction:	Soil moisture (to depth of 4-6″):
Level of maintenance or turf visability:	Level of wear:	Sunlight exposure (amount and intensity):
Fertilization (type, rate, frequency):	Mowing height/frequency:	Irrigation (amount and frequency):
Herbicide applications (what, rate, when):	Unusual chemical exposure (road salt, household, automotive?)	Client tolerance of pest injury:
Injury pattern:	Circles or blotches? Spots?	Streaks or rows? Overall, uniform injury?
Presence of weeds? Species:	% in sample area:	
Evidence of disease pathogen or fruiting bodies?	Where and what form?	
Presence of insects or frass: Sampling technique(s)?	on blades? in thatch? by roots?	What species? Average number of insects found per sample?

CHAPTER 2

CARE OF TURFGRASS

People appreciate various uses of turf: for playing fields, for erosion control, to moderate the temperature in the landscape. However, few people are aware of the ecological benefits of a healthy turfgrass stand. Vigorous turf stands can resist and withstand pest attack, and require fewer pesticide applications. The extensive fibrous root system of turf improves soil by adding organic material. Pollutants, dust, and other particles in snow and rain stick to turf roots, rather than leaching into the groundwater. Finally, turf stands are one of the most efficient biological systems for breaking down pesticides. These features clearly make healthy turfgrass more than purely an aesthetic concern.

Non-pest disorders as well as pests injure turf. Turfgrass disorders include:

1. Improper turfgrass species selection.
2. Lack of air movement.
3. Too hot, dry, or wet weather.
4. Too much or not enough of some nutrients.
5. Too low or high pH.
6. Soil compaction.
7. Competition with the roots of trees and shrubs.
8. Excessive traffic or wear.
9. Too much thatch.
10. Improper height of cut.
11. Too much or little sunlight.
12. Poorly maintained mowers.
13. Improper irrigation.
14. Disease pests.
15. Animal pests.
16. Weeds.

If items 1 through 13 are not a problem for the turf, rarely are pests damaging. Most turfgrass injury is directly or indirectly due to inappropriate growing conditions that occur naturally or are imposed by maintenance practices. To better manage pests, turf managers must be aware that *pest problems are often a result, rather than the cause, of poor quality turf.* This chapter discusses the impact of growing conditions on turf quality, procedures for establishing new turf, and sound turf maintenance practices.

Requirements for Healthy Turf

Appropriate temperatures and amounts of water, nutrients, and sunlight are necessary for healthy turf growth. When one or more of these climatic and soil conditions do not fall within the acceptable ranges, turfgrass becomes stressed. Growth first slows and then ceases. If stress is severe or occurs over a long time, grass plants may die. Weakened turf may thin out and be invaded by weeds. In addition, stressed grass plants have less energy to combat a pest attack and recover from injury.

Water

The greatest influence on turf health and quality is water. Plants need water to grow and maintain tissues, and to cool themselves. Cooling occurs in plants as it does with humans—through evaporation of water. This is known as sweating in people, and **transpiration** in plants. Relative humidity, wind, and the availability of water, affect a turf stand's ability to release heat.

Due to transpiration, the temperature of turfgrass can be lower than that of the surrounding air. Grass plants exposed to sun are often unable to transpire enough, and can have temperatures above that of the surrounding air. Researchers at the University of Illinois recorded the action of transpiration. On a day when air temperature was 100°F, they measured a canopy temperature of irrigated turf at 87°F, while non-irrigated turfgrass stand was 113°F.

When water is limited, turf growth stops, transpiration decreases, and the crown temperature increases. Eventually grass plants brown-out and go dormant. While turfgrasses can survive long periods of dormancy, brown grass in the landscape or on a golf course is not acceptable to many people.

Temperature

As with all types of plants, turfgrass species are adapted to certain climatic regions. The factor that most limits where grasses are found is their tolerance for cold temperatures. Based on cold tolerance, grass species are divided into three categories for the United States and southern Canada:

Cool/cold grasses: Kentucky bluegrass; perennial ryegrass; fine fescues; tall fescue; bentgrass.

Transition grasses: tall fescue; zoysiagrass; Bermudagrass.

Warm/hot grasses: zoysiagrass; Bermudagrass; St. Augustine grass; centepedegrass, bahiagrass.

The northern third of the United States, including Michigan, is a cool/cold grass adaptation zone. With few exceptions, cool-season grasses are used in Michigan because they grow best in cool temperatures and remain green until it becomes quite cold. Cool-season grasses brown-out, yet survive the winter in a dormant condition.

Shoot growth is greatest in cool-season grasses when temperatures are between 60-75°F. Maximum root growth occurs when soil temperatures range between 50-65°F. Temperatures beyond these ranges affect the entire grass plant. The use of oxygen (respiration) in plants increases with temperature. Conversely, the process of making food **(photosynthesis)** declines with high temperature. Increased plant activity with decreased food production creates a shortage of energy in the plant; the plant is forced to use stored food to survive. As a result, both the root and shoot systems of plants suffer because there is less energy available to maintain old growth and produce new growth. With a reduction in the root system, there is a smaller volume of soil from which to draw water. Not surprisingly, turf undergoing heat stress is usually also suffering from drought.

Sunlight

All plants require sunlight for photosynthesis. The amount of sunlight plants prefer varies with species and cultivar. Generally, grasses do best when grown on sunny and partially-sunny sites. Turf grown in areas without adequate amounts of sunlight is shallow-rooted, thin, and more prone to diseases. Indeed, in some situations shade is the primary cause of turf problems.

Soil and pH

All plant managers know that soil conditions influence the development and quality of plants. However, you must also understand the complexity of soils and their effect on the moisture, air, and nutrients available to plants. Soil requires many years to develop under natural conditions. While it is easily destroyed by disturbances such as construction grading, it is not easily reclaimed.

Soil is composed of **inorganic particles** (material made of minerals and does not contain carbon), **organic matter** (material that contains carbon such as decaying organisms), water, air, and soil organisms. An ideal soil contains 50% organic and inorganic solid particles, and 50% open space. The open spaces, or **soil pores,** are filled with either water or air. The percentage of pores occupied by water depends on the soil type, drainage pattern, and the time of the year.

Inorganic soil matter includes sand (largest in size), silt (medium-sized), and clay particles (smallest in size.) **Soil texture** is defined by the percentage of large versus small particles making up the soil. Clay particles have the greatest ability to bond to nutrients and water, but compact tightly together, reducing the soil space occupied by air. Clay soils are known for their density and "wetness," or lack of air-filled soil pores. Compared to sandy, coarse soils, clay soils are typically low in oxygen and are easily compacted. An ideal soil, which has good nutrient and water-holding capacity as well as plenty of air-filed pores, is composed of all sized particles.

Soil pH is a measure of soil acidity. Turfgrass typically grows well in soil with a pH from 5.0 to 7.5 (see pH chart). Soil pH greatly affects the availability of nutrients to plants. Soil with a pH far from the 6.0-7.0 range can be deficient in certain nutrients, such as phosphorous and iron. These elements form insoluble compounds outside of this pH range, and are therefore not available for roots to absorb. Add lime to raise soil pH, and sulfur to lower it. As with all soil adjustments, never add these materials to adjust pH without first testing the soil.

Soil pH and nutrient content can be determined through analysis of soil samples. Most **soil analysis** is done by a laboratory, but soil test kits are available to purchase. Collect the samples from the top three inches of the soil. To ensure that the samples represent the entire area, combine samples taken from several spots. Regardless of the size of the stand, a minimum of twelve samples should be taken. Thoroughly mix the samples in a plastic container or paper bag. Do not contaminate samples by mixing them in a metal container. Turf areas that differ significantly in grass type, use, or growing conditions should be analyzed

<table>
<tr><th colspan="5">Soil pH and Plant Tolerances</th></tr>
<tr><th>The pH Scale</th><th>Description</th><th colspan="2">Plant pH Tolerance</th><th>pH of Familiar Products</th></tr>
<tr><td>1</td><td></td><td colspan="2"></td><td>hydrochloric acid</td></tr>
<tr><td>2</td><td></td><td colspan="2"></td><td></td></tr>
<tr><td>3</td><td></td><td colspan="2">some bog plants</td><td>vinegar, apples</td></tr>
<tr><td>4</td><td>very strongly acid</td><td rowspan="3">acid-loving plants such as blueberries and rhododendrons</td><td></td><td>beer</td></tr>
<tr><td>5</td><td>strongly acid</td><td rowspan="3">growing range for turf-grass</td><td>fresh beans</td></tr>
<tr><td>6</td><td>slightly acid</td><td>fresh corn</td></tr>
<tr><td>7</td><td>neutral</td><td>optimum for most plants</td><td>distilled water, human blood</td></tr>
<tr><td>8</td><td>slightly alkaline</td><td colspan="2">plants may suffer from boron and manganese deficiency</td><td>bicarbonate of soda</td></tr>
<tr><td>9</td><td>strongly akaline</td><td colspan="2"></td><td></td></tr>
<tr><td>10</td><td>very strongly alkaline</td><td colspan="2"></td><td>milk of magnesia</td></tr>
<tr><td>11</td><td></td><td colspan="2"></td><td></td></tr>
<tr><td>12</td><td></td><td colspan="2"></td><td>trisodium phosphate</td></tr>
<tr><td>13</td><td></td><td colspan="2"></td><td>lye</td></tr>
</table>

Adapted from *Lawn Care* by H.F. Decker and J.M. Decker.

separately. Carefully read and follow the instructions given by the laboratory conducting the analysis.

Nutrients

Both the percentage of clay particles and organic matter determines the nutrient-holding capacity of soil. Nutrients in a soil are in constant flux, becoming more or less available as soil conditions change. There are many fertilizers marketed for use on turf. These products contain varying amounts of the 16 mineral elements essential for turf growth and development. You must understand the function of nutrients, and determine which should be supplemented for the turf stand you manage. Remember, even when you suspect that injured turf is showing symptoms of a nutrient deficiency, soil analysis is the only reliable method of diagnosis.

The following is a description of the nutrients most important to turf. Included are the chemical abbreviations of the nutrients, as they are commonly referred to by fertilizer labels and other sources.

Nitrogen (N). Nitrogen is an essential element for plant growth and is used in large quantities by turf. Dry turf clippings are about 5% nitrogen by weight. Turf deficient in N may have poor color, decreased elasticity, and is less able to compete with weeds. Nitrogen is often unavailable to turf roots because it leaches through the soil rapidly and is absorbed by soil organisms. Due to nitrogen sinks and turf's large demand for N, turfgrass is more responsive to nitrogen applications than any other element. Periodic applications of nitrogen fertilizer are necessary to maintain good quality turf. However, do not exceed a rate of one pound of actual nitrogen per 1000 square feet, during a single application. Nitrogen from agricultural and landscape fertilizer can contaminate surface and ground waters. Also, too much nitrogen results in a thin root system relative to top growth, increased disease, and reduced drought and wear tolerance. The greenest lawn is not necessarily the most healthy lawn. Avoid over-application of nitrogen.

Phosphorous (P or P_2O_5). Phosphorous is important for root development, maturation, and seed production. This element is found chemically bound to oxygen; two particles of phosphorus are bonded to five oxygen particles. Since this molecule is practically immobile in soil, few soils are deficient in phosphorous. Turf deficient in P_2O_5 shows purpling of grass blades. This symptom can be confused with the color change induced by cold weather. Phosphorous fertilizer must be delivered directly to turf roots. This can be done by fertilizing after aeration or by liquid fertilizer injection. Because P_2O_5 is strongly adsorbed to soil particles, erosion can carry hazardous amounts of phosphorous into surface waters. Except with newly-established turf stands, phosphorous applications should be limited without evidence of deficiency. A soil test of 50 pounds of P_2O_5 per acre is adequate for turf growth.

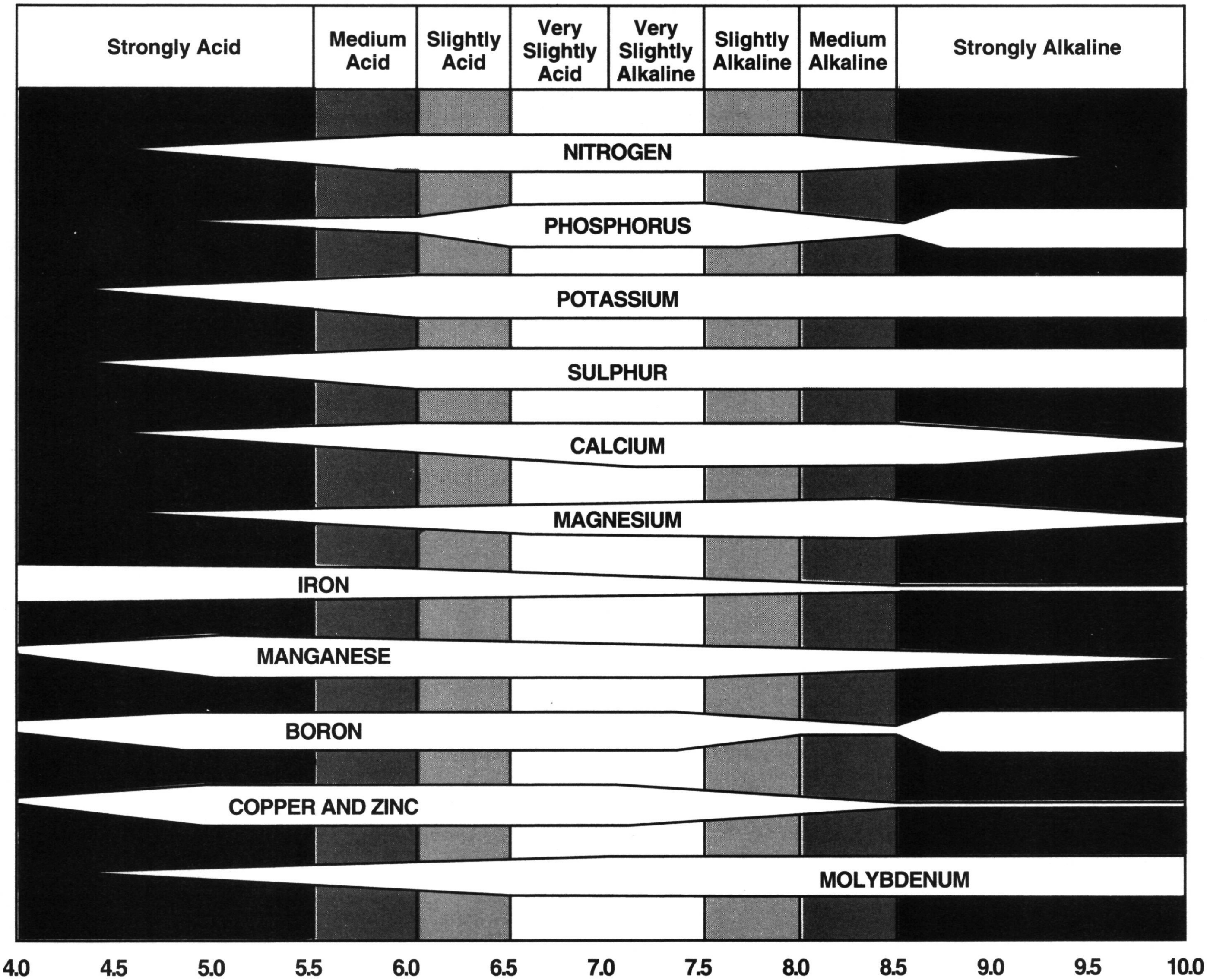
Potassium (K or K_2O). Turf uses potassium in quantities second only to nitrogen. This element is important for rooting, and wear and climatic stress tolerance. While rarely visually evident, turf deficient in potassium has yellowing and dead blade tips. Even though the level of K_2O in a soil is high, it may not be available for absorption by turf roots. Therefore, routine application of potassium fertilizer at a ratio of 3:2 (3 parts nitrogen to 2 parts potassium) is beneficial in many situations. Potassium application does not result in dramatic growth or green-up. However, do not interpret lack of visual improvement as a lack of benefit.

Micronutrients. Micronutrients are elements used by plants in relatively small amounts. They include manganese, boron, copper, and zinc. Typically, micronutrients required by turf are naturally present in Michigan soils in adequate amounts. High soil pH can render these elements insoluble, making them unavailable to turf roots. The accompanying chart shows the influence of soil pH on nutrient availability. Iron (Fe) is an example of a micronutrient that is commonly deficient in alkaline soils (those with a pH greater than 7.) Iron is required for chlorophyll production, and therefore the green coloring of plants. It is also important for root and shoot development and drought resistance. Iron-deficient turf usually has blotchy yellow patches. Severe iron deficiencies may result in white grass blades or death of plants. Application of iron fertilizer will provide temporary green-up of turf. Since the deficiency is due to soil alkalinity, long-term treatment requires modifying the soil pH.

Soil Organisms

Living and decaying soil organisms contribute greatly to a soil's organic matter and fertility. As they burrow, organisms aerate the soil and increase drainage. Feeding soil organisms break down organic matter, making nutrients available for absorption by turf roots.

Earthworms are the best known of soil organisms, but great numbers of microorganisms also occupy the soil. One teaspoon of soil can contain a billion bacteria, a million fungi, and several thousand algae. Fortunately, most of these or-



pH effect on nutrient availability.

ganisms improve soil conditions for plant growth.

Turf managers who appreciate the benefit of soil life are careful not to destroy it with unnecessary use of soil sterilants, pesticides, and fertilizers.

Establishing Turf

Turf managers often must continually battle disorders that are a result of poorly-established turf. Prevent chronic turf problems by carefully selecting and installing planting material.

Grass Plant Selection

For successful turf establishment, it is crucial to select grass species or varieties that are best suited to the growing conditions and the planned use of the site. There are dozens of varieties of Kentucky bluegrass, perennial ryegrass and fine fescue commercially available for planting in Michigan. Grass species and varieties differ in their appearance, wear tolerance, and maintenance requirements. They also differ in their susceptibility to damaging pests and tolerance of poor growing conditions. Turf types vary in:

- susceptibility to pests
- compaction tolerance
- soil type preference (sand, silt, loam)
- tolerance of shade
- tolerance of drought
- tolerance of wear
- cultural (maintenance) intensity tolerance
- thatching tendency
- fertilization rate preference
- mowing height preference

No variety will have all the features you want. Choose turfgrass varieties that have the characteristics most important to site conditions and use. Check the list of new turf varieties recommended by Michigan State University researchers (see Resources and accompanying chart.)

New Cultivars Recommended for Michigan Turf

Kentucky bluegrasses

Princeton 104	Glade	Abbey
Midnight	Destiny	Classic
Challenger	Mystic	Cheri
Bristol	Blacksburg	Georgetown
Lofts 1757	Adelphi	Haga
Eclipse	Ram-1	Able 1
Asset	Dawn	Freedom
Aspen		

Fine fescues

Aurora	Victory	Banner
SR 3000*	Shadow	Pennlawn
Reliant	Enjoy	Flyer
Valda	Epsom	430
Scaldis	Mary	Boreal
Beauty		

Tall fescues

Jaguar II	Bonanza	Falcon
Tribute	Trailblazer	Aztec
Rebel II	Cimmaron	Thoroughbred
Amigo	Legend	Rebel
Eldorado	Apache	Taurus
Monarcho	Wrangler	

Perennial ryegrasses

Saturn	Charger	Riveria
SR 4100*	SR 4000*	Omega II*
Allaire	Blazer II	Manhattan
Tara	Palmer	Barry
Manhattan II	Rodeo	Commander*
Pennant*	Competitor	Citation II*
Runaway	Dasher II*	Birdie II*
Repell*	Belle	Rival
Lindsay		

*Contains endophytes.

Adapted from "1990 Recommended Turfgrass Cultivars for Michigan" by B.E. Branham and M. Collins.

Turf stands made up of several grass types have greater genetic variation, are better able to resist pests, and adapt to different environmental conditions. For this reason, grass seed is usually marketed as **blends** of grass plant varieties or **mixes** of grass species. For instance, perennial ryegrass and Kentucky bluegrass seed is often combined in seed mixes. Perennial ryegrass will dominate in the shady areas of the stand where Kentucky bluegrass dies out. Species mixtures increase the range of genetic diversity and the ability to adapt to different conditions. However, they are not as uniform and do not have the quality of blends.

The choice of planting material is nearly as important as mix or blend selection. Purchase only top-quality turf planting materials. Although it may seem expensive, the cost of quality seed, sod, or vegetative material is low considering the length of time the turf will be used and the expense of its maintenance.

Seed of some fescue and ryegrass varieties contain **fungi endophytes.** This type of seed contains naturally-occurring fungi that are harmless to grass plants, but acts as a biological control. The endophyte fungi live inside grass plants and secrete toxins that kill or repel chewing insects. Note that this type of grass should not be used as forage. Endophyte fungi can be harmful when consumed by livestock. Otherwise, use seed containing endophytes for turf stands whenever possible.

Planting Procedures

You can avoid or reduce several turf problems by following proper planting procedures. Preparing a site for a new turf stand requires much planning, materials, and labor. Planting techniques are thoroughly described in many turf care references (see Resources) and are summarized here.

1. Eliminate weedy perennial grasses such as quackgrass and bentgrass.
2. Rough-grade the area to be planted so that it has the desired slope and a uniform surface.
3. If needed, amend the soil to improve drainage or the availability of nutrients.
4. Analyze the soil and adjust soil pH or nutrients if needed.
5. Plow, rototill, disc, or otherwise work the soil to a depth of at least 6 inches.
6. Remove stones and debris. Use a soil probe or shovel to check for buried rocks and other debris. Check for adequate top soil depth.
7. Smooth-grade the area. The surface must be free of high and low spots. It is difficult and expensive to correct drainage problems after turf establishment.

8. Apply "starter" fertilizer and rake into the soil surface. Base your selection of preplant fertilizer on soil analysis.
9. Plant seeds, sod, or vegetative material. In Michigan, it is best to plant seed in late summer. Avoid planting vegetative materials during dry weather.
10. Lightly rake seedbed to cover seeds.
11. Apply weed-free straw, peat, or other mulch.
12. Water newly-planted materials thoroughly. Allowing vegetative planting material to dry out will result in significant losses.

Post-Planting Care

Be certain to carry out proper post-planting care. Even the best soil preparation, planting materials, and planting procedures will not guarantee successful turf establishment without appropriate post-planting care.

Watering. The amount and frequency of watering depends upon weather conditions. Generally, keep new stands *moist but not wet*. Decrease the frequency and amounts of irrigation as seedlings begin to develop and vegetative material starts to produce roots. Check the water requirements of new stands regularly, so that adjustments can be made before turf becomes stressed.

Mowing. Mow as soon as new turf grows past the desired height. Always keep mower blades sharp and properly adjusted for clean cutting. Dull blades may pull up seedlings, or make ragged cuts that are more prone to disease infection.

Fertilizing. New stands benefit from fertilization a couple of weeks after seedlings emerge or new roots develop. Fertilizing helps developing grass plants by stimulating root and shoot growth. Low nitrogen fertilizer (analysis of $N:P_2O_5:K_2O$ = 2:1:1 or 1:1:1) should be applied at a low rate such as one-half pound of actual nitrogen per 1000 square feet. Be sure to include potassium in the fertilizer program since it is particularly beneficial to establishing turf plants. To avoid burning soft, new grass plants, water fertilizer in immediately after application.

Pest management. Seedlings are tender and newly-planted grasses have sparse root systems. Although weeds are often a problem in new turf stands, it may be unwise to expose delicate grass plants to herbicides or other pesticides. Use other methods such as pulling weeds and mowing until turfgrass plants become established. If you choose to apply a pesticide, check the label for uses and rates on newly-established grass.

Maintaining Turf

Maintaining turf is often the greatest landscape cost. However, we seldom give adequate time and attention to planning and implementing turf care. It is well worth the time, effort, and money to tailor turf management activities to meet the specific needs of turf stands.

Influence of Turf Use and Visibility on the Level of Maintenance

The darker the shading the more maintenance required.

Aesthetic Importance of Turf	Turf Use and Wear: high	Turf Use and Wear: medium	Turf Use and Wear: low
high	Example: golf course tees and greens; major athletic fields.	Example: lawns of public buildings which are accessible to people; lawns of estates.	Example: turf framing important structures or natural sites that are not accessible to people.
medium	Example: play areas.	Example: homeowner lawns; golf course fairways.	Example: turf surrounding hospitals and commercial buildings.
low	Example: outdoor exhibit grounds.	Example: overflow parking areas used infrequently.	Example: turf of freeway medians and shoulders.

There is no benefit to managing turf at a level of visual or wear quality above that required for its use (see Turf Use diagram.) Neither the aesthetic value nor utility of roadside grasses would be improved through intensive mowing, fertilizing or irrigation. A good turf manager maintains turf to meet specific site requirements.

Frequently, one site contains multiple levels of turf use. For instance, lawns surrounding the entrance of a government building have great visual impact and landscape importance, but may undergo little wear. The main purpose of such a lawn is to frame the building and ornamental plants. Turf in a park next to the building not only must have a lush, green appearance, but also be able to withstand heavy foot traffic. Resistance to compaction and wear are important features for turf in picnic and play areas. Finally, a turf stand on a hill behind the parking area of the same building may have greater value for erosion control than as a landscape planting. It would require a different management scheme.

Management practices must reflect tolerances of turfgrass species and varieties to maintenance stresses. For instance, Kentucky bluegrass is the preferred turfgrass for Michigan home lawns, but does not thrive when mowed at heights of less than one inch. Golf course greens planted with Kentucky bluegrass would rapidly change to low-growing weeds and annual bluegrass. This explains why managers of some intensively-managed areas perceive annual bluegrass as a desirable turf plant, while lawn care companies treat it as a weed.

Maintenance practices that take turf growing requirements into consideration cause less stress for turfgrass plants. Maintenance practices can be manipulated to lessen the susceptibility of turf to stressful situations. The following is a discussion of such practices.

Watering

Natural rainfall is generally adequate to support healthy, green turf during the spring and fall. However, the dry periods of summer stress grass and may cause it to go dormant. Too much water is as damaging to turf as drought. When turf is saturated, transpiration is slowed and infectious disease encouraged. Research shows that an average of 40% of irrigated water is more than turf requires.

Supplying appropriate amounts of water is not a simple task. When deciding how much and when to irrigate, consider weather conditions, soil type, grass variety preference, and turf use and maintenance practices.

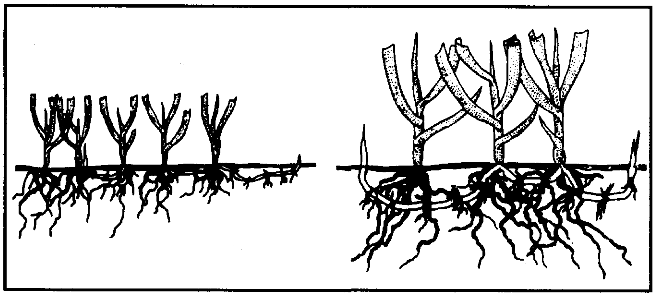
The amount of water used by turf is measured as **evapotranspiration;** the amount of water that evaporates from turf stands plus the water used in transpiration. When the amount of water lost due to evapotranspiration is greater than the amount turf absorbs, wilting and stress occurs. Evaporation pans are inaccurate for measuring evapotranspiration rates. Models and computer programs are available that translate turf type and condition, wind, dew point, precipitation, and canopy temperature into irrigation requirements.

Managers of consumer lawns and other less-intensely maintained turf usually take less scientific approaches. The "footsteps" method is a crude, but effective way to determine turf water requirements. You need to irrigate when turf begins to wilt and does not spring back when crushed (footsteps linger in turf.) It is generally thought that turf requires a total of one inch of water per week, from rainfall plus irrigation. Use a rain gage, or the weather service to measure rainfall and determine the amount of irrigated water needed to obtain the one inch requirement. Most sources recommend applying supplemental water once a week during the early morning hours. *Note that you cannot properly irrigate turf with an automatic irrigation system set once during the growing season!*

Under certain circumstances, researchers found that the standard, weekly waterings can cause turf to dry out and become stressed. During hot, droughty periods turf may better benefit from daily, light, afternoon waterings. Watering during the heat of the day cools grass plants and just replaces evaporated water. In addition, research conducted at Michigan State University found that injury due to patch diseases, including necrotic ring spot, was reduced on susceptible turf that received light, frequent waterings during the summer. Michigan State turf specialists recommend that managers of diseased turf replace only the water lost in evapotranspiration, and do not saturate thatch. This is best accomplished during hot, dry periods by applying daily a small amount of water (one-two tenths inch) during the heat of the day. Since this practice will not deliver a full inch of water per week, regularly check the moisture of deeper soil and apply additional water when necessary.

Mowing

Regular mowing at the correct cutting height with properly set and maintained equipment will generate a dense, uniform, vigorous turf. Though mowing is one of the most costly maintenance procedures, it often becomes a routine practice that managers do not evaluate. Adjusting mowing practices to suit a particular stand is a simple task



Mowing lower than preferred by grass species or variety reduces root growth and plant vigor.

that greatly contributes to the well-being of turf.

Low-cut turf requires more care than high-cut turf to maintain acceptable quality, as a rule. Low-cut turfgrass of many varieties may not produce enough food to maintain plant vigor. When you lower the mowing height, you reduce the root system. Root reduction decreases the amount of water available to support the stand. Cutting turf too short often results in poor turf performance and pest problems. Golf course superintendents have long recognized the stress imposed upon greens by cutting heights of ⅛ to ¼ inch. High-maintenance turf stands planted with grasses that prefer a low cutting height (see the accompanying table) experience less stress. Where the mowing height is not dictated by the turf's use, mow at preferred heights.

The table provides cutting-height ranges because cutting height preference is determined by more than grass type. When environmental conditions cause stress, standard mowing may harm turf. The height of cut can be a valuable management tool when modified as the specific needs of turf change. For instance, during hot, dry periods turf stands need more water. To conserve water in grass plants experiencing drought, mow less frequently and at a higher height of cut. Turf will undergo less evapotranspiration and therefore less stress if mowed during the cooler hours of the day.

Turf managers have long debated whether to remove clippings. A strong argument against clip-

Cutting Heights for Cool-Season Grasses

Grass Type	Low Cut (inches)	Preferred Cut (inches)	High Cut (inches)
Kentucky bluegrass common types	1¼	2 to 3	4
Kentucky bluegrass improved types	¾	2	3
Perennial ryegrass common types	1½	2 to 3	4
Perennial ryegrass turf types	¾	1½ to 2	3
Fine fescue	1	1½ to 3	4
Tall fescue pasture types	2	2½ to 3½	4
Tall fescue turf types	1¼	1½ to 3	3
Creeping bentgrass	¼	½ to ¾	1
Colonial bentgrass	½	¾ to 1	2
Annual bluegrass	¼	½ to 1	2
Smooth bromegrass	2	3 to 4	5

From *Landscape Management* by J.R. Feucht and J.D. Butler.

ping removal is the resulting loss of nutrients. Each year degrading clippings provide 4 pounds of nitrogen, 1 pound of phosphorous, and 2 pounds of potassium per 1000 square feet. When clippings are regularly removed, fertilization must be increased by 25-50%.

Clippings are routinely removed from low-cut, high-maintenance stands to improve appearance and texture. Managers also routinely remove clippings with the belief that this practice prevents excessive thatch build-up. However, clipping removal is not necessary in many of these situations. Mowing at a low height of cut or with a mulching mower creates clippings that rapidly disappear and degrade under the turf canopy. As fewer landfills accept yard waste, managers and homeowners recycle clippings as an acceptable alternative to clipping disposal.

Remove clippings when required for turf use, or as a management technique to limit the inoculum of some diseases. Only for these purposes is clipping removal worth the effort and the loss of nutrients.

Fertilizing

Adequate fertilization plays a major role in producing and maintaining a dense, pest-resistant turf stand. High-quality turf requires much fertilizer each season. On the other hand, if the primary purpose of turf is to give a naturalistic appearance and prevent erosion, then fertilization once every few years may be adequate. If the management goal is to promote grass plant growth, as with turf recovering from wear or pest damage, high nitrogen fertilizer is recommended. To maintain the vigor of a healthy turf stand, fertilizers with less nitrogen should be used.

Consider the condition of the turf especially when planning high-nitrogen applications. Nitrogen stimulates leaf growth. Turf that has a less than optimal root development or is exposed to heat/drought stress can be injured if "pushed" by nitrogen fertilizer.

Besides assessing fertilizer requirements with regard to turf use and condition, managers must determine nutrient levels of the soil (see the Soil and pH section of this chapter.) Soil is in a constant state of change. Have soil samples analyzed regularly, such as every three years.

Types of Fertilizers. Many liquid and solid turf fertilizers are available. The characteristics of common materials used in fertilizers are summarized in the accompanying table. The material used in a fertilizer determines the rate nutrients are released into the soil. **For instance, water-soluble**

Characteristics of Fertilizer Materials for Turf

Material	Type	Nutrient Content %	Soil Reaction	Rate of N Release	Burn Potential
Ammonium sulfate $(NH_4)_2SO_4$	inorganic	21 (N)	strong acidifier	water soluble	moderately high
Ammonium nitrate	inorganic	33.5-34 (N)	acidifier	water soluble	high
Urea $CO(NH_2)_2$	synthetic organic	45-46 (N)	acidifier	water soluble	moderately high
Activated sewer sludge	natural organic	5-6 (N)	no change	slowly soluble	low
Urea-formaldehyde	synthetic organic	38 (N)	no change	slowly soluble	low
IBDU	synthetic organic	31 (N)	no change	slowly soluble	low
Sulfur-coated urea	synthetic organic	31 (N)	acidifier	slow release	low
Triple super-phosphate $Ca(H_2PO_4)_2$	inorganic	45-46 (P_2O_5)	no change	—	low
Muriate of potash KCL	inorganic	60-62 (K_2O)	no change	—	high
Potassium sulfate K_2SO_4	inorganic	50-53 (K_2O)	no change	—	moderate
Ferrous sulfate monohydrate	inorganic	31.5 (Fe)	acidifier	—	high

Adapted from *Landscape Management* by J.R. Feucht and J.D. Butler.

nitrogen, such as urea, is readily available to turf roots and provides a quick response after application. These materials are the least expensive forms of nitrogen. However, water-soluble N fertilizers have a high potential for chemically burning turf. **Slow-soluble** forms of nitrogen include natural and synthetic organic fertilizers. Slow-release products are formulated so that elements are released relatively slowly over time. Slow-release products are more expensive to purchase than water-soluble fertilizers, but fewer applications at higher rates are possible with less chance of burn.

Complete fertilizer contains nitrogen, phosphorus, and potassium. As a rule, turf fertilizers have a high ratio of nitrogen to phosphorus and potassium. The ratio of these three nutrients ($N:P_2O_5:K_2O$) is called the **fertilizer analysis.** Common turf fertilizer analyses include 20-10-5, 20-5-10, and 21-3-7. A complete fertilizer with the analysis of 20-10-5 contains 20% nitrogen, 4.4% actual phosphorous (10% P_2O_5), and 4.5% actual potassium (5% K_2O). One hundred pounds of a 20-10-5 fertilizer contains 20 pounds of nitrogen; five pounds of this fertilizer spread over 1000 square feet would supply 1 pound of nitrogen.

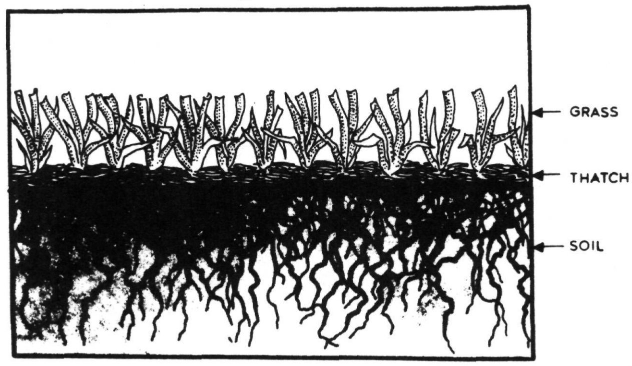
Fertilizer burn. Most turf managers have first-hand experience with fertilizer burn on turf. Fertilizer burn usually occurs when heavy rates of soluble fertilizer are applied to frozen ground, onto wet foliage, or during hot weather. If the injury is restricted to the grass blades and weeds, there is no root damage and the turf will recover. Severe burn, however, can kill grass plants. Most fertilizer burn can be eliminated by avoiding water-soluble materials and high nitrogen rates, and by preventing materials from remaining on foliage. Follow these guidelines:

- Do not apply fertilizer when turf is stressed.
- Apply fertilizer evenly.
- Do not spill fertilizer onto turf.
- Apply fertilizer only when foliage is dry.
- Use granulated or pelleted fertilizer rather than pulverized materials.
- Water-in soluble fertilizers immediately after application.
- Use insoluble, organic forms of nitrogen.
- Apply a maximum of 1 pound of N per 1000 square feet at a single application.

Aerating

Compacted and heavy clay soils contain less air and have a hard, surface that drains poorly. Turf growing in such soils lack air and beneficial micro-organisms, and suffer from poor drainage. Root development and turf quality declines.

Mechanical aerators create holes in compacted and heavy soils. This practice increases the movement of air in the soil and improves drainage. Machines that remove cores from the soil are generally more efficient aerators than those that spike or slit the soil. Coring machines remove a quarter to one inch diameter cores and deposit them on the surface of the turf. When practical, break up deposited cores by dragging chain-linked fence or similar material over them. Cores of poor quality soil should be discarded. Holes will more rapidly be covered by turf if fertilizer is applied directly after aeration. Fall is the best time to aerate turf, when weed seed germination is at a minimum.



Thatch is the layer of organic material that develops between the soil surface and the green growth of grass.

Dethatching

A layer of thatch exists in all turf between the green vegetation and the soil surface. Thatch is composed of tightly intermingled living and dead stems, leaves, and roots. A small amount of thatch in turf is beneficial. A light thatch layer reduces soil compaction, moderates soil temperature, and limits evaporation of soil water. Too much thatch, however, restricts water and air movement into the soil, and may encourage disease and insect pests. High nitorgen fertilization accelerates thatch production. Also, some grasses are more likely to produce thick thatch layers (see Thatching Tendency chart.)

Turf-inhabiting organisms (including earthworms) break down thatch. Heavy fertilization and routine pesticide applications can significantly reduce these organisms. Because production is increased and break-down decreased, excessive thatch can be a problem of intensively-managed turf. Too much thatch is undesirable because it favors the development of disease, reduces drought, cold and heat tolerance, and impairs the movement of air, water, fertilizer, and pesticide into the soil.

To determine if a stand has excessive thatch, cut a pie-shaped wedge out of the turf and measure the thickness of the thatch layer. If greater than one-half inch thick, take steps to reduce thatch.

Thatch Production of Kentucky Bluegrass Varieties.		
Thatching Tendency		
low	medium	high
Kenblue Park Bonnieblue Monopoly Parade Vantage	A-20 A-34 Adelphi Baron Fylking Majestic Merion Plush Rugby Sydsport Victa	Touchdown Glade Nugget

Adapted from "Illinois Pesticide Applicator Training Manual 39-1."

Practices that relieve soil compaction also help break down thatch. Vigorous hand-raking will remove thatch on small turf areas. Machines equipped with vertical knives or tines can remove thatch on larger areas. Dethatching machines cut and extract organic debris from turf. Because dethatching thins turf stands, thatch removal should be done during cool, moist periods when turf can recover quickly.

Turf in Shaded Areas

Turf grasses are sun-loving plants, and generally do best in full to partial sun. Some grasses, such as listed here, are more tolerant of shade than others.

Turf Performance on Shady Sites:

Satisfactory: rough bluegrass, fine fescue

Fair: tall fescue, perennial ryegrass

Poor: Kentucky bluegrass

Avoid stressing turf by matching the sunlight requirements of the grass species and variety to site conditions.

In addition to not meeting the sunlight requirments of grasses, there are two ways shade injures turf. Turf shaded by trees and shrubs often suffers from drought. Not only do the large, woody plants compete with turf for water, but also their canopies catch falling rain and snow thereby preventing moisture from reaching the turf below. Turf shaded by buildings and hills suffers from the opposite problem; the turf often remains too wet because of reduced wind and sun exposure. The snow is slow to melt in these shaded areas, resulting in conditions that favor snow mold diseases.

To increase the amount of light and air movement turf receives, prune off lower branches and thin out the crowns of shade-producing trees and shrubs. Since little can be done to reduce the amount of shade cast by permanent structures, these areas should be planted with fine fescue and other shade-tolerant grasses. When irrigating grasses in shade, remember that shaded areas stay moist longer; check that shaded turf is dry before watering.

To improve the quality of high-maintenance turf, root pruning may be necessary to lessen competition between tree and shrub roots and turf roots. Cut only the surface roots that extend into the lawn; leave deeper roots to lessen injury to trees and shrubs. Use this practice sparingly and limit the amount of roots pruned in a given year. Beware that some shallow-rooted trees and shrubs, including maple, beech, and evergreens, will not tolerate root pruning.

For several reasons it is important not to overfertilize shaded turf. Fine fescue, the dominant cool-season grass used in shade, requires only half the nitrogen as bluegrass. Fertilizing fine fescue at full bluegrass rates weakens it. Since grasses in shade have a reduced rate of photosynthesis, even regular rates of nitrogen may "push" too much growth, weakening the grass plant. Finally, nitrogen stimulates fungi, which are already abundant in moist, shady areas.

After years of leaf fall, decomposing leaves may turn soil acid. Aeration and pH adjustment may be necessary to establish turf underneath trees, especially evergreens.

Turfgrass may never become established in shade despite repeated attempts. In such situations use of mulch or shade-tolerant ground covers such as periwinkle, pachysandra, purple wintercreeper, and English ivy, is an acceptable alternative.

Despite efforts of homeowners and turf managers to maintain healthy turf that can resist pest injury, pests may periodically develop to damaging levels. The rest of the chapters of this manual focus on pest management options and techniques.

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. Name an ecological benefit of a healthy turf stand.

2. Most turfgrass injury is due to inappropriate growing conditions. *(True or False?)*

3. Turf uses water for what two purposes?

4. Why are warm-season grasses like Zoysiagrass not used for Michigan lawns?

5. What is photosynthesis? Does the rate of this process increase or decrease as the temperature increases? How does temperature stress grass plants?

6. Grasses are sun-loving plants, but some varieties prefer heavy shade. *(True or False?)*

7. Why is a mixture of soil particle sizes the ideal soil for plants?

8. How does soil pH affect the availability of nutrients?

9. Which nutrient does turf use in the greatest quantity?

10. How does over-applying nitrogen injure turf?

11. Define micronutrient. Name two micronutrients.

12. How do soil organisms contribute to the well-being of turf?

13. How are turf stands of blends or mixes superior to stands of a single variety or species?

14. Why should turf managers use seed containing endophytes? When should endophyte seed not be used?

15. As a part of post-planting care, herbicides should be used to control germinating weeds. *(True or False?)* Why?

16. Describe how a lawn with necrotic ring spot should be watered during hot, dry periods of the summer. Why does this differ from the standard recommendation?

17. How does mowing height affect turf?

18. Under what circumstances should you remove clippings?

19. What is a complete fertilizer?

20. Describe four ways to avoid fertilizer burn.

21. Soils that are compacted lack what three things important for turf growth?

22. How can a light layer of thatch benefit turf?

23. Name three ways nitrogen fertilization can injure shaded turf.

24. Name three ways shade injures turf.

CHAPTER 3

PEST MANAGEMENT TECHNIQUES

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

There are two types of pest management tactics: immediate, short-term suppression and long-term maintenance of non-damaging pest levels. Most pest problems require the use of both types of tactics. For example, the warm-weather turf disease Rhizoctonia brown patch attacks the new growth of grass plants. Rhizoctonia fungi can only enter and infect moist grass blades. Applying fungicide to protect susceptible turf from Rhizoctonia infection is a short-term suppression tactic that provides immediate, but not long-lasting control. Without changing the environmental conditions to discourage moist conditions and to limit new, soft growth during infection periods, Rhizoctonia will be an ongoing problem. Because your final goal is to create turf stands that maintain pests below injury thresholds, you must use both long-term and short-term suppression tactics. In this instance, turf managers should limit moist conditions around susceptible turf as much as possible, especially in warm, humid weather. Avoid excessive irrigation, and increase air movement by removing sheltering plants or structures and clippings. Finally, limit the growth and spread of Rhizoctonia by avoiding high-nitrogen fertilizing.

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 4 of this manual. The following is an overview of alternative methods of pest management.

Plant Resistance

The first step in discouraging pest activity and promoting rapid recovery from pest injury is to assure the health and vigor of turf. Healthy turfgrass plants are better able to combat pests and withstand pest injury. Matching the grass plant variety or species to site conditions is essential to turf vigor. There are some grasses that are more tolerant of poor growing conditions. For instance, varieties of fine fescue would be a better choice of turf for shaded areas than Kentucky bluegrass. Unirrigated areas should be planted with grass varieties adapted to droughty conditions (see Drought Stress chart.)

Performance of Turfgrass Under Drought Stress

Turfgrass	Performance Rating
Smooth bromegrass Tall fescue	very good
Kentucky bluegrass Canada bluegrass Sheep fescue Chewings fescue Red fescue Hard fescue	good
Perennial ryegrass	medium
Annual ryegrass Colonial bentgrass	fair
Creeping bentgrass Rough bluegrass Annual bluegrass	poor

Adapted from *Landscape Management* by J.R. Feucht and J.D. Butler

Certain species or varieties of grasses are resistant to damaging pests. For instance, some types of tall fescue and perennial ryegrass contain endophyte fungi. Endophyte fungi do not harm grass, but effectively repel or kill insect pests (see Grass Plant Selection, Chapter 2.) Researchers continually work to produce more grass varieties that are resistant to serious diseases. Establishing turf resistant to the most troublesome disease(s) relieves managers of chronic maintenance headaches. Whenever possible, make use of resistant grass species and varieties.

In areas where turf is stressed because the wrong varieties were planted, the growing conditions should be changed to promote grass health and deter pest development.

Cultural Controls

Turf managers commonly incorporate cultural controls such as raking, thatch removal, and aeration. Turf maintenance practices such as mowing, fertilizing, and irrigation are also important cultural controls. Using these practices to provide the greatest benefit to turf is described in Chapter 2.

The majority of useful turf cultural controls limit disease inoculum and pest habitat. **Inoculum** is any stage, structure, or form of a pathogen that can cause disease. Many turf diseases, including pink snow mold and leafspot, live in and form fruiting bodies on grass plants and debris. The spores they release are disease inoculum. To reduce the spread of diseases, collect and dispose of the inoculum-infested clippings. Other cultural practices for pest management include removing thatch (fusarium patch), improving air movement over the turf (pythium blight, powdery mildew), and avoiding heavy watering (summer patch).

Modifying or eliminating rodent habitat helps reduce turf injury caused by some vertebrates. For instance, voles (mice) require sheltered areas near turf stands. Removing ground cover, weeds, litter and other vole refuges will in turn reduce the population of this pest. You can also discourage skunks from settling near turf stands by removing nearby refuge sites. Seal up ground-level openings under porches and in building foundations.

Probably the most common cultural control for turf management is mowing. Weeds are reduced in turf stands by an average of 90% when turf is mowed at its preferred height. Explaining this benefit to clients may motivate them to mow their lawns at the proper height.

Mechanical and Physical Controls

Mechanical and physical controls are tactics that physically separate the pest from the host plant. These tactics are easy to do and are totally nontoxic, making them useful for turf IPM programs.

Hand-removal

Slime mold is an example of a disease that you can readily control by physically removing it. Mowing or raking slime-molded areas helps remove infected grass and allows for rapid turf recovery. Hand-removal techniques are also a useful insect management option, especially for those areas where pesticide applications are undesirable or impractical. Some golf course superintendents hand-pick cutworm larvae on tees and greens to prevent exposing golfers to insecticides. Growing cutworm populations can be limited by mowing at a low height and disposing of clippings. This practice is also used to manage chinch bugs and sod webworm larvae.

Mowing turf at its preferred height is an effective weed control tactic.

Pulling weeds is an effective although labor-intensive practice. Hand-removal is not a practical method to manage weeds in established turf. However, it may be the only weed-control option for newly-planted stands of tender grass.

Traps

Vertebrate pests can be removed from turf areas by trapping. 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 (voles), rats, moles, 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

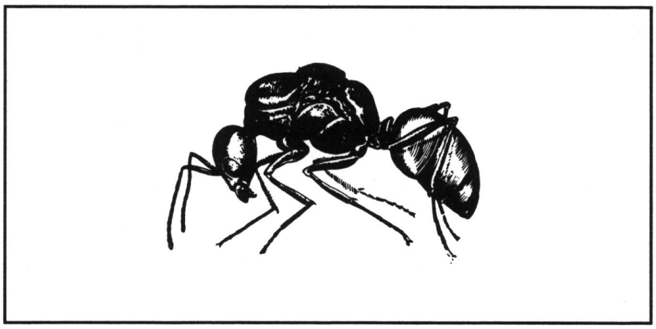
Barriers physically prevent the pest from coming in contact with grass plants. Barriers buried underground protect turf with a varying degree of success by preventing the movement of tunneling vertebrates into valuable turf stands.

Repellents

Repellents reduce pest activity on turf through devices that annoy or frighten pests. Ideally, pests encountering taste, odor, visual, hearing, or vibration repellents leave the protected area. The effectiveness of these devices varies. Over time pests become used to and are no longer scared by the repellent. As yet, repellents for vertebrate turf pests like moles and ground squirrels provide only limited protection. Chemical repellents are defined as pesticides by law.

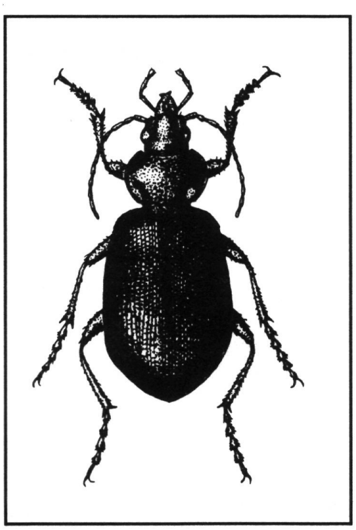
Biological Controls

Biological controls limit pests through naturally-occurring and introduced parasites, predators, and diseases. Predators actively search out and consume several prey insects. Insect parasites develop in or on a single host insect. Natural enemies of pests are abundant in turfgrass including species of fungi, parasitic wasps, ants, beetles, spiders, and nematodes. Unfortunately, people seldom appreciate the importance of beneficial organisms until the biological balance of the system is upset.

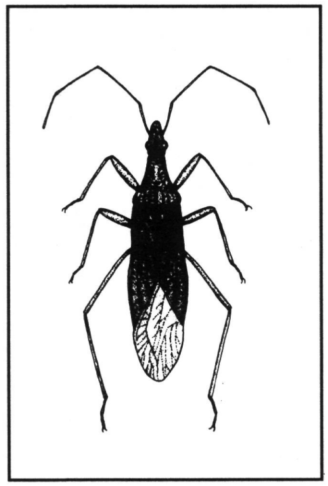


Several ant species are found in Michigan turf consuming insect eggs and larvae.

Predaceous and parasitic insects are usually more sensitive to insecticides than turf-feeding pests. Insecticides destroy insect pests, but also big-eyed bugs and other natural enemies. Chinch bugs often become damaging after an insecticide application because the big-eyed bugs have been killed.

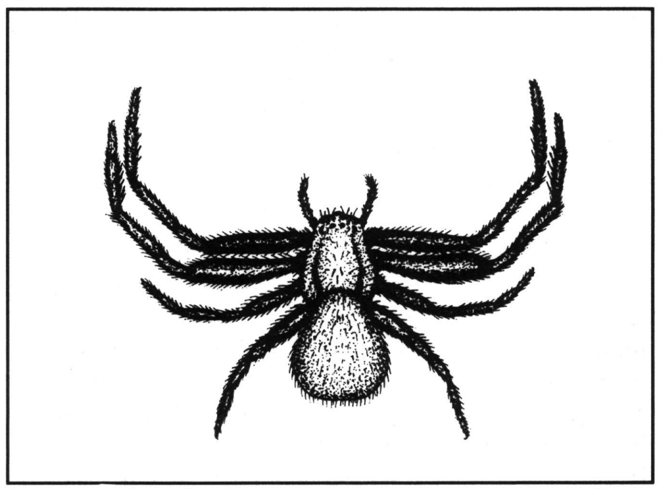


Species of ground beetles are found under debris on the ground. They possess powerful jaws and prey on most pests living on the soil surface, including caterpillars, grubs, and slugs.



Damsel (or Nabid) bugs are light brown in color and are commonly found on the foliage feeding on insect eggs and larvae.

When monitoring turf for pests, do not mistake big-eyed bugs for chinch bugs. Although their coloring, shape, and wing pattern is similar, big-eyed bugs have huge eyes compared to chinch bugs. You should be able to recognize important natural enemies of Michigan turf pests. Several are pictured here.



All spiders feed on insects and other small arthropods. Less familiar, but common species of spiders do not build webs, but rather hunt down prey on soil or plants. These include wolf spiders, crab spiders, and jumping spiders. They are important in controlling beetle, caterpillar, and leafhopper pests.

Protect established populations of beneficials by avoiding unnecessary environmental disturbances including pesticide applications. Remember, only 10% of all homeowner lawns develop insect infestations requiring insecticide applications. When pesticides are necessary, target the application and avoid broad-spectrum and highly-toxic products.

Because populations of beneficial organisms depend directly upon the availability of pests to survive and grow, *a turf stand cannot be both pest-free and benefit from biological control.* Do not attempt to wipe out a pest population; take time and care to use only the amount of pesticide required to prevent unacceptable turf injury.

The United States government imports and studies hundreds of species of natural enemies to limit serious crop and forest pests. Successful natural-enemy release programs exist for agriculture, forestry, and turf. For instance, the release of a fungal parasite virtually eliminated the Rhodesgrass scale, a serious pest of St. Augustinegrass. Researchers are currently exploring the use of weed-feeding insects and fungal diseases to suppress weeds. Since importing and releasing organisms can result in new pest problems, this management activity is restricted to government personnel.

Companies have formulated several pest pathogens into microbial insecticides. The most commonly used microbial insecticide is *Bacillus thuringiensis* or **Bt.** This bacterial disease kills many insect larvae including armyworm, cutworm, sod webworm and other caterpillars. Another example of a bacteria microbial is *Bacillus popullae* or milky spore disease that attacks Japanese beetle, European chaffer and other white grubs. Parasitic nematodes *(Steinernema carpocapsae* and *Heterorhabditis sp.)* are marketed for management of sod webworm, cutworms, and grubs. Sources of microbials are listed in the Resources section of this manual.

When properly applied, pathogens provide turfgrass protection without endangering the environment or nontarget organisms. Unlike their chemical counterparts, however, microbial insecticides are not likely to provide immediate suppression. When insects exist at high levels, unacceptable injury can occur in the time it takes pests to succumb to the disease. It is best to use microbial insecticides as a long-term tactic to help maintain insect populations at low levels.

Review Questions: Chapter 3

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 grass is better able to resist and recover from injury by pests. *(True of False?)*

3. There are grass varieties that are resistant to serious turf diseases. *(True or False?)*

4. No grass varieties can repel insect pests. *(True or False?)*

5. Name 3 routine lawn care practices that are also cultural pest controls.

6. Give an example of one disease and one insect that can be managed with hand-removal techniques.

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

8. Explain why turf cannot at the same time benefit from biological control and be pest-free.

9. Name three beneficial insects that control turf pests in Michigan.

10. How can you encourage pest control by beneficial organisms already existing in your turf stand?

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

12. Are microbial insecticides best used for short-term suppression or long-term maintenance of pest populations? Why?

CHAPTER 4

PESTICIDE APPLICATION

Properly selected and applied pesticides are useful tools in IPM programs. Pesticide applications should be as safe and simple to do as possible. Attempting to "make do" with inadequate equipment, time, or personnel increases the chance of poor pest management, turf injury, and accidental pesticide contamination. Because of such errors, you may be faced with legal fines and jeopardize your professional reputation. This chapter outlines points to consider when choosing pesticides and application equipment, and techniques to apply them safely and effectively.

Selecting a Pesticide

Classification of Pesticides for Turf Use

Pesticide Classification	Pest Controlled
Insecticide	Insects and related animals
Acaricide	Mites and ticks
Nematicide	Nematodes
Fungicide	Fungi
Rodenticide	Rats, mice and other rodents
Avicide	Birds
Herbicide	Weeds

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. The Pesticides chapter of the Core manual discusses categories and pesticide toxicity, and this information is summarized in the tables accompanying this section. The wide variety of commercially-available pesticides reflects the manufacturers' attempts to market products that best manage each type of pest problem. Carefully consider the pesticide characteristics and how they will affect your particular problem.

Choose a pesticide that is:

- Labeled for the pest.
- Capable of the desired level of control.
- Least disruptive to the environment.
- Not phytotoxic to the turf or other ornamental plants.
- Economically practical.
- Compatible with other plant management practices.
- Acceptable to the public.

Your first concern when selecting a pesticide is that it is labeled for the pest, and for use on turf. *To use any pesticide in a manner inconsistent with its labeling is a violation of federal and state law.* Often there will be several pesticides labeled for a pest. Which should you apply? Do not choose a pesticide based solely on how quickly it kills the most pests. Other pesticide characteristics often prove more important, since it is rarely necessary or desirable to eradicate a turf pest.

Pesticide Toxicity

To help conserve natural enemies and limit applicator risk and public concern, whenever possible use pesticides with the highest LD_{50} (lowest toxicity). Many useful pesticides are in Categories III and IV (see Signal Word table.) Because they are considered 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 influences its ability to limit pests and its potential for endangering nontarget organisms. **Broad-spectrum pesticides** are developed to suppress a wide range of pests. This feature makes broad-spectrum pesticides convenient, but hazardous to nontarget

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	Over 50 through 500 mg/kg	Over 500 through 5,000 mg/kg	Greater than 5,000 mg/kg
Inhalation LD_{50}	Up to and including .2 mg/liter	Over .2 through 2 mg/liter	Over 2.0 through 20 mg/liter	Greater than 20 mg/liter
Dermal LD_{50}	Up to and including 200 mg/kg	Over 200 through 2,000 mg/kg	Over 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

organisms biologically similar to the pest. Limit the use of these pesticides to situations where there is more than one target pest.

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. They kill the pest without harming the host plant. Systemic herbicides that are applied to weed foliage will also kill the roots.
Broad-spectrum:	Pesticides that limit two or more pests. Sometimes labeled as multipurpose chemicals. A broad-spectrum pesticide may be protectant or systemic in its action.
Residual:	Pesticides that continue to be effective for an extended period of time after application.
Nonselective Herbicide:	Herbicides that are toxic to all desirable and weed plants.
Selective Herbicide:	Herbicides that kill some plants, but do little harm to others. They are useful for eliminating grass plants in flower beds and ridding lawns of broad-leaf weeds.

Pests that are destructive for long periods of time or are highly mobile may best be managed with a pesticide that remains effective for a longer time **(residual pesticide.)** Use of a residual pesticide may reduce the number of applications required to control persistent pests. But, remember that a residual pesticide is not useful if it remains active after the period of pest susceptibility. Do not expose nontarget organisms to pesticides more than is necessary to manage pests.

Systemic pesticides are absorbed into and travel within the plant. This mode of action makes **systemic herbicides** superior to **contact herbicides** in treating persistent, perennial weeds. Contact herbicides kill only the plant portions to which they are applied, leaving the underground plant parts that produce new top growth. Systemic herbicides travel inside of weeds, killing both top and underground plant parts. Insect pests feeding on plants consume **systemic insecticides** which makes these insecticides useful for controlling insects that are difficult to reach with contact sprays. There is less risk of injuring beneficial and nontarget organisms when using systemic insecticides, since much of the material is within the plant.

Pesticide Formulation

There are advantages and disadvantages associated with the use of any one of the many pesticide formulations (see Formulations table.) 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.
- Liquid formulations are easier than dry formulations to measure in the field.

Pesticide Formulations						
Formulation	**Description**	**Application Method**	**Relative Risk When Handling**	**Risk of Moving Off Target**	**Advantages**	**Disadvantages**
Emulsifiable Concentrates (E, EC)	Liquids with the active ingredient dissolved in one or more solvents	manual and hydraulic sprayers	high	moderate to high	very little residue; non-abrasive; little agitation required	can be phytotoxic; easy to over or under apply; corrosive to equipment, readily absorbed through skin
Wettable Powders (WP) and Soluble Powders (SP)	dry preparations containing concentrated pesticide; spray solution equals WP mixed into water and SP dissolved into water	hydraulic sprayer	moderate	moderate to high	low cost; easy to store and transport; not phytotoxic	easily inhaled; WP requires constant agitation; SP requires moderate agitation; wears pumps and nozzles
Flowables (F, L)	finely ground wettable powder formulation sold as a thick suspension in a liquid; flowable liquid is then mixed into water	manual and hydraulic sprayers	moderate	moderate	will not clog nozzles; easy to store and transport; only requires moderate agitation	easy to over or under apply; may be phytotoxic; residues difficult to remove from containers
Granules (G)	dry, low concentration, ready-to-use formulations; size of particles are the same and larger than dusts	manually and mechanically spread	low	low	no mixing; penetrates dense foliage; less problem with drift; application equipment inexpensive and easy to use	not suitable for foliar application; broadcast applications affects nontarget organisms.
Baits	pesticide mixed with food which attracts the pest	manually spread	low	low	no mixing; minimal contamination	may attract children, pets and other nontarget organisms

- During storage, subfreezing temperatures have less affect on dry formulations than liquid formulations.
- 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 to drift.
- Volatile herbicides have the potential to drift or contaminate stored pesticides.
- Some materials are more phytotoxic than others.

Your choice of pesticide formulations is in large part limited by the application equipment available.

Pesticide Application Equipment

No matter how simple or sophisticated, application equipment must be in proper working order and correctly calibrated to deliver at a uniform and consistent rate. Familiarize yourself with all equipment operation and maintenance procedures. Use an equipment safety checklist such as the sample

Mechanical Equipment Safety Checklist

Regularly inspect equipment for any of the following problems:

- ☐ Worn hoses.
- ☐ Poor hose to reel attachment (leaking).
- ☐ Poor hose attachment to spray gun or boom (leaking).
- ☐ Leaking spray gun or nozzles.
- ☐ Poor adjustment of spray gun or nozzle 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.

in this section to check for malfunctioning and worn parts. Keep a record of the maintenance schedule for all equipment. These practices will help you avoid costly accidents and breakdowns.

When equipment malfunctions, do not put off repairs nor take repair "short cuts." This type of approach only creates an unnecessary risk of accidents. Experienced applicators frequently can repair or at least pinpoint the cause of sprayer problems. A chart of common sprayer problems is provided in this section.

Which type of equipment is best to use for a turf application depends upon the target area, type of pest, and pesticide formulation. The following describes turf application equipment and its maintenance.

Granular Spreaders

Granular spreaders consist of a hopper to hold pesticide and a metering device (feeder gate) that regulates the flow of granules through the outlet holes at the bottom of the hopper. A mechanical agitator at the base of the hopper provides continuous feeding of the material to the feeder gate. Check for a good agitator when selecting a spreader. Look for a spreader whose design is such that granule flow stops when the applicator stops, even if the outlets are in the open position. Choose a model that is easy to fill and clean.

Granular spreaders should be thoroughly cleaned after each job or at the end of each day's use. Remove corrosion on the feeder plates or agitator with a wire brush, file, or sandpaper. Be sure that you securely tighten all nuts and bolts and lubricate the equipment according to the manufacturer's specifications. Keep the outlets free of lubricant because it can be phytotoxic to turf.

Granular spreaders are used to apply granular formulations of pesticide and fertilizer.

Drop (gravity) spreaders are available in widths from one-half to 3 feet. An adjustable sliding gate opens the outlet holes and the granules flow out by gravity feed. A revolving agitator activates when the spreader is in motion to assure uniform

Common Sprayer Problems

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

From "Ornamentals and Turf Manual," University of Maryland Cooperative Extension Service.

dispensing. Drop spreaders provide somewhat uniform coverage, but create an application pattern with abrupt edges. Therefore, even a small error in steering will result in untreated or overapplied strips. Also, some drop spreaders will not deliver larger-sized granules.

Rotary spreaders distribute granules to the front and sides of the spreader usually by means of a spinning disc or fan. This method creates more drift than drop spreader application. Most rotary spreaders produce a swath width of 6 to 8 feet. Both power-and hand-driven models are available.

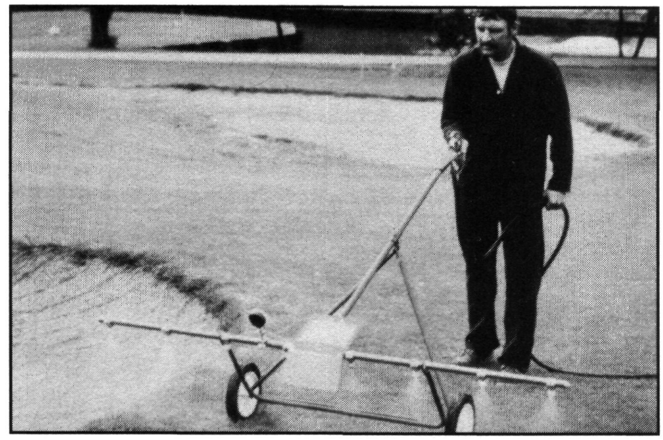
Spray Output Equipment

The four basic components of sprayers, as outlined in the Core, are the tank, pump, valving, and output. The component that has the greatest impact on applications is the output. Whether a spray gun, a single nozzle, or a boom, the output part of a sprayer is designed to accurately and effectively deliver the spray solution. Although manufacturers have developed guns and nozzles for practically every type of spray application, only a few are commonly used for turf.

Shower head guns create a wide spray stream useful for turf applications.

Traditional **spray guns,** which were designed for ornamental plant applications, are not useful for spraying turf because of the difficulty in obtaining uniform coverage. The **ChemLawn shower head gun,** and similar models by other manufacturers, is specifically designed for lawn applications. These guns create a wide spray stream, and can be fitted with different nozzles to adjust the rate of output from about one-half to 4 gpm. Drift is limited, as the droplets are relatively heavy. These guns are most commonly used with power sprayers for landscape lawn applications.

A **spray wand** is a long, rigid tube that attaches the hose to a single nozzle. Wands allow applicators to make low-volume, spot treatments with great accuracy.



A golf course turf applicator uses a hand-operated spray boom.

Spray booms deliver spray material to nozzles. The length of the boom and its height from the ground determines the swath width. Spray booms for turf range in size from small, hand-operated models to large units mounted on tractors.

Spray booms, and some wands and guns are fitted with **nozzles.** Nozzles break up spray solution into droplets and spread them in a specific pattern. Nozzles are classified by the spray delivery pattern, spray angle, discharge rate and materials from which they are made. The Core manual describes various nozzles. See the accompanying table for a summary of those commonly used for turf applications.

The nozzle orifice size is determined by the size of the nozzle, or by interchangeable discs. Manufacturers supply information sheets on the delivery rate (usually gallons per minute) of their nozzle models at various operating pressures. Select nozzles that will provide the desired droplet size and application rate when used according to the manufacturer's recommended range of pressures. Nozzles used outside specified rates and pressures will not distribute material uniformly.

Abrasive materials like wettable powders cause nozzles to wear. As they wear, the orifice becomes larger and the nozzle output increases. Lessen wear by using hardened stainless steel, chrome-plated brass, or ceramic nozzle components. To reduce nozzle wear due to abrasion, use nozzle screens to filter out larger dirt and pesticide particles.

Nozzle screens also reduce clogging of nozzles. Consult nozzle manufacturers' recommendations when choosing the mesh size of screens. Check and clean nozzle screens frequently. Use of screens may affect pressure at the nozzle. Check for a change in the rate of output after installing or changing nozzle screens.

Nozzle Types and Uses

Nozzle Type	Distribution of Droplets	Main Uses	Wettable Powder Abrasion Resistance
Flat Pattern	uniform when the boom is at the proper height	herbicides, fungicides, or insecticides	brass: poor plastic: fair stainless steel: good hardened stainless steel: best
Broadcast	not uniform	herbicides for complete removal of vegetation	good, but not often used with wettable powders
Flooding Fan	not as uniform as flat fan	liquid fertilizer and pre-plant incorporated herbicides	likely good, but not often used with wettable powders
Hollow Cone	not as uniform when used on a boom; best for directed spraying	insecticides or fungicides	relatively good

Controlled Droplet Applicators (CDAs)

These sprayers are commonly called rotary spray nozzles. CDAs have a spinning cup with small grooves that spiral up the inner wall. The nozzles are gravity-fed from the spray tank and are powered by small electric motors. Centrifugal force moves spray solution in the spinning cup up the grooves. When the spray solution reaches the edge of the cup, it flings out in a hollow-cone pattern. The spray droplets fall nearly vertically onto the target. The droplet size varies with cup diameter, speed, and flow rates. Large truck-mounted and small hand-held models are available.

Controlled droplet applicators are well-suited to turf IPM because they provide adequate coverage with small amount of pesticide. Delivery rates of 3 gallons of spray per acre or less are possible. Low volume application reduces the amount of water and fuel used and allows use of smaller and lighter spray equipment.

Small-Capacity Sprayers

Small-capacity sprayers are used for spot treatments and small turf areas. They are also useful for applying pesticide spray solution to areas that are inaccessible to larger units. Small-capacity sprayers are relatively inexpensive, simple to operate, maneuverable, and easy to clean and store. Most are hand sprayers that use compressed air to pressurize the tank and deliver spray solution. They may be fitted with a wand, gun, or small boom.

Compressed-air sprayers hold 1.5 to 5 gallons of spray and can be carried by hand or on a shoulder strap. The applicator shakes the tank for a uniform spray mixture. Keeping wettable powders in solution can be a problem with this type of agitation. A hand-operated pump develops a head

Small-capacity sprayers are used for spot treatments and small area applications.

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. Some compressed-air sprayers use a pre-charged cylinder of air or carbon dioxide to provide pressure. A pressure valve maintains the spraying pressure between 20-60 psi, and hydraulic agitation keeps materials in solution. These units are bulky and are therefore mounted on wheels. Compressed-air sprayers are useful for a variety of spray jobs, as they can be fitted with an adjustable spray gun, wand, or a small boom.

Knapsack (backpack) sprayers are used for many of the same kinds of applications as compressed-air units. The applicator supports the weight of the 2 to 6 gallon sprayer his or her shoulders to lessen fatigue. A hand-operated piston or diaphragm pump supplies pressure. To maintain pressure, the applicator must provide strokes for the pump every few seconds. A uniform mixture of spray is maintained by mechanical or hydraulic agitation. Like hand-held model, these units usually are fitted with an adjustable gun or a wand.

This pick-up truck, equipped with a hydraulic sprayer and large tank, is typical of the equipment used for large-volume lawn applications.

Hydraulic Sprayers

Most large-scale turf applications are made with hydraulic sprayers. **Hydraulic sprayers** deliver spray material through a hand-held gun or multinozzle boom. The rate and distance of the spray depends upon the pressure the solution is pushed through the nozzles. Hydraulic sprayers produce pressures that range from nearly 0 to 500 psi. Application rates of 1 quart per 1000 sq ft to over 100 gallons per acre are possible. Hydraulic sprayers have 30 to 1000 gallon tanks and are usually mounted on tractors, trucks, or trailers.

Applying Pesticides

How you apply a pesticide to turf is as important to successful pest management as your choice of pesticide and application equipment. Apply only the amount of pesticide necessary to get the desired level of pest control. Over-applying material does not result in better pest control, but rather wastes money and exposes the applicator and environment to unnecessary contamination. Under-application results in poor pest management.

Application Technique and Pest Habits

Pesticide is wasted when applied where pests are not. For example, pest infestations commonly occur only on weakened, susceptible turf areas. It is a waste of time and material to apply pesticide to an entire lawn for control of crabgrass that is localized around a cement drive. Use the monitoring techniques discussed in Chapter 1 of this manual to decide precisely where to apply pesticides.

Once you apply a pesticide, be certain other activities do not undermine its effectiveness. For instance, preemergent herbicides form a chemical barrier that prevents weed seeds from germinating. Disturbances to the treated area, such as footsteps, break the barrier and may reduce the action of some herbicides.

The pesticide application technique should reflect pests' feeding, germinating, or inoculation habits. Using a contact insecticide spray will not effectively control root-feeding grubs. Many grub insecticides are formulated as granulars, so that the material can penetrate the turf and reach the soil. Many fungicides act as a plant protectant by preventing fungal inoculum from entering the plant leaf. The level of control produced by protectant fungicides depends upon effective coverage of grass blades.

As these examples illustrate, it is critical to *tailor pesticide applications to pest habits*. Refer to the pesticide label and other pest management resources for application timing and technique, and protective gear recommendations.

Applying Granular Pesticide

Practice or review the following granular application techniques:

1. Fill the spreader on a paved surface. Spills are more easily cleaned off pavement than turf.
2. Begin the application by moving counterclockwise around the right margin of the property. Make two complete swaths around the perimeter of the turf stand (this area is the header strip.) Avoid casting material into flower beds or across the property line by closing the openings that feed the right side of the spreader.
3. Treat the area with series of parallel passes that overlap one-half the width of the previous swath. Overlapping swaths assures uniform distribution of granules. Make applications parallel to the street so that uneven growth and color responses will be less obvious.
4. Because you have already treated the header strip, turn the spreader off before beginning a turn. Be sure to turn the spreader on as you leave the header strip.
5. Shut off the spreader as you come to obstacles. Go to the opposite end of the pass and come back to the obstacle.

6. Keep the spreader level. Do not pump the handle up and down as you walk.
7. Remember to walk at a consistent pace.
8. Never stop with the spreader in the open position, as too much product is likely to be released.
9. Do not operate the spreader backward; unacceptable patterns or rates will result.

Follow these techniques, and carefully calibrate your spreader (see Chapter 5) to insure proper granular pesticide rate and placement.

Operating and Maintaining Sprayers

Properly operating and maintaining spray equipment is essential for safe and effective pest management. Routine maintenance significantly reduces repair costs and prolongs the life of equipment.

Before spraying. Put on appropriate protective equipment and gear. Rinse out the entire system and remove and clean the gun, nozzles, nozzle screens, and strainers. Check to be sure that all nozzles are of the same type, size and fan angle. Do not overtighten nozzle caps or use cracked ones, especially if they are plastic. After filling the tank with water, check the lines, valves, seals and tank for leaks. Adjust nozzle height and spacing as suggested by the nozzle manufacturer and the pesticide label. To limit drift, set the boom no higher than is necessary to get good coverage. Check nozzles for uniform output and then spray water on the pavement and watch for streaks as the spray dries. Replace any nozzle with a flow rate five percent more or less than the average, as well as those producing heavy or light streaks.

During spraying. Check the label and put on at least the recommended protective gear. Do not operate pumps at speeds or pressures higher than specified in the owner's manual. Do not use travel speeds too high for the conditions of the turf. Check for nozzle clogging and changes in nozzle patterns during applications. If nozzles clog or other trouble occurs in the field, shut off the sprayer and move to an unsprayed area before dismounting to work on the sprayer. Remember to put on all necessary protective gear before attempting sprayer repairs. Clean and unclog nozzles with a toothbrush or toothpick. Do not use metal objects on nozzles. *Never try to unclog a nozzle by blowing through it with your mouth.*

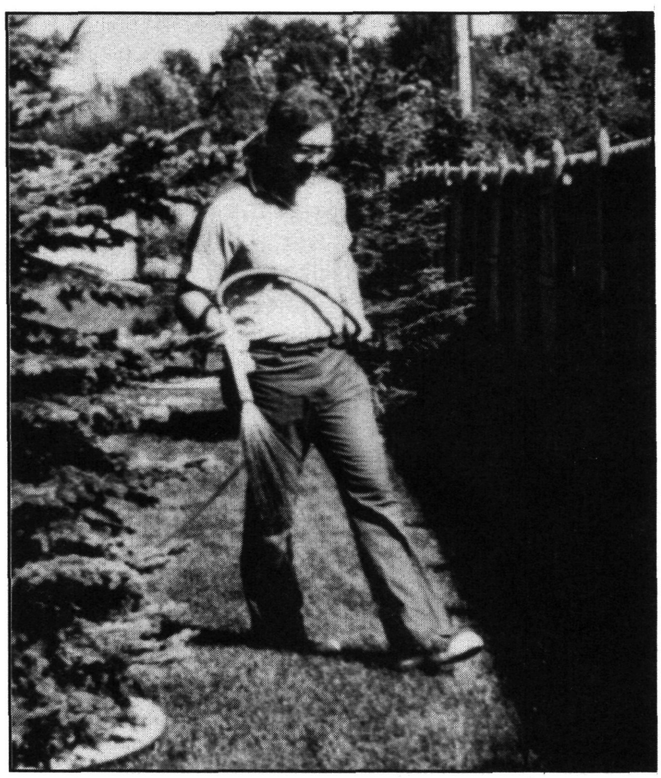
After spraying. Before removing protective gear, wipe off the surfaces of spray trucks, tanks, guns, booms, and hoses preferably after each use. Flush out residues inside of spray guns, nozzles, hoses, and the pump by running fresh water from the spray tank through the nozzle. Be sure to spray the rinse water back into the spray tank. The Michigan Department of Agriculture established procedures for washing and rinsing pesticide residues from equipment in 1991. Check Regulation 637 of the Michigan Pesticide Control Act for your legal obligations.

While wearing protective gear, clean the inside and the outside of the sprayer thoroughly before switching to another pesticide and before doing any maintenance or repair work. Skin readily absorbs pesticide residues that can cause serious pesticide poisonings.

Remember, herbicide residues cannot be adequately washed off of application equipment. Never use herbicide application equipment for any other type of application. Tighten or repair all leaky tank seals and fittings. Make sure sight gauges can be read. Check pressure gauges frequently against an accurate test gauge. Inspect all strainers, screens, and nozzle tips after each day of spraying. Clean them if necessary by soaking and brushing; never use metal objects for cleaning. Do not allow hoses to become kinked or abraded; rinse the hoses frequently to prolong their life.

Applying Pesticide Sprays

The following are guidelines for making pesticide spray applications on foot with a shower head nozzle. Some of these techniques can be applied to boom spraying as well.



Hold the hose in front of you and walk at a comfortable pace. Take care not to drift onto landscape plants.

1. Hold the shower head nozzle at an angle pointed away from your feet and legs.
2. Hold the hose comfortably in front of you. Do not drape the hose around your neck or around your back.
3. Squeeze the trigger only partly open and start the side to side motion.
4. Apply pesticide uniformly and accurately—concentrate on pattern, walking speed, and pressure.
5. Spray in parallel swaths. Do not walk in circles or change directions within a spray area.
6. Sidewalks and driveways are straight edges that make excellent guides as you begin spraying. Avoid curved flower beds as a starting place.
7. Maintain a straight walking line by heading toward a tree, fence post or other landmark.
8. Walk at a comfortable pace holding the gun close to your side. Move your forearm (elbow to hand) from side to side in a steady motion. Do not spray with your wrist only. Your pace is about right if you hit a spot two or three times as you pass it.
9. Make parallel overlapping swaths. The degree of taper on spray pattern edges determines the amount of swath overlap required for uniform application. An overlap of one-half swath width is usually used with showerhead nozzles. This technique is sometimes referred to as "overlap back to the footsteps" of the previous swath.
10. Weeds are often found in strips along the margins of streets, sidewalks and driveways. It is important that these areas receive the proper rate, neither more nor less. With the above spray pattern, margins receive only half rate. **"Trimming"** is a technique where another half dose is applied. You trim by speeding up the rate of the side-to-side arm movements and walking at a faster pace. Practice your trimming technique, since applicators use it frequently.
11. When finished with the application, turn off the pressure and place the gun in its hanger or suspend it over the spray tank. After winding the hose onto the reel, release any pressure remaining in the gun by spraying into the tank.

Record Keeping

Besides being an essential part of pest management program evaluation, Michigan law requires commercial applicators to record application information. As stated in Regulation 636, the applicator must record at the time of application the following information:

- 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.

Information that is not required by law but important for your protection and useful for management decision-making includes:

- Name of the applicator.
- Certification or Registered Technician number.
- Product EPA registration number.
- Date of last calibration.
- Time of application.
- Weather conditions during and after application.
- Specific turf area(s) treated.
- Target pest stage at time of application.

Develop a pesticide use sheet to help you collect and store uniform records that include all necessary information.

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. Properly selected and applied pesticides are useful tools in IPM programs. *(True or False?)*

2. Name five things to consider when choosing a pesticide to control a turf pest.

3. List the four ways to classify pesticides.

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

5. What type of pesticide should you use to manage fungi? rodents?

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

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

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

9. What is the abbreviation for wettable powders? flowables? granules?

10. A rotary spreader creates more drift than a drop granular spreader. *(True or False?)*

11. Explain how nozzle output increases with wear? How can you avoid this?

12. Why should you use nozzle screens? Why should you check the rate of output after installing or changing nozzle screens?

13. For what type of turf applications are small-capacity sprayers, (e.g., backpack sprayers) useful?

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

15. Name two causes of loss of pressure with a power sprayer.

16. Why must applicators overlap the previous swath when making granular and spray applications on turf?

17. What is "trimming" and when should you use it?

18. 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?

Pesticide Use Record

Name of applicator: Certification or Registered Technician number:	Date of application: Time of application:
Name of client and address of target area: Specific area(s) treated:	Target pest or purpose: Life stage of pest:
Air temperature: Windspeed and direction:	Soil moisture and texture: Sunny/cloudy: Rain before/after application? When?
Pesticide product name: Pesticide EPA registration number:	Pesticide rate: Amount applied:
Sprayer or spreader used: Date of last calibration:	Nozzle or gun size: Spray pressure or spreader setting:

CHAPTER 5

APPLICATION CALCULATIONS AND CALIBRATION

Accurately mixing pesticides and calibrating equipment is critical to successful pest management. As important as these activities are, applicators frequently do not obtain the desired application rate simply because their equipment was not calibrated properly. A study of over 100 farmers conducted in North Dakota found a number of problems that diminished spray application accuracy.

Percent of Sprayers With Problems	Problem
60%	Calibration error greater than + or − 10% from the applicator's prediction.
43%	Greater than + or − 10% variation in discharge from individual nozzles.
32%	Inaccurate travel speed from that predicted by applicator.
27%	Improper boom height for the nozzle spacing and nozzle discharge angle.
13%	Inaccurate pressure gauges. Many gauges indicate pressure lower than the actual pressure.
8%	Inadequate hose size to supply nozzles.

Note that 60% of the farmers tested did not achieve delivery rates from their equipment within 10% of the desired rate. Under-applying pesticides may not provide adequate control, while an over application could cause plant injury or compromise environmental safety. Both are a waste of time, money, and resources.

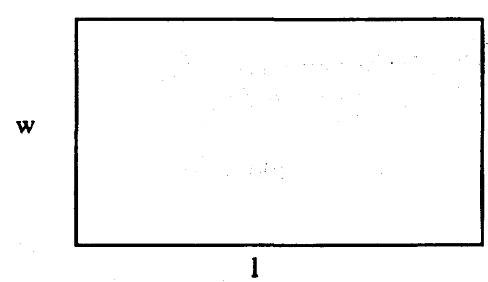
Area Measurement

While the importance of accurate area measurement to an application is obvious, easily measuring irregularly shaped areas can be a challenge. The methods listed here provide a system for easy and accurate area measurement. Method 1 (Divide and Conquer) breaks an area into smaller, more common shapes that are easier to work with. The procedures to determine the area of several common shapes are described in this section. Method 2 (Offset Lines), and Method 3 (Average Radius) are alternative methods for measuring these areas.

Method 1: Divide and Conquer

With this method the irregular-shaped area is divided into a group of simple geometric shapes which can be easily added together. The area of geometric figures can be readily calculated using these formulas:

Rectangle: The area of a rectangle is the length multiplied by the width.

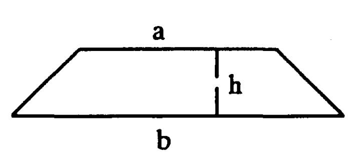


area = lw

Example 1: The length of a rectangular yard is 100 ft. Its width is 50 ft. The area of this yard is:

100 ft × 50 ft = 5,000 sq ft

Trapezoid. A trapezoid is a four-sided figure with two parallel sides. The area is the average length of the parallel sides multiplied by its height.

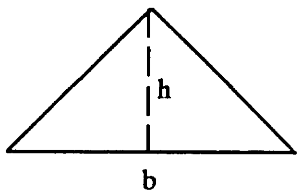


$$\text{Area} = \frac{a+b}{2} \times h$$

Example 2: One parallel side of a trapezoid is 200 ft, and the other is 300 ft. The distance between the two parallel lines (height) is 50 ft. The area is

$$\frac{200 + 300}{2} \times 50 \text{ ft} = 12{,}500 \text{ sq ft}$$

Triangle. The area of a triangle is one-half the base of the triangle multiplied by the height.

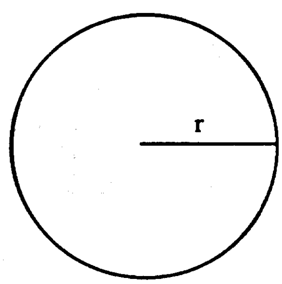


$$\text{Area} = \frac{bh}{2}$$

Example 3: The base of a triangular area measures 200 ft and the height is 400 ft. The area is:

$$\frac{200 \text{ ft}}{2} \times 400 \text{ ft} = 40{,}000 \text{ sq ft}$$

Circle. The radius of a circle is one-half the diameter. The area of a circle is the radius squared multiplied by 3.14 (pi).



$$\text{Area} = \pi r^2$$

Example 4: What is the area of a circle with a diameter of 200 ft? The radius is half of the diameter, or 100 ft. The area of the circle is:

$$(100 \text{ ft})^2 \text{ or } 100 \text{ ft} \times 100 \text{ ft} \times 3.14 = 31{,}400 \text{ sq ft}$$

Example 5: This irregularly-shaped turfgrass area has been broken up into a group of geometric shapes. The area of the shapes can readily be determined and added together to give the total area of the turf stand.

Area A is a circle with a 70 ft radius.

$$(70 \text{ ft})^2 \times 3.14 = 15{,}386 \text{ sq ft}$$

Area B is a rectangle:

$$170 \text{ ft} \times 90 \text{ ft} = 15{,}300 \text{ sq ft}$$

Area C is a triangle:

$$\frac{90 \text{ ft} \times 98 \text{ ft}}{2} = 4{,}410 \text{ sq ft}$$

Area D is a trapezoid. The parallel sides are 80 ft and 140 ft long.

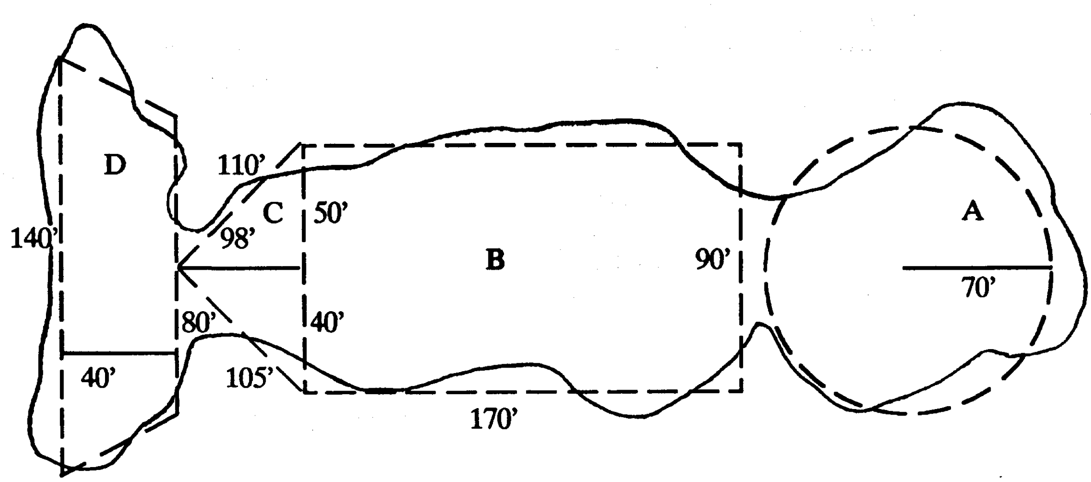
$$\frac{80 \text{ ft} + 140 \text{ ft}}{2} \times 40 \text{ ft} = 4{,}400 \text{ sq ft}$$

The total area of the irregular turf stand is Area A + Area B + Area C + Area D:

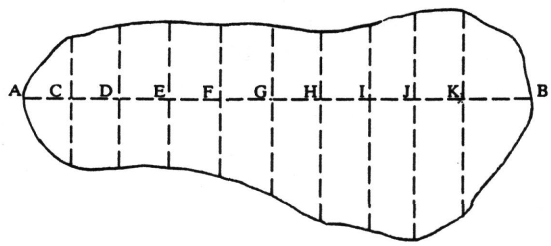
15,386 sq ft + 15,300 sq ft + 4,410 sq ft + 4,400 sq ft = 39,496 sq ft

Method 2: Offset Lines

The "offset line" method is another way to figure the area of irregular turf stands. An irregular area is broken up into a series of trapezoids. Lines are drawn at right angles (90°) at regular intervals along a pre-measured line drawn down the middle of the area (points A and B in Example 6.) The uniformity of the turf stand will determine how many offset lines are needed. A fairly uniform-shaped area will require fewer offset lines. Remember, the more offsets used, the greater the accuracy of the calculation.



Example 6:



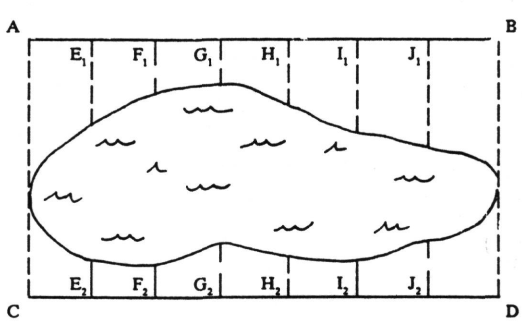
First establish and measure the distance between Points A and B. The fairway of Example 6 (distance between A and B) is 900 feet long. Mark and measure the offsets at regular intervals (the same distance from one another.) The shape of this fairway is relatively uniform, so offsets every 90 feet is adequate. Should a fairway be more irregular, use offsets at least every 45 feet. The offsets are marked in the diagram as lines C through K. The lengths of the offsets in this example are:

A = 0 ft	D = 75 ft	G = 120 ft	J = 210 ft
B = 0 ft	E = 75 ft	H = 150 ft	K = 195 ft
C = 60 ft	F = 90 ft	I = 180 ft	1,155 ft

The total area is found by adding up the lengths of the offset lines and multiplying by the distance between offset lines. The sum of the offset lines in our example is 1,155 ft.

1,155 ft × 90 ft = 103,950 sq ft

Example 7:



You may need to subtract the area of a pond from the total area of a target turf stand. Pond areas can be measured using the offset method. First, mark a rectangle around the pond with two opposite sides touching the pond edge (lines A-C and B-D.) The distance between A and B should be the same as between C and D. Measure offset lines at regular intervals from the outside lines to the edge of the pond. In this example, the offsets are 10 feet apart. There are actually two lines and the pond distance making up each line (e.g. E1 and E2, and the distance across the pond at that point.)

E1 = 14 ft	F1 = 8 ft	G1 = 7 ft	H1 = 10 ft	I1 = 14 ft	J1 = 17 ft
+	+	+	+	+	+
E2 = 6 ft	F2 = 4 ft	G2 = 8 ft	H2 = 4 ft	I2 = 4 ft	J2 = 6 ft
20 ft	12 ft	15 ft	14 ft	18 ft	23 ft

Subtract line set totals from the distance between A and C (50 ft) to find the length of the pond at that point. These are the offset lines.

A-C distance		line set totals		offset length
50 ft	–	20 ft	=	30 ft
50 ft	–	12 ft	=	38 ft
50 ft	–	15 ft	=	35 ft
50 ft	–	14 ft	=	36 ft
50 ft	–	18 ft	=	32 ft
50 ft	–	23 ft	=	27 ft
		offset total	=	198 ft

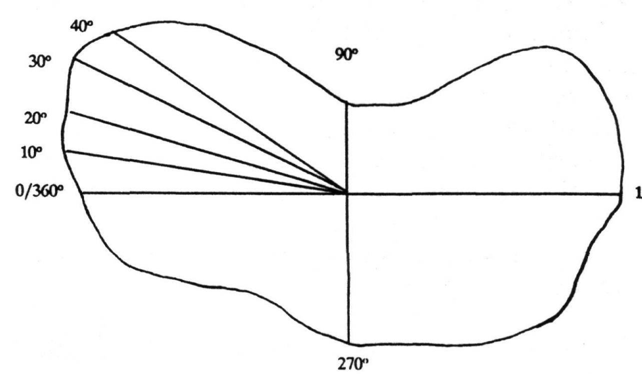
Now multiply the offset total by the distance between offset lines to find the area of the pond.

198 ft × 10 ft = 1,980 sq ft

Method 3: Average Radius

This method converts the irregularly-shaped area into a circle. From a central point in the turf area, measure the distance to the edge of the area. Mark distances at 10° increments so that there are 36 radius measurements. Use the average radius to figure the area.

Example 8:



If the 36 measurements taken from Example 8 totaled 1,731 ft, then the average radius is:

$$\frac{1{,}731.6 \text{ ft}}{36} = 48.1 \text{ ft}$$

The area of this turf stand is:

$3.14 \times (48.1)^2 = 7{,}264.7$ sq ft

Calibrating Application Equipment

Turfgrass professionals use a variety of pesticide application equipment in their operations. The following sections outline methods to calibrate drop and rotary granular spreaders, plus several sprayers including small hand pump (hand can), backpack, power sprayers, and boom systems.

There are several factors involved in applying pesticides that can be manipulated to achieve the intended rate of application. They are ground speed, output from the machine, and concentration of the solution. With each piece of equipment or material, one of these items may be easier to change than another. The following methods and examples will explain these concepts and provide a reliable system for calibration.

Granular Spreaders

Drop and rotary spreaders are the most common granular spreaders used by turf managers. Changing the orifice size of either type directly changes the flow of material and is the most important factor in calibrating these devices. Altering the ground speed of granular spreaders may be difficult for the applicator and only slightly affects the rate of application. The concentration of pesticide in the granular material is set by the manufacturer and is not possible to manipulate.

Output. The size of the meter opening determines the flow of the material from the spreader. The rate in which granules flow from the hopper through the meter openings is affected by granule weight, size, shape, and the carrier material (clay, ground corn cob, etc.). Do not attempt to mix granules with different characteristics. You must recalibrate your equipment whenever you change from one material to another. High humidity may cause some granules to clump, resulting in uneven distribution. Suggested settings to achieve specific application rates may be listed in the operator's manual or on the product label. These are a good reference to begin the calibration process. For accurate application, each piece of equipment must be calibrated for every type of material.

Ground Speed. As with any manually-operated equipment, the speed you walk must be consistent throughout calibration and applications. Pick a speed that is comfortable for you on the application area. Equipment that is bouncing over rough terrain will result in inconsistent coverage. The speed of the spreader agitator roughly corresponds to ground speed. However, the flow of granules through the orifice is not necessarily proportional to ground speed. *Doubling the ground speed does not always double the application rate.*

Calibration. First, determine the swath width of the spreader. The swath of a drop spreader is simply the width between the wheels, or the width of the bottom of the hopper. The swath created by rotary spreaders will be different with each material because some types of granules will travel farther than others. Approximate the correct orifice opening for your rotary spreader, make a small test run, and measure the swath width. Next, determine the rate of the material to be applied on the target area. Most product labels refer to the rate as pounds of material per thousand square feet.

Method 1: The easiest way to calibrate granular spreaders is to use a pan or shroud to catch and weigh the output. Pans for drop spreaders and shrouds for rotary spreaders are available from some manufacturers.

1. Measure a test course approximately 50 feet long. A shorter test course is acceptable, but remember that the longer the course the more accurate your calibration. The test area should have terrain similar to that of application areas.

2. After putting some material in the hopper, select an orifice opening and install the catch pan or shroud. The spreader can then be taken over the test course making sure the material is caught in the pan or shroud.

3. Remove the captured material and weigh it in pounds.

4. Figure the square feet of the test course by multiplying the spreader swath width by the length of the test course. Divide the amount of delivered material (pounds) by the square feet of the test course to determine the amount of material you have applied per square foot. Simply multiply this figure by 1,000 to determine the amount you applied per 1,000 sq ft.

5. Compare the rate delivered by the test run (your application rate) with the label rate. Make appropriate changes in the orifice size and repeat the procedure until your application rate is within plus or minus 5% of the recommended rate.

Method 2. A precise measuring scale is required for this method, because a small amount of material is used. Start by laying a pre-measured sheet of plastic over a portion of the test course, or mark off a measured area on a sweepable surface such as concrete or asphalt. Make certain the plastic sheet or the surface is clean and is wider than the swath width of the spreader.

1. After putting some material in the hopper, select an orifice opening. Mark the surface or lay the plastic down on the test course. Take the

spreader over the test course making sure the spreader is delivering material well before the test area.

2. Carefully recover the material from the test area and weigh it in pounds.

3. Determine the square feet of the plastic or marked surface. Divide the amount of material(pounds) by the square feet of this test area to determine the amount of material you have applied per square foot. Simply multiply this figure by 1,000 to determine the amount you applied per 1,000 sq ft.

4. Compare the rate delivered by the test run with the target rate. Make appropriate changes in the orifice size and repeat the procedure until the delivery rate is consistent with the target rate.

Example 9: You recover 4.75 pounds of granules over the test course as described in Method 1. Your rotary spreader has a swath width with this material of 8 feet, and the course is 40 feet long. What is your application rate per 1,000 sq ft?

test course area is $40 \text{ ft} \times 8 \text{ ft} = 320 \text{ sq ft}$

your application rate (per one sq ft) is $\dfrac{4.75}{320 \text{ sq ft}} = .01484 \text{ lb per sq ft}$

your application rate (per 1,000 sq ft) is $.015 \text{ lb} \times \dfrac{1{,}000}{\text{sq ft}} = 15 \text{ lb per } 1{,}000 \text{ sq ft}$

If the label states that this product should be applied at the rate of 9 pounds per 1,000 sq ft, is your application rate acceptable? First, find what 5% of 9 pounds is:

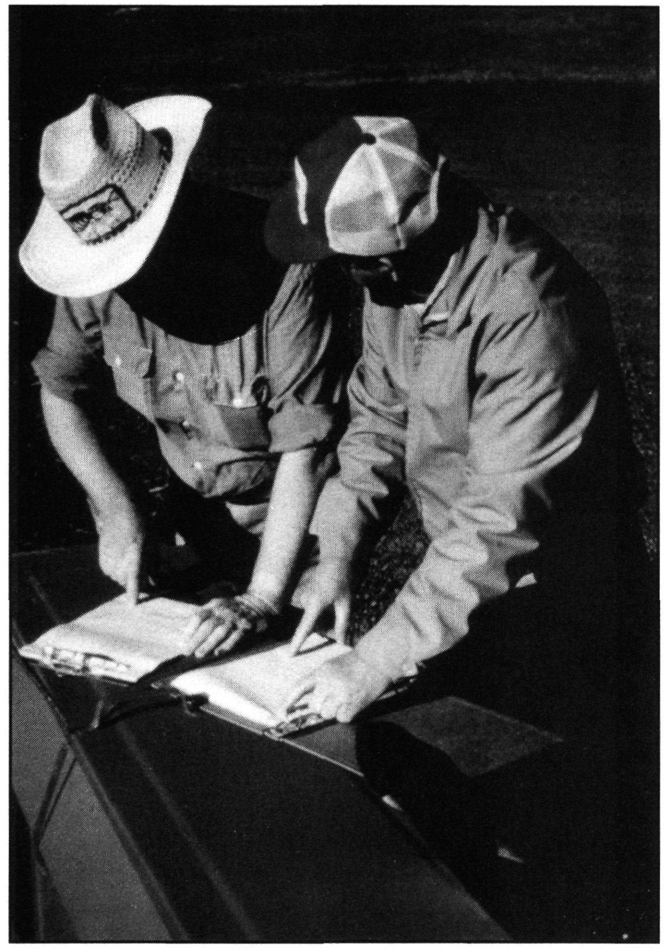
$.05 \times 9 \text{ lb} = .45 \text{ lb}$

To be within plus or minus 5% of the label rate, your application rate must be within the range of 8.55 lb to 9.45 lb. You are applying over 5 pounds too much per 1,000 sq ft. You must adjust the orifice size and recalibrate.

Sprayers

Turf managers use a variety of sprayers for pesticide applications. The key factors involved in proper delivery and calibration are ground speed, pressure, and output or orifice size. Understanding how to manipulate these factors will allow applicators to perform successful spray applications.

Ground Speed. The speed at which an applicator walks or operates the spray vehicle is directly related to the rate of application. If the forward speed is doubled, nozzles pass over the target area for only half of the original time, which cuts the application rate in half. Therefore, it is critical to successful applications to maintain a con-



Take care to accurately calculate target area size, figure pesticide rates, and calibrate equipment.

stant speed whether traveling uphill or downhill, on soft or hard terrain, or over bumps. When using backpack or vehicle-driven sprayers, be sure to calibrate on the same terrain as the target area so that a comfortable speed is selected. Traveling at high speeds over rough terrain with a full tank can damage the frame of a sprayer or "whiplash" a boom out of shape. Booms that are bouncing up and down or swinging from side to side produce application rates that vary as much as 50%.

Pressure. Maintaining consistent pressure is also critical for proper application, but changes in pressure do not have the direct influence on application rate as described for speed. For example, in order to double the spray output, the pressure must be increased by four times. All pumps and nozzles have a range of acceptable operating pressures. Check the manufacturer specifications and work within the guidelines. Excessive pressure produces inconsistent output and smaller droplets that are more likely to drift. Low pressure results in weak spray patterns and poor coverage. Any time an applicator changes the pressure or modifies the sprayer (changes hoses or couplings), the sprayer must be recalibrated. Because of friction, the pressure is reduced as the spray solution flows through a hose. The longer the hose, and the more couplings in the hose, the greater the reduction in pressure.

Output. The output of a sprayer is determined by the pressure and the type of nozzle used to deliver the solution. There are nozzles available that produce a wide range of application rates and changing the nozzle is the most effective way to modify the output. An applicator must determine the desired output for each application and choose the nozzle(s) that best correspond to those specifications. Manufacturers of nozzles and guns supply a chart of their products and the output at given pressures. Once the nozzle and pressure have been determined, the calibration process can begin.

Calibration. There are many methods used to calibrate sprayers; find one you are comfortable with and use it often. The following is only a sample of procedures that can be used to calibrate single-nozzle manual and power sprayers, and boom systems.

Small Manual Sprayers (Hand Can): The flow of material from a hand can sprayer is difficult to regulate, because the pressure changes dramatically each time the applicator pumps the sprayer. Applications requiring a consistent flow are not recommended for this sprayer. Products appropriate for hand cans are mixed as a specific "percent solution" and sprayed on the foliage until wet. For example, a product label may specify to mix 2.0-3.0 ounces of product per gallon of water and spray to wet. The applicator then only needs to estimate how much material is required to complete the job. Check the product label for suggested hand can applications.

Showerhead Nozzles: A showerhead nozzle delivers a relatively wide pattern (2-3 feet) through multiple streams as the name implies. Many applicators move this pattern from side to side as they walk to cover as much area as possible in one pass. This technique requires a great deal of practice so that walking speed and hand motion is smooth and consistent, and the material is uniformly applied. Once this technique is perfected, then the sprayer can be calibrated. First, set the pressure of the sprayer making sure it is within manufacturer guidelines for the pump and nozzle. Then proceed with step one.

1. Determine the output per 1,000 sq ft or per acre that is appropriate for the job based on the product label, type of application, and equipment used.
2. Mark off a test course at least 40 feet long and determine your swath width. Calculate the area in square feet of your test course.
3. Fill the tank with water and spray the test course using the technique you will be using during the actual application. Always begin spraying before you enter the test course.
4. Record the number of seconds required to spray the test course. To increase your accuracy, spray the test course at least three times and use the average number of seconds for all the tests.
5. Determine the volume of water applied to the test course by spraying into a bucket the exact number of seconds it took to cover the test course. Measure this amount in gallons.
6. Divide the gallons collected in Step 4 by the square feet of your test course. This is the gallons of solution applied per square foot. Multiply by 1,000 to determine the gallons per 1,000 sq ft or multiply by 43,560 to determine the gallons per acre. This is your output.
7. Compare your output with Step 1. Make any necessary changes in nozzles, walking speed, or pressure and recalibrate, to achieve an acceptable output.
8. Refer to the pesticide calculation section to determine the amount of pesticide needed for the job and to add to each tank.

Once an acceptable output is achieved, be sure to record the pressure, area of the test course, time and volume. Take care not to change your walking speed or spray swath width. Recalibrate often: weekly or daily. Also be sure to recalibrate if you change nozzles or hose length, or otherwise modify your spray system.

Example 10: You want to determine the output of a power sprayer with a showerhead nozzle. You choose a 40 foot long test strip and your swath width is 6 feet wide. You sprayed the 240 square foot course in 45, 41, and 48 seconds. What is your output per 1,000 square feet and per acre if the amount of spray delivered into the measuring bucket in 45 seconds is 1.25 gallons?

$$\text{your output (per one sq ft)} \text{ is } \frac{1.25\text{ gal}}{240\text{ sq ft}} = \frac{.0052\text{ gal}}{\text{per sq ft}}$$

$$\text{your output (per 1,000 sq ft)} \text{ is } .0052\text{ gal} \times \frac{1{,}000}{\text{sq ft}} = \frac{5.2\text{ gal}}{\text{per 1,000 sq ft}}$$

or

$$\text{your output (per acre)} \text{ is } \frac{.0052\text{ gal}}{\text{per sq ft}} \times 43{,}560 = \frac{226.5\text{ gal}}{\text{per acre}}$$

Backpack Sprayers: For backpack sprayers to be used most effectively they should be fitted with a gauge at the hand valve or have a pressure regulator so the operator can maintain a constant pressure during application. The "ounce method" calibration process can be used to calibrate backpack sprayers. First, determine the desired output, select an appropriate nozzle, and set the pressure at a level that is within the manufacturer specifications for the nozzle and pump. Then proceed with step one of the "ounce method." If your backpack sprayer is fitted with a boom system, follow the instructions for boom sprayers.

Boom Sprayers: The biggest challenge of boom sprayers is to deliver a consistent output from all nozzles throughout the spray operation. As with backpack sprayers, first determine the desired output and select the appropriate nozzles. Set the pressure at a level that is within the manufacturer specifications for the nozzles and the pump. Before calibrating the output, using the "ounce method," make sure all nozzles are delivering the same rate by catching the spray of all nozzles and determine the average output. Replace any nozzles that are not delivering within plus or minus 5% of the average output or do not have uniform patterns.

Ounce Method

1. Determine the band width (backpack) or distance between nozzles (boom system) and select the length of the test course from the chart provided here.

Band Width or Distance Between Nozzles (inches)	Test Course Length (feet)
10	408
12	340
14	291
16	255
18	227
20	204
22	185
24	170
26	157
28	146
30	136
32	127
34	120
36	113
38	107
40	102

2. Clearly mark the test course in terrain that is the same as the treatment area.
3. Walk or drive the sprayer through the test course using a speed that is comfortable for the terrain. Precisely time the seconds it takes to complete the test course. Make sure not to start the timing from a dead stop. Repeat this procedure several times and use the average time.
4. With the sprayer running, catch the output from one nozzle for exactly the same number of seconds it took to run the test course. *The nozzle output in fluid ounces is equal to the gallons per acre output of the sprayer.* For example, it took an average of 37 seconds to walk/drive the test course. In 37 seconds you collected an average of 45 ounces of water. The sprayer's output is 45 gallons per acre. To determine your output in gallons per 1,000 sq ft, simply divide your final answer by 43.56 (the number of 1,000 sq ft units per acre). For the example above, the output per 1,000 sq ft is 45 divided by 43.56, or 1.03 gallons per 1,000 sq ft.
5. If your sprayer's output does not match the desired output, then adjust the speed, pressure, or nozzle(s) and start again with Step 1.

Example 11: You are using a boom system to apply a pesticide that has 12 inches between nozzles. It took you 75, 77, and 73 seconds to travel the 340 foot test course. You collected 53 ounces of water during the averaged (75 sec) travel time. What is the volume of water in gallons applied per acre and per 1,000 sq ft?

Your output per acre using the "ounce method" is 53 gallons per acre. To convert this into gallons per 1,000 sq ft, divide the answer by 43.56.

$$\frac{\text{53 gal per acre}}{43.56} = \text{1.21 gal per 1,000 sq ft}$$

The answers are 53 gallons per acre and 1.21 gallons per 1,000 square feet output.

Pesticide Calculations

Once the output of the sprayer has been determined, the actual amount of material required for the spray operation can be easily calculated. The steps listed below will determine the amount of water and pesticide needed to complete the job, and the amount of water and pesticide to add to each tank load. To complete these steps you need to know the recommended rate of the pesticide, the total area to be treated, and the capacity of the spray tank. Each step contains a procedure for areas measured in acres and areas measured per 1,000 square feet. Be careful to consistently use acres *or* 1,000 square feet throughout your calculations.

1. To determine the **total amount of water** and pesticide needed for the job:

   If area is measured in **acres**—

   A. Multiply the sprayer output (gallons per acre) by the total acreage of the treatment area. This is equal to the total amount of solution (water plus pesticide) required.

   B. Multiply the recommended rate per acre of the pesticide by the total acreage. This is the total amount of pesticide required.

   If area is measured per **1,000 square feet**—

   A. Multiply the sprayer output (gallons per 1,000 square feet) by the units of 1,000 square feet of the treatment area. For example, an area of 1,600 square feet has 1.6 units of 1,000 square feet. This is equal to the total amount of solution (water plus pesticide) required.

   B. Multiply the recommended rate per 1,000 square feet of the pesticide by the units of 1,000 square feet of the target area. This is the total amount of pesticide required.

2. To determine the **amount of pesticide** for each tank load:

   If area measured in **acres**—

   A. Divide the spray tank capacity (in gallons) by the gallon per acre output to determine the acreage covered by one tank load.

   B. Multiply the acreage covered by one tank load by the recommended rate per acre to determine the amount of pesticide needed in each full tank load.

   If area measured per **1,000 square feet**—

   A. Divide the spray tank capacity (in gallons) by the gallons per 1,000 square feet output to determine the units of 1,000 square feet covered by one tank load.

   B. Multiply the units of 1,000 square feet covered by one tank load by the recommended rate per 1,000 square feet to determine the amount of pesticide needed for each full tank load.

Example 12: You need to spray 10 acres of turf. Your boom sprayer has a 100 gallon tank and is calibrated to provide an output of 75 gallons per acre. The recommended rate for the liquid pesticide is 2 quarts per acre. How much spray mix will be needed for a 10 acre target area, and how much pesticide is added to each tankful?

total spray mix for the job	is	75 gal per acre	×	10 acres	=	750 gal
area covered by one tankful (acres)	is	100 gal / 75 gal per acre	=	1.33 acres		
pesticide added per tankful	is	1.33 acres per tankful	×	2 qts per acre	=	2.66 quarts per tankful

Example 13: Your backpack sprayer has a capacity of 3 gallons and is calibrated to deliver an output of 1.5 gallons per 1,000 square feet. You need to spray a turf area that is 4,000 square feet. The label of the pesticide you wish to apply specifies that 6 fluid ounces of the pesticide be applied per 1,000 sq ft. How much total spray mix will you need and how much pesticide must be added to a full tank load?

total spray mix for the job	is	1.5 gal per 1,000 sq ft	×	4.0 sq ft 1,000 sq ft units	=	6.0 gal
area covered by one tankful (1,000 sq ft)	is	3 gal / 1.5 gal per 1,000 sq ft	=	2.0 1,000 sq ft units		
pesticide added per tankful	is	2.0 1,000 sq ft units per tank	×	6 fl oz	=	12.00 fl oz

Review Questions—Chapter 5

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

1. A golf green is nearly round in shape. The distance from the cup in the center of the green to the edge is 50 feet. What is the area of the green in square feet? In acres?

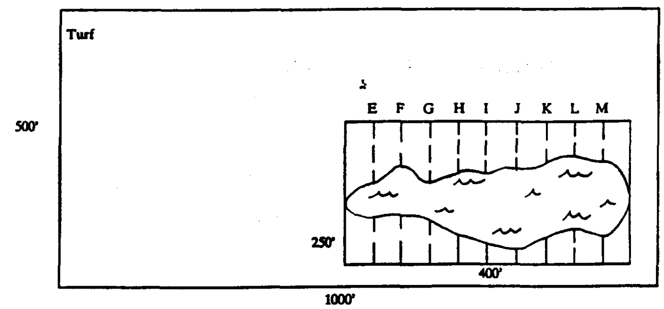
2. A homeowner's lot is 200 feet by 125 feet. The house is 36′ × 50′. If all of the other ground is turf, what is the area of the lawn?

3. If a pesticide label recommends to apply 8 ounces of product per 1,000 sq ft, how many ounces of pesticide are needed to treat the lawn in Question #2?

4. Using the offset method, figure the area (in acres) of a stand where the distance between offsets is 60 feet. The total length of all the offsets is 1,200 ft.

5. You wish to apply herbicide to the rectangular stand in the diagram. Calculate the area (in square feet) to be treated. The lineset totals are (not including the pond):

E=160	J=70
F=150	K=70
G=140	L=90
H=120	M=30
I=90	



6. You need to find the total square feet of a roughly round turf stand. You marked the center of the stand and took 36 measurements to the edge at 10° intervals. If the total of the 36 measurements is 2,174 feet, what is the area of the stand in square feet?

7. You wish to broadcast a granular herbicide at the label rate of 8 pounds per 1,000 sq ft. You apply 2.5 lb of the herbicide to a 50 ft test course. The spreader creates a 7 foot swath. Answer the following:
   a. What is the area of the test course?
   b. What is your application rate per 1,000 sq ft?
   c. Is this rate acceptable (within ± 5% of the label rate?)

8. A granular soil insecticide recommendation calls for a broadcast application at a rate of 5 lbs product per 1,000 sq ft. Your spreader has a 10 foot swath. The test course length is 50 ft.
   a. You catch 3.5 pounds of product during the test application. How does this compare to the label rate?
   b. You adjust the orifice and catch 2.6 pounds on the test run. Are you ready for the application?

9. You have chosen the pressure, nozzle, and speed and are now calibrating a sprayer with a showerhead nozzle. Your swath width is 8 feet and you run tests on a 100 foot-long test course. It takes you an average of 30 seconds to walk the test course. You measure the output of water in 30 seconds as 1.3 gallons. What is your output per 1,000 sq ft and per acre?

10. An insecticide label recommends applying 30 fluid ounces of product per 1,000 sq ft. Your 50-gallon sprayer delivers .8 gallon of water during the time it takes to travel a 50 feet long test course. Your swath width is 8 feet.
    a. What is your output per 1,000 sq ft?
    b. How much insecticide is needed to cover a 2,800 square foot target area?

11. The herbicide label recommends a broadcast application of 3 pounds of formulated product per acre. Your boom sprayer has a 100 gallon tank, and the nozzles are 26″ apart. It takes you an average of 60 seconds to travel the 170 foot test course. The nozzles deliver an average of 54 ounces in 60 seconds.
    a. What is your output per acre with this sprayer?
    b. How many acres can you spray with each tank of spray mixture?
    c. How much herbicide is needed for each tankful of water?

12. During calibration of a boom sprayer, you find that the flow rates for the six nozzles are:

Nozzle	flow rate (ounce per minute)
#1	30.0
#2	30.5
#3	29.0
#4	32.0
#5	28.0
#6	30.5

Is the difference between the the delivery rates of the nozzles acceptable?

Conversions of Weights and Measures

Weights

1 ounce	=	28.35 grams
16 ounces	=	1 pound
	=	453.59 grams
1 gallon water	=	8.34 pounds
	=	3.785 liters
	=	3.78 kilograms

Length

1 foot	=	30.48 centimeters
3 feet	=	1 yard
	=	0.9144 meter
16.5 feet	=	1 rod
	=	5.029 meters
5,280 feet	=	320 rods
	=	1 mile
	=	1.6 kilometers

Speed

1.466 feet per second	=	88 feet per minute
	=	1 mph
	=	1.6 kilometers per hour (kph)

Liquid Measures

1 fluid ounce	=	2 tablespoons
16 fluid ounces	=	1 pint
	=	0.473 liter
2 pints	=	1 quart
	=	0.946 liter
8 pints	=	4 quarts
	=	1 gallon
	=	3.785 liters

Area

1 square foot	=	929.03 square centimeters
9 square feet	=	1 square yard
	=	0.836 square meter
43,560 square feet	=	1 acre
	=	0.405 hectare

Volume

27 cubic feet	=	1 cubic yard
	=	0.765 cubic meter
1 cubic foot	=	7.5 gallons
	=	28.317 cubic decimeters

CHAPTER 6

PESTICIDE SAFETY

Pesticide applicators are legally and socially responsible to safely handle and apply pesticides. Federal and state regulations that assure safe pesticide use are discussed in the Pesticide Laws and Regulations chapter of the Core manual (E-2195). 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 shortcuts. Compare the checklist at the end of this chapter with your pesticide handling practices to see which of the common causes of accidents you could avoid. Read this chapter and understand the safety guidelines for pesticide use, storage, and disposal. The Michigan Department of Agriculture's Regulation 637 specifies many legal requirements concerning the safety guidelines presented here. These requirements must be followed by commercial applicators. The last section of this chapter explains how safe practices can enhance your public relations.

Applicator Safety

Pesticide manufacturers spend much money researching potential hazards associated with the use of each product. *You must comply with the label guidelines for protective gear.* The Pesticide and Human Health chapter of the Core manual outlines the types and use of applicator gear. Applicator gear is only effective if it fits well and is clean. Protective gear may be expensive, but is important for your safety. Take good care of it. 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 available and clean all necessary gear before you mix or apply pesticides.

Pesticide-saturated filters and cartridges harm rather than protect applicators.

You may choose to wear more protective gear than the label requires. This is an especially good idea for people who have a naturally-low cholinesterase level (see next section), and those who use pesticides regularly. The following chart summarizes protective gear recommendations provided by the Professional Lawn Care Association of America (PLCAA.) Note that the PLCAA recommendations may be more strict than those on product labels.

Applicator Cholinesterase Level

Cholinesterase is an essential chemical in the nervous system of many animals including humans and insects. Some insecticides, especially carbamates (carbaryl, oxamyl) and organophos-

PLCAA Protective Gear Recommendations

Filling and Mixing

Dry fertilizer only:	disposable dust mask or respirator with dust filter
Pesticides:	goggles or face shield; head gear; coveralls or apron; boots; gloves; full respirator when using powdered insecticides; dust mask or respirator with dust filter when using Dacthal or Benomyl
Filling hand cans:	wear gloves for all materials
Application	
Fertilizer only:	boots; gloves
Insecticides or liquid slow-release nitrogen:	boots; gloves; goggles (when high-pressure spraying)
Handling Spills:	wear all protective clothing and equipment recommended for the material spilled

phates (diazinon, dursban, malathion, acephate), work by fatally inhibiting cholinesterase levels in insects. These insecticides also inhibit the cholinesterase level of applicators. If enough exposure occurs, an applicator's cholinesterase can fall below a healthy level and the applicator suffers from insecticide poisoning. Factors other than exposure to certain pesticides may alter cholinesterase activity. These include smoking, drugs, alcohol, liver disease, and genetic inheritance. If you participate in cholinesterase-inhibiting activities or are frequently exposed to carbamates or organophosphates, you should establish a regular cholinesterase testing program with your doctor.

As well as being a part of the nervous system, cholinesterase is present in the liver, plasma, and red blood cells. The cholinesterase level in plasma or red blood cells can be measured by blood analysis. Regular testing of blood is a means of monitoring employees for exposure to cholinesterase-inhibiting insecticides. Everyone has a different "normal" level of cholinesterase in their nervous system, so a baseline level must first be established. This should be done off-season, before any exposure to pesticides. The baseline level can then be compared to cholinesterase levels taken during the spray season. Applicators whose cholinesterase level has significantly dropped should avoid further exposure to cholinesterase-inhibiting insecticides until normal levels return. The Professional Lawn Care Association of America has developed guidelines for cholinesterase exposure and testing. The chart accompanying this section gives a summary of these recommendations.

PLCAA Cholinesterase Testing Recommendations

- A pre-exposure cholinesterase level should be taken for anyone exposed to cholinesterase-inhibiting pesticides during tank filling and/or application operations. Baseline values are determined each year.
- Anyone whose pre-exposure value is below the concern status (0.5 pH/hour) should not be involved with pesticides for longer than eight weeks.
- When cholinesterase-inhibiting pesticides are in use, blood should be taken and the plasma analyzed every three weeks. For applicators not handling cholinesterase-inhibiting pesticides regularly, testing should be conducted as follows:
  - after any three consecutive days of cholinesterase-inhibiting pesticide use.
  - at the end of three weeks when such pesticides where applied for two consecutive days each week.
- If plasma analysis shows a drop in cholinesterase to the concern status (0.5 pH/hour), red blood cell cholinesterase should be monitored.
- If red blood cell cholinesterase is less than 70% of baseline levels, the applicator must not be exposed to cholinesterase-inhibiting pesticides. The applicator's cholinesterase can be retested as soon as five days after removal from exposure. The applicator may resume handling these pesticides when red blood cell cholinesterase has returned to 75% of the baseline value.

Pesticide Poisoning and Symptoms

Most pesticide poisonings result from accidents, or careless and ignorant use. Yet, even cautious applicators who follow the label, maintain equipment, and apply pesticides with safety in mind are at risk of pesticide overexposure. Should an accident occur, the best defense against serious harm to yourself and others is to *be prepared*. Always know the brand and chemical name, formulation, and rate of the pesticide you are transporting and applying. Have available and know how to use clean-up and first-aid materials. Use the following checklist as a guide to pesticide first-aid and safety materials for the truck and work station. To be prepared means you must be 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 (cat litter)
- ☐ fire extinguisher
- ☐ Human Pesticide Poisoning or Poison Control Center 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, what part of the body is exposed, the amount absorbed, and the general health of the individual. The Pesticides and Human Health chapter of the Core manual explains the most common symptoms. These 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 by anyone who may have been overexposed to pesticides.

Be prepared for accidents.

Because of their widespread use and high acute toxicity, organophosphates are responsible for more pesticide poisonings than any other class of

Symptoms of Pesticide Poisoning

Fungicides — general

- headache
- skin irritation
- sweating
- muscle twitching or fatigue
- nausea, diarrhea
- coughing, hoarseness, chest pains
- burning sinuses,throat or lungs

Phenoxy Herbicides
(MCPP and 2,4-D acid, salts, esters and amine)

- skin irritation
- eye irritation
- irritation of mouth and throat
- abdominal pain and vomiting
- diarrhea
- chest pain
- muscle twitching and weakness

Arsenical Herbicides
(cacodylic acid, DSMA, MSMA)

- mild skin irritation
- ingestion may result in burning of the throat, stomach irritation, vomiting and bloody diarrhea

Insecticides — general

- headache
- visual disturbances (blurred vision)
- abnormal eye pupils (dilated or pinpoint)
- greatly increased sweating, salivation, tearing, or respiratory secretions

Insecticides — cholinesterase inhibiting
(Dursban, Diazinon, Dylox, Orthene, Sevin, Oftanol)

Mild Poisoning

- fatigue
- headache
- dizziness
- blurred vision
- excessive sweating and salivation
- nausea and vomiting
- stomach cramps or
- diarrhea

Moderate Poisoning

- unable to walk
- weakness
- chest discomfort
- pinpoint pupils
- earlier symptoms become more severe

Severe Poisoning

- unconsciousness
- severe pinpoint pupils
- muscle twitching
- secretions from mouth and nose
- breathing difficulty
- coma
- death

pesticides. Small doses of organophosphates "add up" in the nervous system during the spray season and may result in poisoning without obvious symptoms.

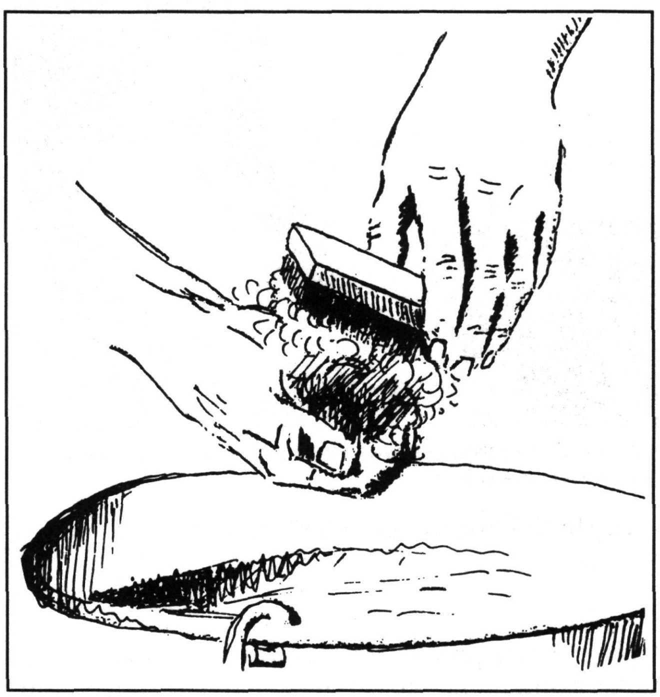
An applicator who is ill after handling pesticides is not necessarily poisoned. If you suffer from any of the mentioned symptoms and believe the cause may be from pesticide exposure, see your doctor. *Let your doctor decide whether pesticide poisoning has occurred.*

First Aid Procedures

First aid treatment varies according to the type of exposure. Be familiar with appropriate first aid measures before beginning applications. There will be little time or opportunity to look up first aid should you need it. 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, immediately 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 *all* 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.*
- If there is either pain or reddening of the eye after rinsing, get medical attention.

Oral Exposure

- If a pesticide has gotten into your mouth, but you have not swallowed it, rinse your mouth with large amounts of water.
- If you have swallowed some pesticide, decide quickly whether to induce vomiting by checking the label:

  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 emulsifiable concentrates 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. Do not use salt water to induce vomiting.

The victim should be lying face down or kneeling forward while vomiting to prevent vomitus from entering the lungs. Collect some vomitus so that the doctor can run chemical tests. *Do not waste 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.

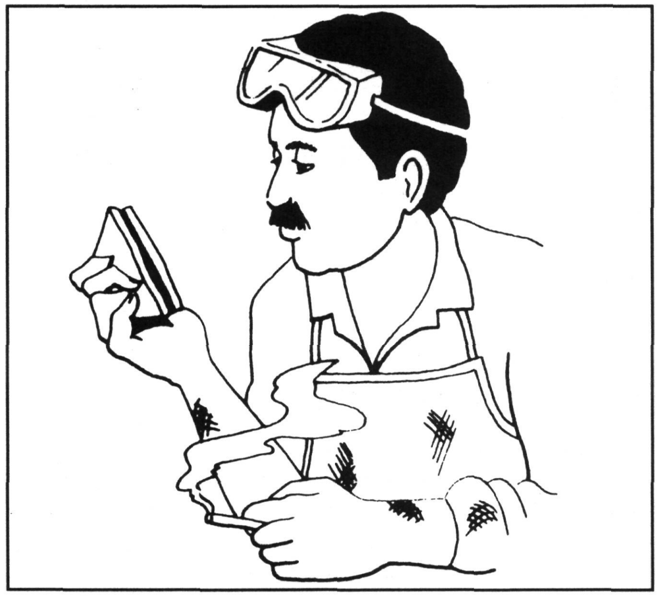
Safe Pesticide Handling

Preventing mishaps when applying pesticides is the most effective way to protect yourself, non-target organisms, and the environment. Applicators rely heavily upon application equipment to accurately and safely apply pesticides. Properly maintain all application equipment to keep it operating safely. Many common pesticide accidents, such as blown hoses and leaking tanks and nozzles, can be avoided by routine equipment inspection and maintenance, as discussed in the equipment section of Chapter 4.

Mixing and Loading Pesticides Safely

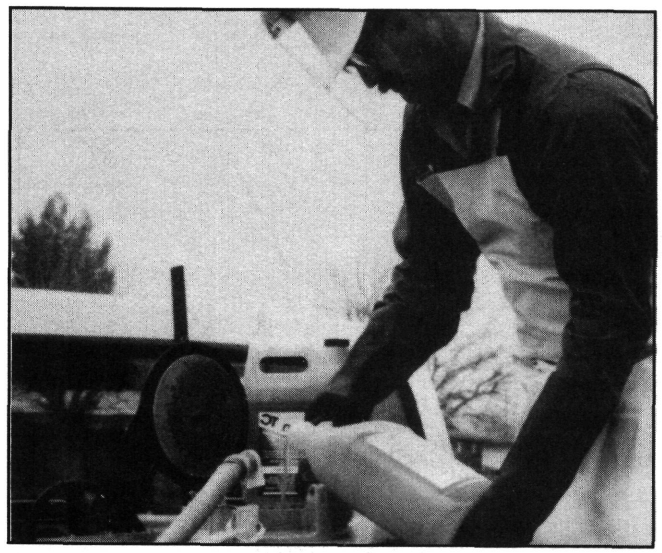
Mixing and loading concentrates are some of the most hazardous activities involving pesticides. Carefully read and follow the mixing/loading operations guidelines set for commercial applicators in Regulation 637. Some of the requirements and general safety guidelines include:

- Put on protective clothing and gear (gloves, respirator, goggles, coveralls, etc.) before handling pesticides.
- Before opening the container, review the pesticide label to be familiar with mixing and usage directions.
- *Do not mix above the recommended rate.*
- Never eat, smoke, or chew gum when handling pesticide concentrates.
- Mix in an area that has plenty of light and ventilation and is sheltered from the wind.
- The mixing pad must be of a material that will not absorb spills, such as concrete, plastic, or stainless steel.
- The mixing pad must be designed to contain pesticide spills.
- To prevent contamination and back-siphoning when filling the spray tank, do not allow the water pipe or hose to contact 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.
- When filling a spray tank, do not leave it unattended.



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

- 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 or on the daily route.
- Rinse all measuring devices and put rinse water into the spray tank. Mark and store these utensils in the pesticide storage area.
- Triple rinse or power rinse pesticide containers as you empty them.



Note that this applicator is wearing the required protective gear including a face shield.

Triple rinsing and **power rinsing** makes 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. Residues in plastic and metal containers are more rapidly removed by power rinsing. Power rinsers are attached to a garden hose and have a puncturing device surrounded by nozzles. To catch dripping pesticide and rinsate, hold the empty container over a spray tank then insert a rinser into the bottom or side of the container. Squeeze the rinser trigger to release jet streams of water into the container. Rinsate will flow out of the opened top of the container and into the spray tank. Power rinsing involves splashing rinsate; wear protective gear.

Studies have shown that at least 14.2 grams of active ingredient remain in an empty, but unrinsed five-gallon container of a liquid pesticide formulation (see Triple Rinse graph.) 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 from large quantities of unrinsed containers. Be sure to triple or power rinse empty pesticide containers before disposal.

Applying Pesticides Safely

What happens to pesticides after application? Ideally, all of the pesticide applied is in place to control pests, and completely breaks down after pests are controlled. Unfortunately, even when carefully applied, some pesticide will have undesirable effects. The Pesticides and the Environment chapter of the Core manual describes adsorption, volatilization, runoff and the other paths applied pesticides take in the environment. It is your responsibility to limit the damage and contamination associated with inappropriate pesticide fates. Consider the following undersirable effects of pesticide use:

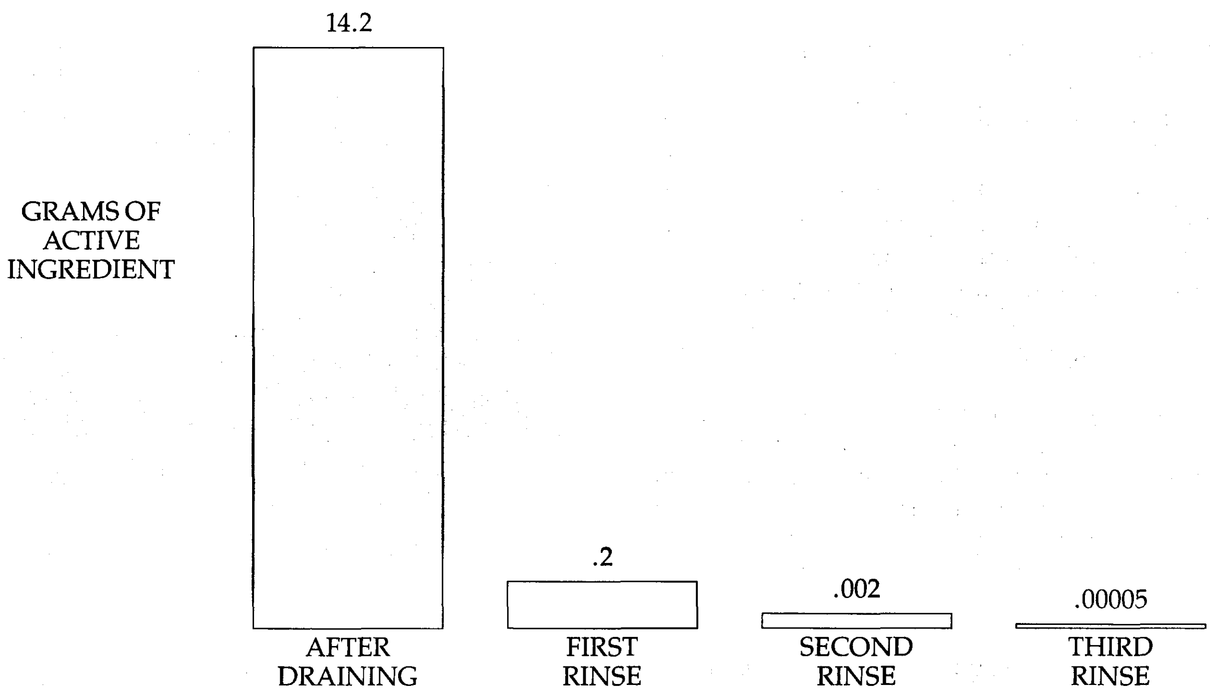
- destruction of pest predators and parasites
- suppression of decomposers resulting in thatch build-up
- effect on wildlife
- exposure to people and pets
- risk to applicator
- runoff to streams and ponds and possible groundwater contamination.

As discussed in Chapters 2 and 3, pesticides harm decomposers and other beneficial organisms in turf. This reduces natural pest control and turf vigor, and therefore the level of pest control provided by the pesticide application. The impact of pesticides on wildlife is also a concern for applicators. Almost every insecticide used on turf is toxic to fish and waterfowl. Pesticides must not drift or runoff into water. Many turf pesticides can injure songbirds. Some immediately kill birds coming into direct contact with spray residues. Other pesticides cause in birds chronic injury such as illness and nesting failure.

Wildlife are indirectly exposed to pesticides as they feed on contaminated organisms. DDT, Lin-

Triple Rinse and Pesticide Removal

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



dane, and other pesticides accumulate in plankton, aquatic insects, and fish. Animals, including valued fish and birds receive a dose every time they consume contaminated prey. Even today, trout in the Great Lakes have one billion times more DDT in their bodies than can be found in the surrounding water. Applicators who cause wildlife kills will be subject to negative public reaction if not legal action.

Since most turf stands are in areas frequented by people, it is especially important for Category 3A (turf) applicators to be safety conscious. People depend upon you to protect them and their children and pets from pesticide spray and residues. Before applying pesticides, carefully inspect the area surrounding the targeted turf. Have clients close house windows and move cars that are near the application area. *Check over fences* as a part of your inspection, and 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.

Take care not to apply materials to ornamental trees and shrubs. Not only is this a misapplication, but also may cause injury to ornamental plants. *Beware of fruit and vegetable plants near targeted turf.* If you inadvertently apply pesticide to a food plant, it is best to remove set fruit or vegetables.

In 1991, the Michigan Department of Agriculture (MDA) will establish posting and notification regulations (as part of Regulation 637) for commercial applicators. For information concerning your legal responsibilities, contact the MDA Pesticide and Plant Pest Management Division at 517-373-1087.

Clear children and pets from the target and adjacent areas. Do not apply pesticides in the presence of onlookers, clients, or other people who are not wearing the appropriate protective gear. Take all precautions to prevent it, but be prepared to handle an accidental exposure of a non-employee. *Remain calm.* Except in severe poisonings, there is no need to rush to the emergency ward. Instruct the exposed person through first aid procedures. Provide the person with the product name, rate, label, and MSDS sheet, and advise them of poisoning symptoms for that product. The victim may wish to consult their physician or have a medical examination. This is a wise practice that you should encourage.

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 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. Any harm that could come to curious children would be your responsibility. Never leave operating application equipment unattended. Do not take even short breaks away from the site without first securing all equipment.

People rely on you to apply pesticides safely.

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.** If the reentry period is not stated, it is generally safe for people and pets to enter an area after pesticide sprays have dried and dusts have settled.

Storage and Disposal

Storing hazardous materials increases your liability. Stored pesticides can degrade or become banned for use, and packaging and labels deteriorate. Try to limit the amount of materials you store 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 may produce extremely toxic smoke. By federal law you must file reports when storing certain chemicals. To determine whether 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 many 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

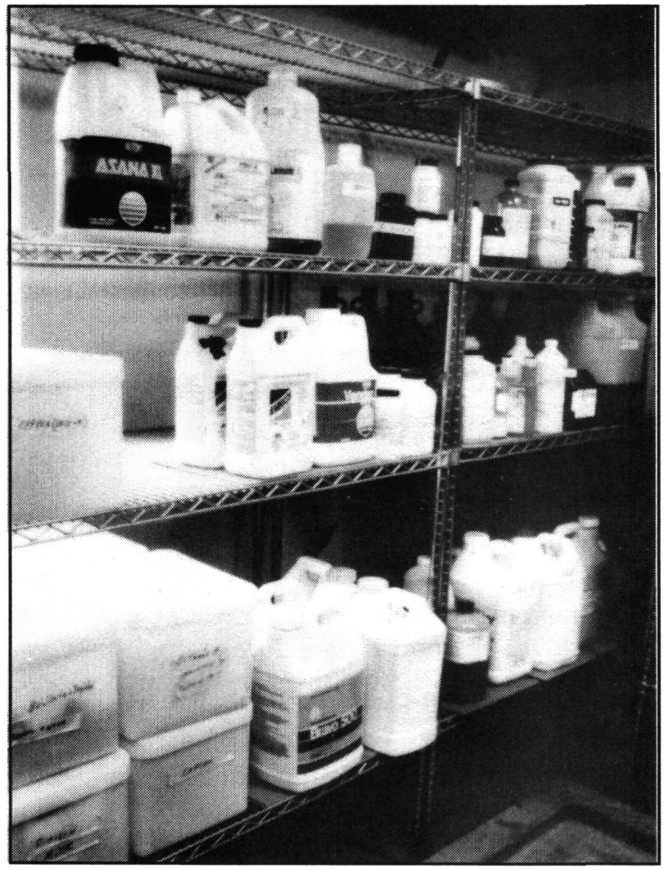
- If possible, have a separate building used only to store pesticides. Do not locate this building within 2000 feet from a community well, or within 800 feet of a non-community well as defined in Michigan Safe Drinking Water Act. Local restrictions also may apply.
- Secure the area with fences and locks. Bar any windows.
- Provide good ventilation.
- Post the area with highly-visible signs indicating 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.

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 cat litter.
- Keep a supply of soap and clean 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.
- Keep containers out of direct sunlight.
- 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 may attract curious 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, or on "as needed" basis.
- Mix only what you need for the application o route.
- Apply any leftover pesticide solutions according to the product label.
- Use all opened containers of pesticides before the end of the season.

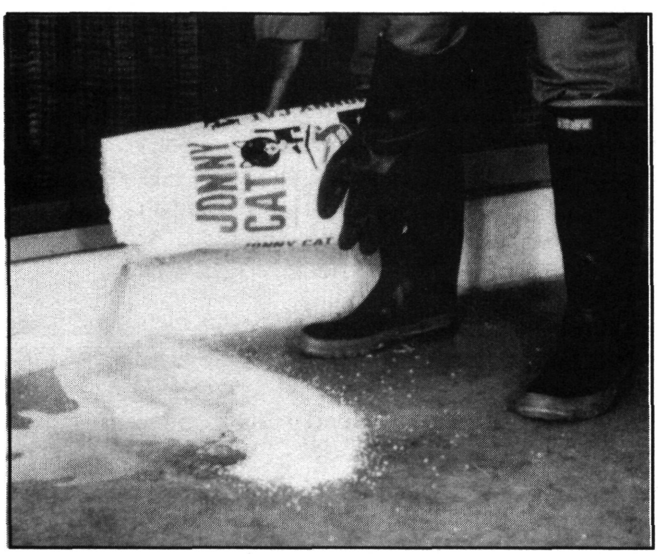
If there are leftover, unopened pesticides, return products to the dealer or manufacturer, or offer it to another qualified applicator. If these disposal options are not possible, consult with the MDNR

Waste Management Division at 517-373-2730. Before disposing of pesticide wastes, commercial applicators must 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 any amount of concentrate that may escape 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 breaks, 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. Use nozzles with built-in check valves or install check valves on the boom to prevent pesticide from dripping when the boom pressure is off. Since spray guns frequently develop leaks during use, have available 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.



Have absorbent material available wherever pesticides are stored, mixed and applied.

Contain the Spill. Pesticide spills must be contained to avoid contaminating groundwater, soils, sewers, and surface water. If the pesticide is flowing, 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. If these materials are not on hand, use dry fertilizer or soil. Handle the saturated absorbent material as you would the pesticide itself.

Clean Up the Spill. Do not attempt to clean pesticides off porous materials such as brooms, or leather shoes and gloves. Dispose of these contaminated items. 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 limit turf 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 dispose properly of contaminated broom, absorbent material, and soil.

Report the Spill. Large spills that 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. If a reportable spill happens, you also must 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 of exposure to these materials. Those who use pesticides must recognize that their neighbors, clients, patrons, and other community members feel they have a legitimate concern about pesticide applications. Citizens pressure community leaders and legislators to regulate pesticide use in urban areas. There will no doubt be increased regulations and restrictions imposed upon pesticide applicators, and greater liability when regulations are disobeyed. The wise applicator is aware that more people are suing to recover damages. Applicators are expected to conduct themselves professionally and with safety consciousness at all times.

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

Regulation 637 of the Michigan Pesticide Control Act

The Michigan Department of Agriculture worked with many groups to create Regulation 637 as a response to public concern over commercial pesticide applications. Following the pesticide handling practices outlined by MDA is not only your legal obligation, but also guarantees your good reputation with the public. The guidelines in Regulation 637 were developed in 1990-91 and concern the work of commercial applicators including:

- Applicator service agreements (contracts.)
- Integrated pest management.
- Protective gear.
- Registry of persons requiring notification before pesticides are applied.
- Pesticide drift management.
- Standards for pesticide use.
- Mixing and loading practices.
- Washing and rinsing equipment.
- Posting requirements.

It is vital that you have a current copy of Regulation 637 and understand what you must do to comply with Michigan law.

The Professional Applicator

Uneducated or inexperienced applicators commonly over-apply pesticide with the misconception that "more is better." Too few applicators regularly inspect the turf to determine if pest levels are at the action threshold, or evaluate the effectiveness of applied tactics. Careless errors, such as using herbicide application equipment for an insecticide application and applying pesticide at the wrong address, have occurred. Most pesticide application problems are within the control of the applicator; prevent problems 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 daily.

Look professional. People judge professional ability and honesty by 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 putting company logo patches on color-coordinated coveralls, jackets, and hats.

Communication. Turf applicators must be able to communicate with the public. Clients often want to know what is wrong with their lawn and what is to be done about it. Client neighbors and visitors of public landscapes also may be curious or concerned. View questions as an opportunity to improve public understanding of pest management. Glib responses such as "I know what I'm doing" or "Don't worry, it's not your property," anger people. The best way to deal with most public concerns is to answer their questions and respond to 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 make up an answer to "save face."

Educating the client is a part of good public relations.

Educate the client. Many applicators find that the greatest obstacle to implementing a turf IPM program is the demand from some clients to take immediate *chemical* action. Because most people are ignorant about turf management, they believe all turf problems can be solved through pesticide applications. Clients often equate gallons of pesticide sprayed with the degree of pest control and the value of your service. All too often, clients do not appreciate the importance of, and are not willing to participate in, proper watering, mowing and fertilizing practices. As a turf care provider, you must educate the client or public so that they will properly maintain the turf as a part of pest management. Also help the client to realize that your knowledge and monitoring skills are valuable services.

The client/public should understand that:

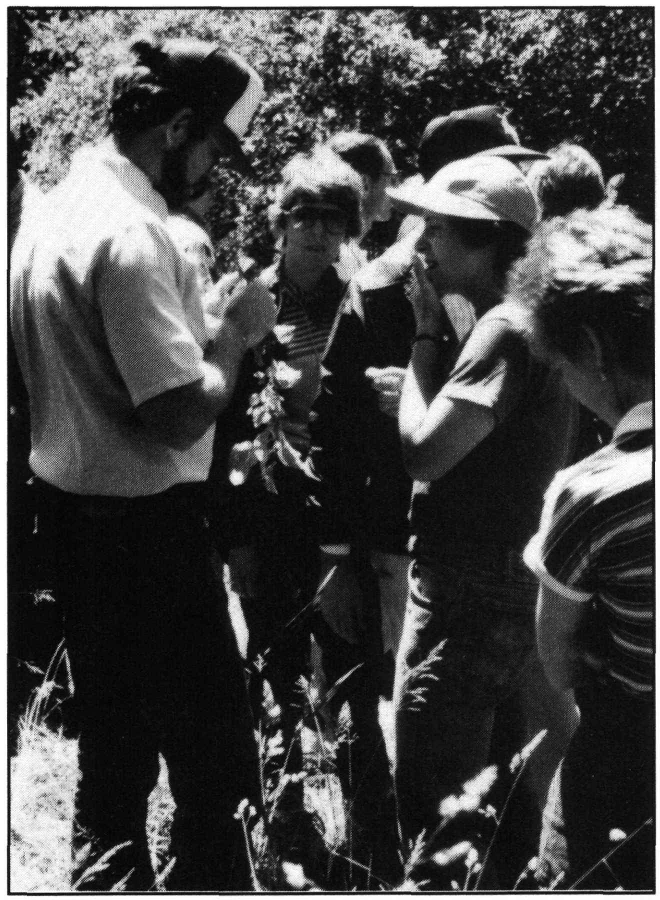
1. Not all insects, fungi, etc. are pests.
2. Turfgrass cannot be both pest-free and benefit from natural controls.
3. There are specific times to implement pest management tactics. Outside of these windows, management efforts are wasted.
4. The turf must be regularly inspected for damage and timing of management tactics.
5. Tactics should be implemented selectively. Often only limited areas of turf require treatment.
6. Pesticides are by no means the only and best method of pest management.

Be informed. Pest management does not end with the completion of the spray season. Professional turf applicators take advantage of every opportunity to learn more about non-pest turf 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 developments in turf management. You can earn pesticide applicator recertification credits by 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 can help you understand and keep current on the requirements of state regulatory agencies such as the MDA, Michigan Department of Natural Resources, and Michigan Department of Transportation. Make sure that you know the latest regulations for conducting your operations. *Ignorance of the law is no defense.* Some of the sources for information include:

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

Training employees. The more experience and training your employees have, the fewer problems on the job. Some problems associated with an inexperienced or poorly-trained employee may simply cost you money, but others may cost you your professional reputation. If you are a supervisor, it is important to educate employees about turf growing requirements, pests, and application equipment and 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 required for all new employees, and be part of a refresher course for experienced employees.



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

Remember, persons who are not certified and are applying pesticides under the supervision of a certified applicator on a commercial basis are required by Michigan law to be a **registered technician.** The MDA 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. Supervision by a certified applicator is required when uncertified applicators apply 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 represent your organization. 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 turf management. Educating the public about IPM practices such as monitoring, setting injury levels, and timing tactics with susceptible pest life stages can be diffiicult, but is extremely important to the success of management programs.

Promote sound turfgrass maintenance as an effective method of keeping the turf vigorous and better able to defend against and recover from pests. Irrigation, fertilizing, mowing and aeration are profitable services that are crucial to limit the stress experienced by turfgrass. Some applicator businesses could benefit by expanding to offer these services.

Experienced applicators who are educated about turf care practices, pests, and IPM will easily meet the requirements of a consultant.

Review Questions—Chapter 6

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

3. What is cholinesterase and why should applicators be concerned about their cholinesterase level?

4. Name the two chemical classes of insecticides that inhibit cholinesterase. Give the name of four specific products.

5. Pesticide poisoning symptoms usually are obvious immediately after exposure. *(True or False?)*

6. Name four symptoms of insecticide poisoning.

7. In case of an emergency, what should you know about the pesticide you are transporting or applying?

8. Describe first aid for dermal pesticide exposure. What should you do if someone's eyes are contaminated with pesticide?

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

10. List five clean-up and first aid items that should be available on application equipment and at the work station.

11. Why should applicators triple-rinse or power-rinse containers.

12. For what should applicators check over fences before applying pesticide to adjacent areas?

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

14. Why should you report stored pesticides to your local fire department?

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

16. What is the best way to dispose of mixed pesticides? What should be done with left-over, unopened pesticides?

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

18. Under Michigan law commercial applicators should, but are not required to, follow the guidelines of Regulation 637. *(True or False?)* Regulation 637 set guidelines for what type of operations?

19. Explain why educating clients about turf care and pest management is important to successful IPM.

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

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

22. Why is it so important for a commercial pesticide business to train employees and keep them up to date?

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 and deteriorating containers?
- ☐ Are the pesticides resting off of the floor on washable (metal) 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 that 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 cat litter or a manufactured pesticide absorbent to soak up spills?
- ☐ Do you always watch your sprayer tank when filling so that pesticide 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 dispose of leftover spray mix in a labeled manner rather than onto 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 Cause Bad Accidents

- ☐ Do you triple rinse or power rinse each container as you empty them?
- ☐ Do you pour the rinse water into the mixing tank?
- ☐ Do you recycle triple-rinsed or power 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.?

Attractive Nuisances Can Result in Lawsuits

- ☐ 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?

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 your management tactics. For example, a seedling is not yet established and is easily eliminated through cultural, mechanical, or chemical methods. A plant in the vegetative stage will take up a herbicide more quickly than a mature plant. "Lawn Weeds and Their Control" (#NCR026) is an Extension publication that includes a chart of the season when the susceptible growth stage of various weed species occurs.

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 prostrate knotweed, foxtail, and crabgrass, germinate from seed in the spring, mature, set seed and die by winter. Chickweed and sheperdspurse are **winter annuals** that germinate from seed in late summer, overwinter, then produce seed the following spring, and then die.

All **biennial weeds** are broadleaf plants with a two-year life cycle. Examples of biennial weeds are Queen Anne's lace, wild carrot, 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.

There are perennial weeds of both monocot and dicot species. **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 parts into the roots and propagules. When they suffer crown loss due to winter dieback or cutting, perennials use the energy reserved in the underground structures to produce new top growth. To successfully manage perennial weeds, you must destroy the underground plant parts.

	Winter Annuals	**Perennials**
	annual bluegrass	bindweed
	common chickweed	blackseed plantain
	deadnettle	broadleaf plantain
	henbit	Canada thistle
	sheperdspurse	curly dock
Cool Season Weeds	speedwell	dandelion
		garlic
		ground ivy
		mouseear chickweed
		quackgrass
		red sorrel
		smooth brome
		tall fescue
		violets
		white clover
	Summer Annuals	**Perennials**
	barnyardgrass	black medic
	common purslane	nimblewill
Warm Season Weeds	crabgrass	yarrow
	foxtails	yellow nutsedge
	goosegrass	
	prostrate knotweed	
	prostrate pigweed	
	prostrate purslane	

Finally, weeds are divided as either cool or warm season. **Cool season plants** grow best during the cool periods of spring and fall. They mature or go dormant during mid-summer. Winter annuals and some perennials are cool-season weeds (see Weed Season list.) Plants that remain dormant or do not germinate until May or June are called **warm season plants.** Summer annuals are warm season plants. Warm season perennial grasses such as nimblewill are considered weeds because they remain dormant and brown in the spring weeks after Kentucky bluegrass green-up.

Weed Identification

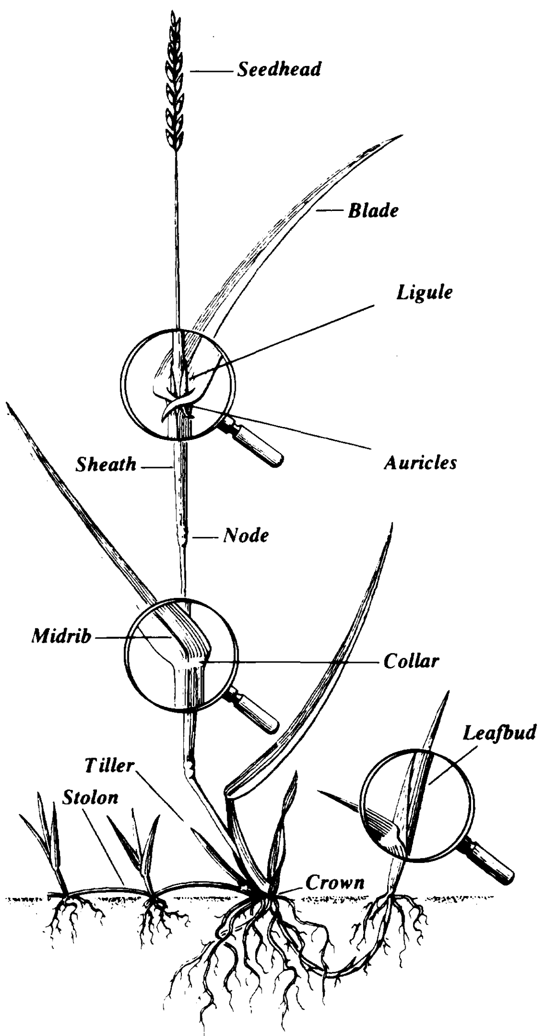
The Pest Identification chapter of the Core manual discusses several features that help distinguish between species of plants. A labeled diagram of the features of grass and broadleaf plants is provided here. Comparing an unknown weed to a picture is the easiest way to identify its species. Several Extension publications (#E0791 and #NCR281) offer large color photographs and descriptions of common Michigan weeds. Other weed identification sources are listed in the Resources section of this manual.

Some weeds, especially grasses and sedges, look alike. However, this does not necessarily indicate that they require the same control measures. Be sure to note the distinctive characteristics for each weed species including growth habit, leaf venation (structure of the veins), leaf shape, rooting structure, and flower type. Should you have difficulty identifying a weed, samples may be sent to the MSU Plant and Pest Diagnostic Clinic (see Resources.)

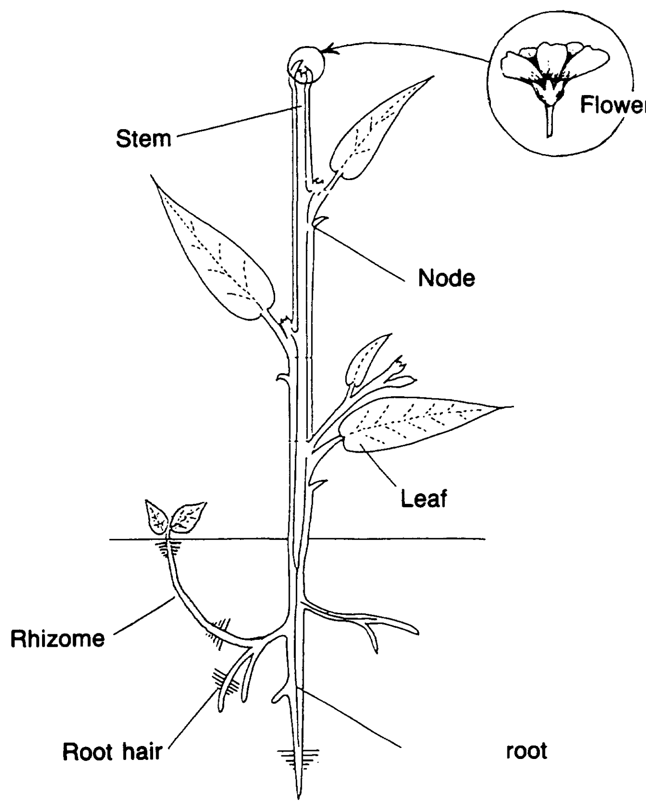
You must look closely at true grasses and sedges to see the differences between them. True grasses have rounded stems with open leaf sheaths. The blades are arranged in two rows and are several times longer than they are wide. The root system is a fibrous network of many small roots. The seedheads of most true grasses are similar to grain. Sedges are grass-like plants with triangular "stems" and closed leaf sheaths. The blades extend in three distinct directions.

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 avoid confusion, refer to the scientific name.

The following drawings and descriptions of the major Michigan turfgrass weeds are arranged by common name and include the scientific name, life cycle, and identification (ID) aids.



Features of a grassy plant.



Features of a broadleaf plant.

Annual bluegrass

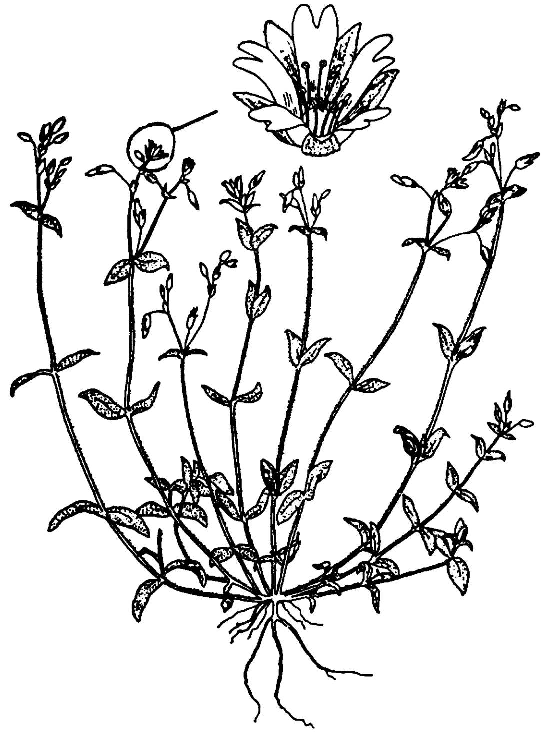
Also called:	Poa, annual speargrass, meadowgrass.
Scientific name:	*Poa annua.*
Life cycle:	Annual or perennial. Reproduces by seed.
ID aid:	Produces a great number of seed heads, regardless of height of cut. Seed heads may give areas an overall whitish appearance. Grows well in late winter, early spring, and fall. May die back quickly during hot weather.

Chickweed, Common

Also called:	Chickweed, starwort.
Scientific name:	*Stellaria media.*
Life cycle:	Winter annual. Reproduces by seeds and creeping stems.
ID aid:	Flowers sometimes appear star-shaped. Leaf stem may have a row of hairs. Trailing growth habit.

Chickweed, Mouseear

Also called:	Starweed, bindweed, winter-weed, satin flower.
Scientific name:	*Cerastium vulgatum.*
Life cycle:	A perennial that acts like a winter annual in Michigan. Reproduces by seed, and by rooting at the nodes.
ID aid:	Leaves are sticky and hairy. Mowing stimulates the vigorous low growth habit.



Crabgrass, Hairy

Also called:	Large crabgrass, purple crab-grass, fingergrass, fall grass.
Scientific name:	*Digitaria sanguinalis.*
Life cycle:	Annual. Reproduces by seed.
ID aid:	Plants generally grow low to the ground with many partially upright stems, giving plants a crab-like appearance. Seeds produced on 3 to 12 finger-like segments at tip of stems. Stems often grow flat along the ground and root at the nodes. Large crabgrass can be distinguished from small crab-grass by the prominent hairs covering the leaf surface. Leaves are twice as wide as the leaves of smooth crabgrass.

Crabgrass, Smooth

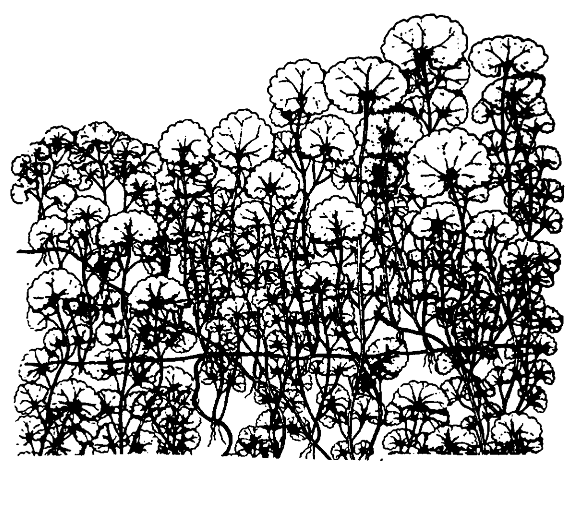
Also called:	Small crabgrass, fingergrass.
Scientific name:	*Digitaria ischaemum.*
Life cycle:	Annual. Reproduces by seed.
ID aid:	Plants generally grow low to the ground with many partially upright stems giving plants a crab-like appearance. Seeds produced on 3 to 12 conspicuous finger-like segments at the top of stems. Plants often grow flat along the ground and root at the nodes.

Dandelion

Also called:	Lion's tooth.
Scientific name:	*Taraxacum officinale.*
Life cycle:	Perennial. Reproduces by seed.
ID aid:	Dandelions flower from April to June. Seeds are produced shortly after the bloom appears. Seeds are yellowish-brown with parachute-like attachment at the upper end. The fleshy taproot contains milky juice.

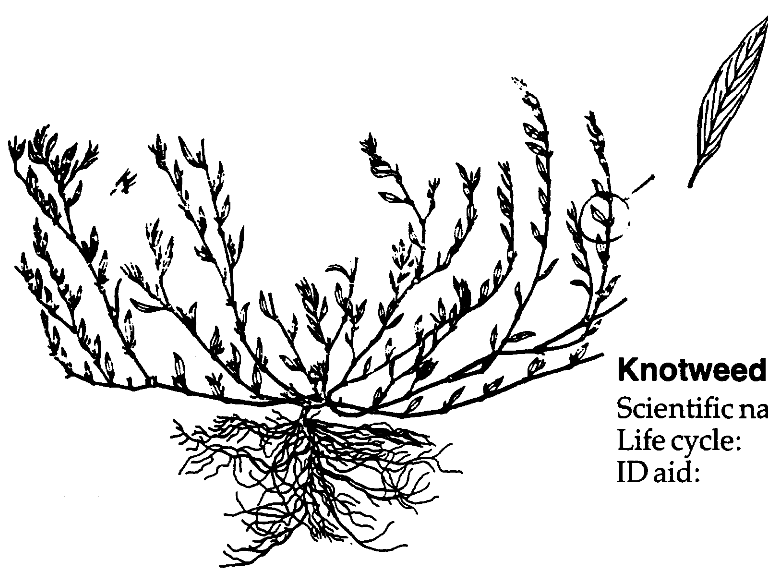
Ground Ivy

Also called:	Creeping charlie, gill-over-the-ground.
Scientific name:	*Nepeta hederacea* or *Glechoma hederacea.*
Life cycle:	Perennial. Reproduces by seeds and creeping stems rooting at the nodes.
ID aid:	Stems are four-sided. Most commonly found in fertile, damp, shaded soil. Forms an extremely dense mat and creeps extensively.



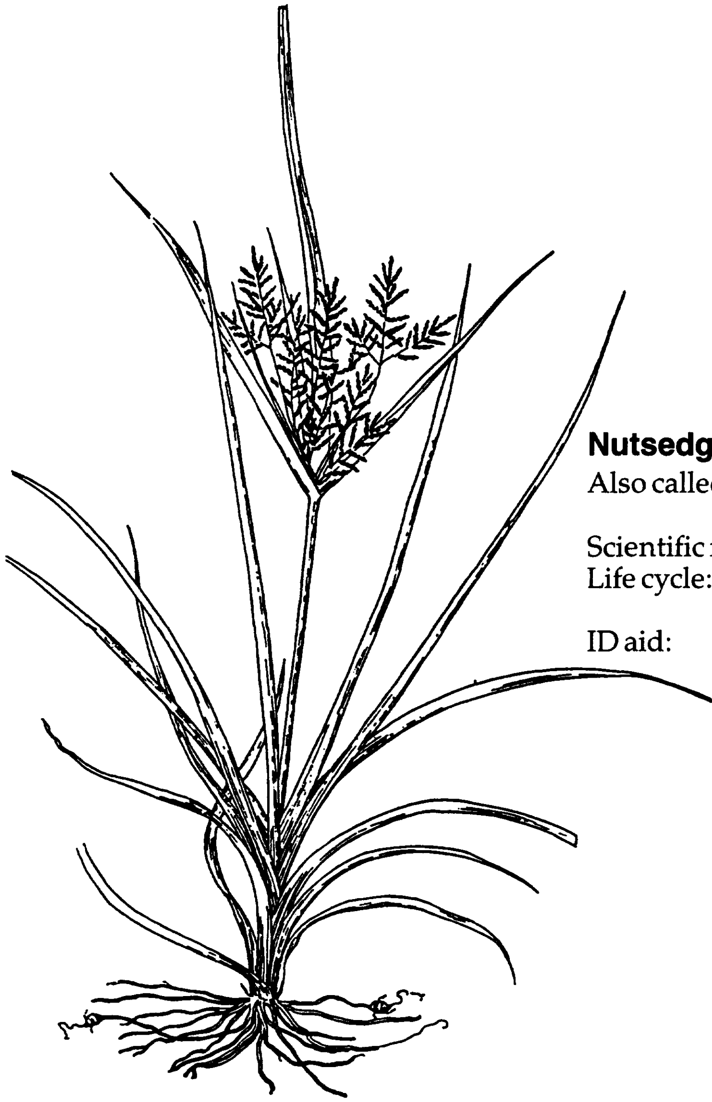
Henbit

Also called:	Dead nettle, blind nettle, bee nettle.
Scientific name:	*Lamium amplexicaule.*
Life cycle:	Winter annual. Reproduces by seed.
ID aid:	Round, hairy leaves have deep veins and coarsely toothed margins. The uppers leaves are attached to the stem; the lower leaves are on petioles. The stems are square and will root at the nodes.



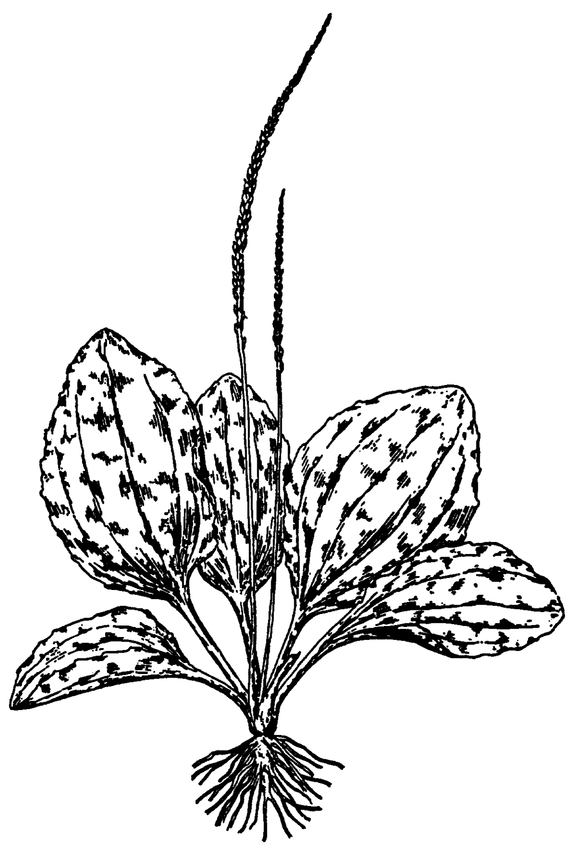
Knotweed

Scientific name:	*Polygonum aviculare.*
Life cycle:	Annual. Reproduces by seed.
ID aid:	Stems grow low to the ground to form an extremely thick mat. Develops a very thin but long taproot. Grows in all soils, but is commonly found in compacted soils. In late winter seedlings are often mistaken for desirable grass.



Nutsedge, Yellow

Also called:	Nutgrass, yellow nutgrass, northern nutgrass.
Scientific name:	*Cyperus esculentus*.
Life cycle:	Perennial. Reproduces by seed and tubers or nutlets.
ID aid:	Stems and leaves are yellow-green. Stems are upright and triangular. The fibrous roots have tubers or nutlets. Prefers wet soils. Very difficult to control.

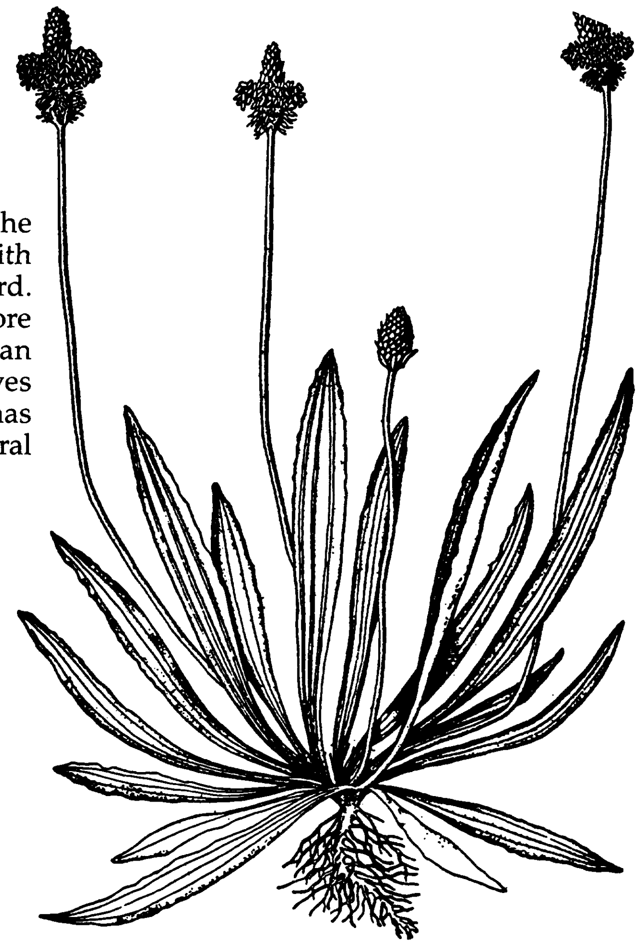


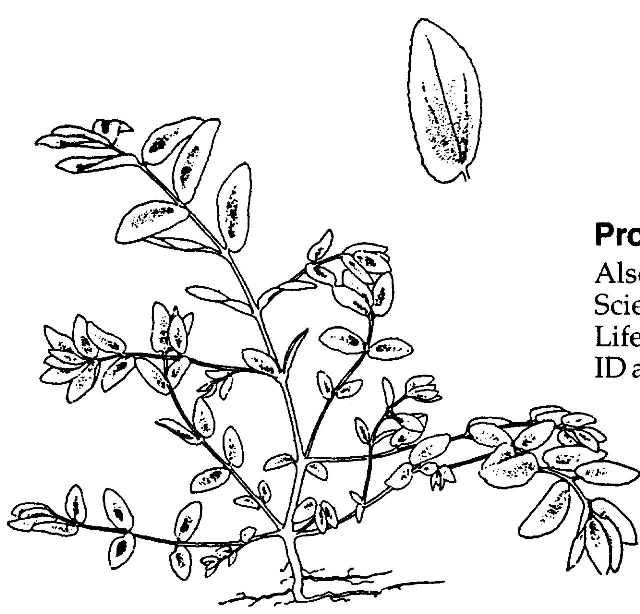
Plantain, Broadleaf

Scientific name:	*Plantago major.*
Life cycle:	Perennial, occasionally an annual. Reproduces by seed.
ID aid:	Under mowed conditions the leaves generally lie flat on the ground with flower stalks extending upward. Unmowed, the leaves grow more upright. Easily identified by the large, broad, leaves at the base of the plant.

Plantain, Narrowleaf

Also called: Buckhorn, ribgrass.
Scientific name: *Plantago lanceolata.*
Life cycle: Perennial. Reproduces by seed and root shoots.
ID aid: Under mowed conditions the leaves lie flat on the ground with flower stalks extending upward. Unmowed, the leaves grow more upright. Narrow leaves form an extremely dense rosette. Leaves often twist or curl. This plant has a taproot with strong lateral roots.



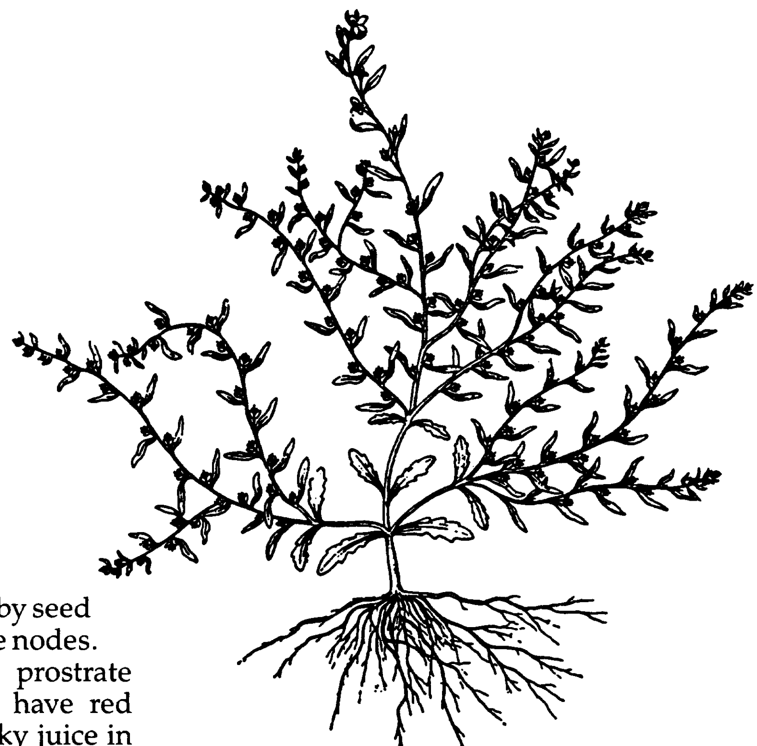


Prostrate Spurge

Also called: Spotted spurge.
Scientific name: *Euphorbia supina.*
Life cycle: Annual. Reproduces by seed.
ID aid: The stems grow flat along the ground to form a thick mat. The branching stems are hairy and may become one foot long. The majority of leaves have a purplish-red spot in the center of the leaf. All parts of the plant contain a milky juice.

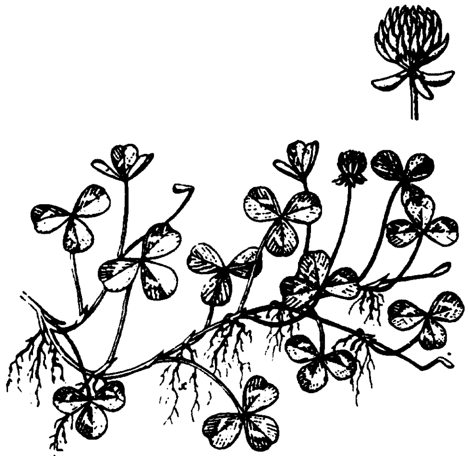
Quackgrass

Also called:	Couchgrass, witchgrass, devilsgrass.
Scientific name:	*Agropyron repens.*
Life cycle:	Perennial. Reproduces by seed and rhizomes.
ID aid:	Extensive creeping rhizomes are yellowish to white and root at the nodes. The rhizomes vary between 2 to 8 inches deep depending on soil conditions and may extend 2 to 6 feet in length. Stems are upright and branched at the crown.



Speedwell, Thymeleaf

Also called:	Creeping speedwell.
Scientific name:	*Veronica serpyllifolia.*
Life cycle:	Perennial. Reproduces by seed and stems rooting at the nodes.
ID aid:	May be mistaken for prostrate spurge, but does not have red spot on the leaf or milky juice in the stem. Heart-shaped seed capsules.



White clover

Also called: Dutch clover, white dutch clover.

Scientific name: *Trifolium repens.*

Life cycle: Perennial. Reproduces by seed and stolons.

ID aid: Distinguished by three leaflets joined together at the base without stalks.

Wood Sorrel

Also called: Oxalis, sour grass, yellow wood sorrel.

Scientific name: *Oxalis stricta.*

Life cycle: Normally perennial, but may be annual. Reproduces by seed.

ID aid: Stems are slender, branched, and root at the lower nodes. Stems covered with loose, curly hairs. Roots very shallow and fibrous. Ripe seed pods break open and "spit out" seed. Flowers can produce the seed from early spring to late fall. Leaves contain a sour juice.

Yarrow

Also called: Milfoil, thousand-leaf, bloodwort.

Scientific name: *Achillea millifolium.*

Life cycle: Perennial. Reproduces by seed and rhizomes.

ID aid: Fine, delicate fern-like leaves. Plant is very aggressive, and grows close to the soil. Can be mowed very short. Very durable and tolerant of compaction. When crushed, has a bitter taste and sharp odor.

Managing Turf Weeds

Injury from insects and diseases, misuse of fertilizer and pesticides, or excessive wear weakens turfgrass and allows weeds to become established. Prevention and immediate repairs of thinned turf are important weed control measures.

Coordinating weed control activities with the susceptible stages of problem weeds can be difficult, but is vital to successful weed management. Keep an inventory and regularly monitor the activity of weed problems in the turf you manage.

There are five strategies used to manage weeds of turfgrass. Keep in mind that most weed problems require the coordinated use of more than one strategy.

1. **Maintain vigorous turf stands.** A vigorous, dense turf stand is the most important step in weed management. If the recommendations outlined in Chapter 2 on grass species selection, installation and turf care practices are followed, then only rarely will weeds be a problem. Be sure to:
   - Mow at the highest cut of the preferred range.
   - Perform dethatching and coring when problem weed seed is not germinating.
   - Fertilize when turf is actively growing, to avoid stimulating weed germination.
   - During hot, dry periods, apply water to match evapotranspiration rates. Water diseased lawns lightly in the afternoon during dry periods.
2. **Prevent seed production.** Weed plants can produce a great number of seeds that are capable of sprouting for decades. One purslane plant can produce 2,000,000 seeds in one season. Management efforts should concentrate on eliminating weeds before the seed production stage. Whenever possible, get rid of sources of weed seed in areas adjacent to valuable turf stands. Beware of introducing weed seed-infested compost, mulches, top-soil, or grass seed.
3. **Prevent seed germination.** It is impossible to completely rid weed seeds from the landscape. Studies in Minnesota show that topsoil sampled to a depth of six inches contains as many as 2,000 seeds per cubic foot. There are several ways to prevent seed from developing into weeds. Most seeds require sunlight for germination. Turf mowed at a relatively high cut (2 inches or more) shades the soil and deters germination. Thick, rapidly growing turfgrass covers areas thinned by pest activity or wear. This prevents weed seed gemination and seedling establishment. Take care not to disturb soil deeper than two inches to avoid bringing dormant weed seeds into soil where conditions are right for germination. Germinating seeds can be suppressed through appropriate applications of a preemergence herbicide.
4. **Limit emerged weeds as seedlings.** 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. In addition, during the rapid growth stage, herbicide is more effectively absorbed and moved within the plant (see Herbicide Effectiveness table.)
5. **Limit susceptible stages of developed weed plants.** Managing developed weeds requires much effort. Most tactics are more effective if implemented when mature weeds have depleted food reserves and are physically weakened. Perennials are weakest during the bud-to-bloom stage. Repeated cutting of perennial and second-year biennials induces stress as the plant is forced to produce new top growth.

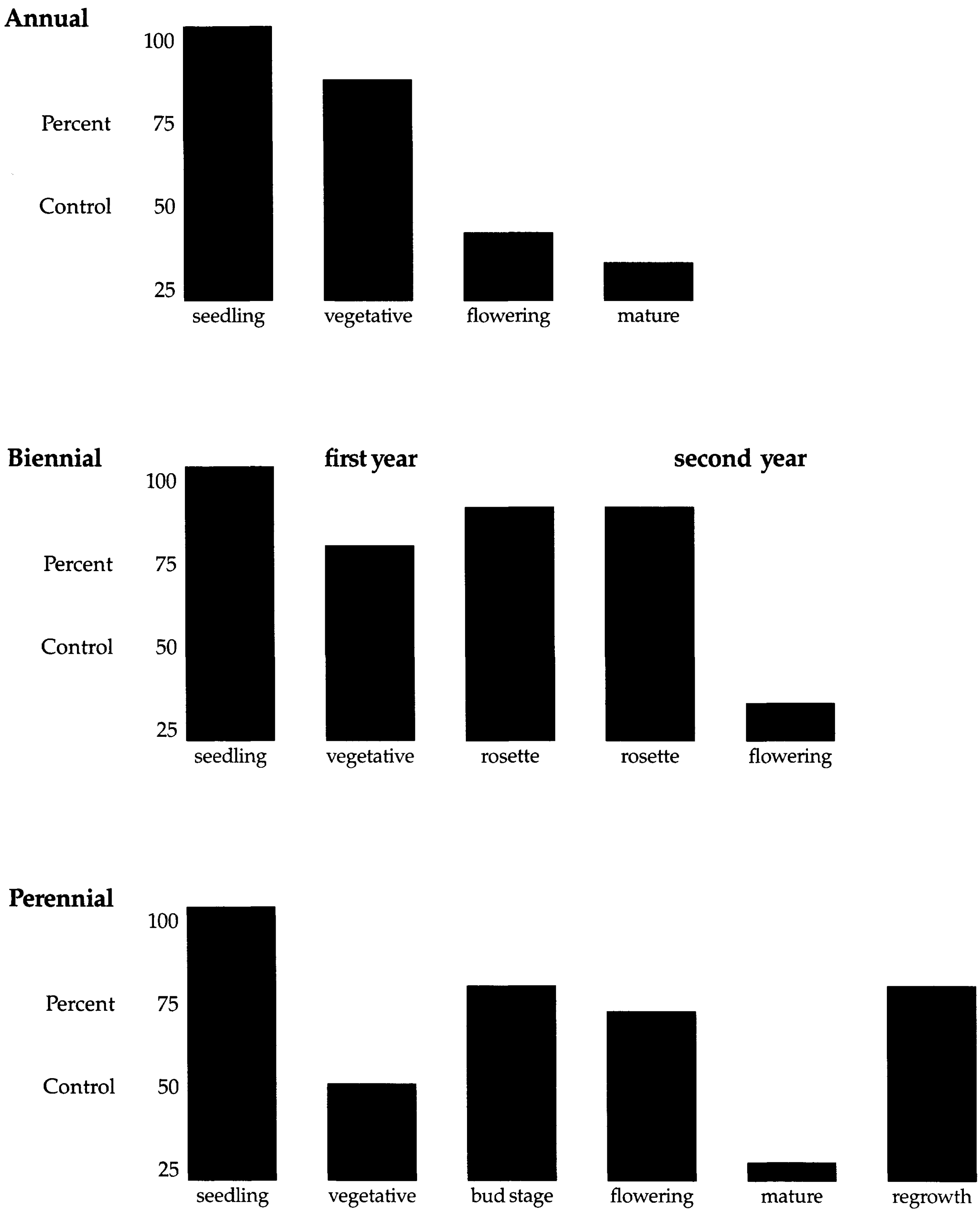
Ideally, you will manage most turf weeds by encouraging vigorous turfgrass. Depending upon the use and maintenance level of the turf, you may be required to use other weed management strategies, including herbicides. Realize that without the use of herbicides, a turf stand will not be free of weeds. However, only turf that has great visual importance or requires uniformity for its use needs to be weed-free.

Using Herbicides

There is a great variety of herbicides marketed for turf 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. The health and vigor of turf must also be considered, as no herbicide is completely harmless to valuable grass plants. Refer to the Extension bulletin #E2178, "Insect, Weed and Disease Management of Commercial Turfgrass" for cool-season grass tolerance to herbicide active ingredients.

How a particular herbicide works on a plant will determine if it successfully kills 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

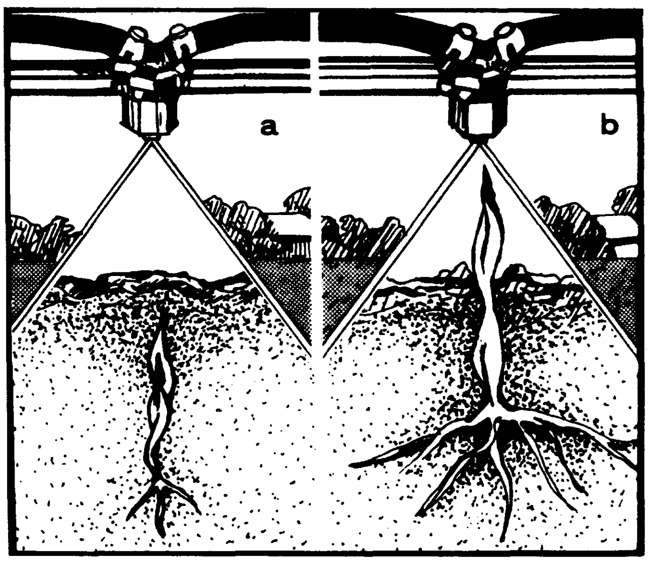
Percentage of Herbicide Effectiveness on Various Stages of Weed Development



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 in some situations, but are inappropriate for use on a site scheduled for immediate planting.

Nonselective herbicides kill most or all vegetation. Use caution 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.



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

Some herbicides are categorized by when they are used. **Preemergence herbicides** retard or prevent the establishment of weeds, and therefore are applied before weed germination. Most require watering-in after application. **Postemergence herbicides** are applied directly to actively-growing weeds. Some are contact herbicides, but most are systemics. Contact postemergence herbicides that are selective in action are effective for eliminating annuals and biennials, and temporary suppression of perennials. Perennial weeds are best managed with systemic postemergence herbicides.

Herbicide Action and Weed Plant Characteristics. The biological and physical characteristics of a weed influence the effectiveness of herbicides. Several of these plant characteristics are listed here:

- **Growing Points.** Growing points that are sheathed or located below the soil surface will not be affected 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.

Herbicide Action and Weather. The level of weed control depends upon the climatic conditions occurring when you apply herbicide. For instance, too much soil moisture may reduce herbicide availability to weed plant roots. Heavy rain can cause soluble herbicides to leach through the soil or run-off the site. However, light rain can be beneficial after a root-absorbed herbicide application; the rain water carries herbicide through the soil to plant roots. Several climatic conditions, such as temperature, light intensity, and relative humidity not only affect herbicidal action, but also the likelihood of volatility. All too often, ornamental plants are injured or killed by herbicide vapors drifting from surrounding, treated turf. Herbicide products differ in their volatility and reaction to weather conditions; it is extremely important that you carefully read and follow label recommendations.

To help you select and properly apply an herbicide for a specific weed problem, refer to "Insect, Weed and Disease Management for Commercial Turfgrass" (Extension bulletin #E2178.) This bulletin lists the most commonly used herbicide active ingredients and the products that contain them, herbicide recommendations for specific weeds, and application tips.

Review Questions—Chapter 7

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

1. Define **weed.**

2. Weeds are not the cause of poor turf performance. *(True or False?)*

3. Explain how weeds injure grass plants.

4. Name three qualities of weed plants that allow them to outcompete turf.

5. How do monocot plants differ from dicot plants? Name three common monocot and dicot weeds.

6. Name the four stages of plant development. Why is this important to weed management?

7. Describe the differences between summer and winter annuals. Name three weeds of each kind.

8. List five features of weed plants that are used in identification.

9. When weeds of two different species look alike, they will require the same type of control measures. *(True or False?)*

10. Explain why scientific names are used to identify weeds.

11. Henbit is a winter annual. *(True or False?)*

12. Is thymeleaf speedwell a monocot weed? Is knotweed a monocot weed?

13. What is the growth habit of knotweed?

14. How can you tell hairy crabgrass apart from smooth crabgrass?

15. Oxalis is a common name and the scientific genus name for what weed?

16. Which weed described in this chapter has fern-like leaves?

17. A vigorous, dense turf stand is the most important step in weed management. *(True or False?)*

18. How can you prevent weed seed production in your turf stand?

19. Explain how turf cut relatively high (2+ inches) can reduce weed seed germination.

20. Why is the seedling stage the most susceptible to management tactics?

21. Maintaining healthy, vigorous turf is enough in itself to keep turf weed-free. *(True or False?)*

22. Selective herbicides are completely harmless to turf. *(True or False?)*

23. How do preemergence herbicides work?

24. Name three physical characteristics of weeds and describe how they influence the effectiveness of herbicides.

25. Describe how rainfall can reduce the action of herbicide. How can rainfall increase herbicide effectiveness?

CHAPTER 8

DISEASES OF TURFGRASS

Diseases are the most difficult plant disorders to diagnose and manage. A disease can simply be defined as a continual disturbance of normal plant function. **Noninfectious diseases,** which cannot spread between plants, are caused by non-living agents such as drought, soil compaction, chemical burn, and nutrient deficiency. These diseases are thought of as cultural and environmental damage, and are discussed in Chapter 2, Care of Turfgrass.

Fungi, bacteria, viruses and other microorganisms cause **infectious diseases** and are called **pathogens.** Although they are not truly microscopic, nematodes are usually considered disease-causing organisms. Infectious disease is passed from plant to plant as pathogens multiply and spread. Infectious diseases of turf are mostly caused by species of fungi, and occasionally by nematodes. This chapter focuses on these pathogens and the infectious diseases most common on Michigan turfgrass.

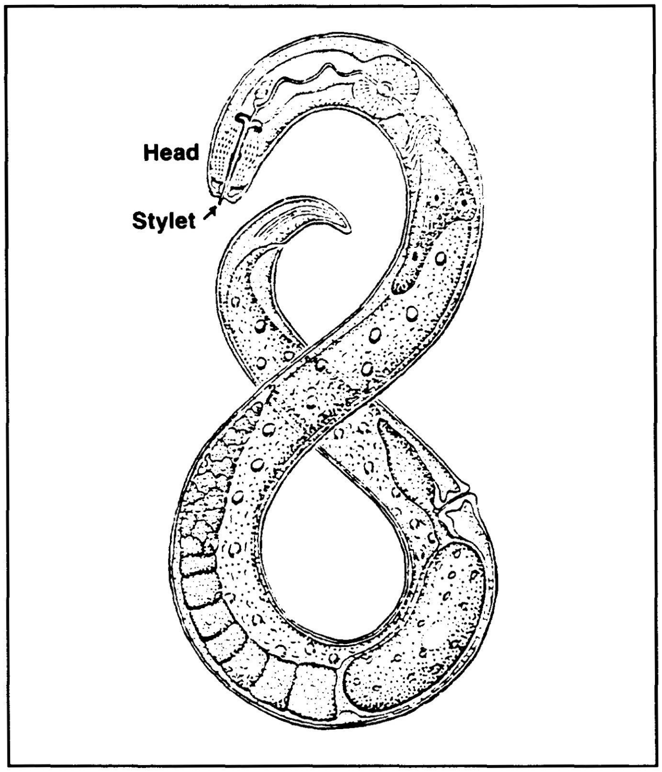
Fungi

Fungi are mostly microscopic organisms. Most feed on decaying organic matter such as dead roots, leaves and animals. Only a few species of fungi attack living plants, and only under specific moisture and temperature conditions.

Plant-parasitic fungi enter through the outer "skin" of plants or through wounds and natural openings in leaves, stems, and roots. After growing in the host for several days to weeks, fungi usually produce seed-like spores. The spores of some fungi germinate on the host while others are transmitted to another plant by wind, splashing water, animals, and equipment. Many fungi produce and release spores on special structures such as mushrooms and conchs. Most fungi species prefer moist conditions for growth, infection, and spore germination. The resting stage of most fungal diseases of turfgrass is found in the leaves, stems and roots of turfgrass. Fungi also overwinter in thatch and near the soil surface.

Nematodes

Nematodes are very tiny (1/50 to 1/10 inch), slender, round worms. They are commonly found living in soil, water, and other organisms. They reproduce by eggs, and are spread by any means that moves nematode-infested plant parts or soil. Only a few of the 1,500 plant-parasitic nematodes feed on turf roots.



Nematodes are tiny, worm-like animals that feed by inserting their stylet into plant cells.

Nematodes have a needle-like mouthpart, or stylet, to puncture plant cells. After injecting digestive juices, nematodes consume plant cell contents. Nematode feeding impairs the ability of roots to absorb water and nutrients which reduces plant growth and vigor. Nematode-infested turf does not respond well to fertilizing and other maintenance practices, and is more susceptible to drought, chemical burn and other pests. Plants have a relatively high tolerance of nematode feeding; depending upon the species, roots can support up to 1,000 or more nematodes without significant injury.

The only way to be sure of the presence and identity of nematodes is to send living turf roots and the surrounding soil to a laboratory. Dig up the injured grass plant or wedge of turf, including the entire root system with soil, and send or bring it to the MSU Plant and Pest Diagnostic Clinic. The address is listed in the following section of this chapter.

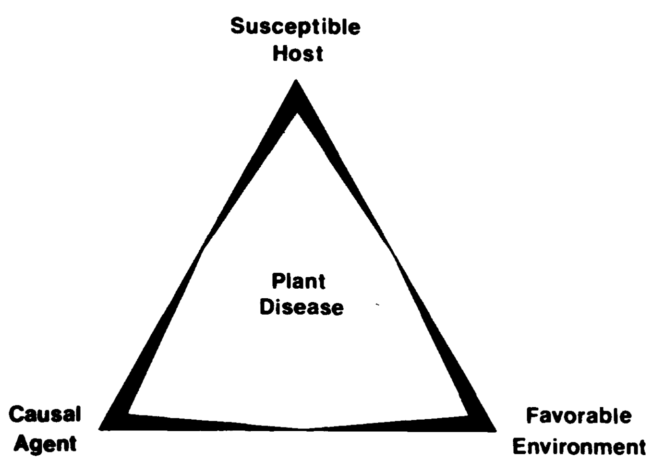
Before seeding a new turfgrass area, the soil should be tested for nematode turf pests. If the soil has plant-parasitic nematodes, use a nematicide to limit them. Most nematicides are extremely hazardous soil fumigants and therefore should be applied only by an experienced applicator who is certified in the soil fumigation standard (applicator category SO).

The Disease Triangle

Not all grass plants exposed to disease inoculum become infected. The development of an infectious disease requires all the following:

(1) A susceptible host grass plant.
(2) Presence of a disease-producing agent.
(3) An environment favorable for infection and development of the disease.

The relationship between these requirements is called the **disease triangle** (see Disease Triangle diagram.) Disease control tactics are an attempt to eliminate one of the disease triangle components.



Turfgrass Disease Diagnosis

For successful disease management, you must first determine if the injury is caused by an infectious disease and by which pathogen. Because pathogens are microscopic, disease diagnosis is difficult. It is nearly impossible to directly determine the species of the disease-causing organism. Instead, you must rely upon the injury symptoms for diagnosis. Pathogens vary significantly in the type of host and environmental conditions they prefer. When diagnosing diseases, consider the growing conditions and variety of infected grass.

There are a number of infectious disease symptoms that are produced at varying times of the year. Read the following turf disease descriptions, and use the key provided at the end of this chapter to aid in infectious disease diagnosis. Extension bulletins and other resources provide color photographs of disease symptoms. When you are unable to determine the causal agent of a disease, samples of damaged plant material and soil can be sent or brought to:

Diagnostic Services
101 Center for Integrated Plant Systems
Michigan State University
East Lansing, MI 48824
(517)355-4536
www.cips.msu.edu

Anthracnose

Description. Anthracnose of annual bluegrass is caused by the fungus *Colletotrichum graminicola.* Patches of infected turf 2 inches to 10 feet wide turn yellow-bronze to reddish-brown. Anthracnose develops most rapidly during prolonged hot, humid weather. When temperatures range in the 80's, and the humidity is high, the small patches of infected turf can thin out an entire fairway. It is at this time that spores are released on black, "spiny cushions" that can be seen with a hand lens on older, blighted leaves. Anthracnose is most severe when annual bluegrass is under stress due to compaction, poor drainage, and improper nitrogen fertility.

Management. During seasons of moderate temperature, discourage anthracnose by applying one-half pound of actual nitrogen per 1000 square feet in June, July, and August. Take extra care to limit all types of stress on annual bluegrass. When conditions favored by anthracnose exist, use fungicides to prevent significant injury to turf.

Dollar Spot

Description. Dollar spot is a serious disease of creeping bentgrass, annual bluegrass, and perennial ryegrass caused by the fungi *Moellerodiscus* and *Lanzia* (formerly *Sclerotinia.*) The disease is easily recognized by the appearance of small bleached-out spots about the size of a quarter or a silver dollar. When the turf is mowed to a height of one-half inch or less, the spots appear as sunken areas. Individual spots may merge and blight larger, irregular areas of turf. Characteristic light-tan lesions with dark-brown to reddish-brown borders girdle the leaf blades of Kentucky bluegrass and bentgrass. White, fluffy, fungal strands can be seen in the early morning.

Management. During periods of severe infection, maintain adequate nitrogen levels. Apply preventive sprays during the spring and early summer when symptoms first occur, and again in late summer and fall.

Fairy Rings

Description. Fairy rings are caused by fungi that live in the soil and break down organic matter. Fairy ring fungi are likely to develop in areas that were previously forested or where stumps or other organic matter is used as fill. Fairy rings develop during the spring and early summer as circles or arcs of dark-green, fast-growing grass. This lush grass results from the increased amount of nitrogen made available to the grass roots as fungi degrade organic matter. A ring of thin or dead grass may develop outside of the circle. Fairy rings may be a few inches to more than 50 feet in diameter. Often after rains or heavy sprinkling many mushrooms suddenly appear within the circle. Occasionally, fairy rings cause turf to turn yellow or be stunted. Although fairy rings on a homeowner's lawn is generally of little concern, they can be a serious problem on golf course greens and other high-maintenance turf.

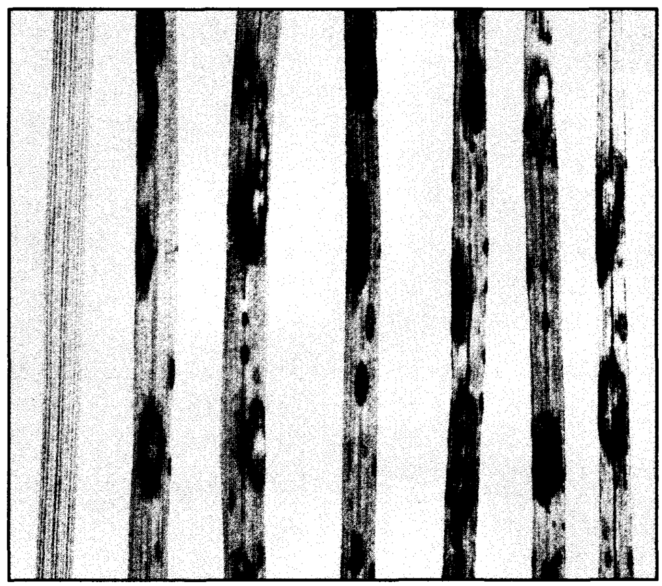
Fairy ring mushrooms often appear suddenly after heavy rain.

Management. Fairy ring symptoms may be masked by nitrogen fertilization. This practice, however, will also stimulate some fairy ring fungi. Getting rid of the rings is difficult and expensive. The fairy ring and infested soil must be completely removed and replaced. Fumigation, the only chemical control for fairy rings, is an especially hazardous process and is therefore not appropriate for homeowner lawns. Fumigation should be used only when absolutely necessary, and be performed by an experienced applicator who is certified in the soil fumigation standard.

Fusarium Patch (Pink Snow Mold)

Description. Pink snow mold is caused by a fungus that survives in turf thatch and residue. When conditions are cool (45°F) and wet, whitish-gray or reddish-brown spots develop. The rounded spots are 2 inches to 2 feet in diameter, and can develop with or without snow cover. Shortly after snow melt, pink fungal strands can be seen on the edges of the spots. Annual bluegrass, perennial ryegrass and bentgrass are highly susceptible to fusarium patch.

Management. Avoid early fall nitrogen fertilization to allow grass to harden off before going into the dormant season. Preventive fungicide treatment may be necessary for valuable, susceptible turf stands. Repair injured turf by raking and replacing matted grass.



Leafspot lesions on Kentucky bluegrass.

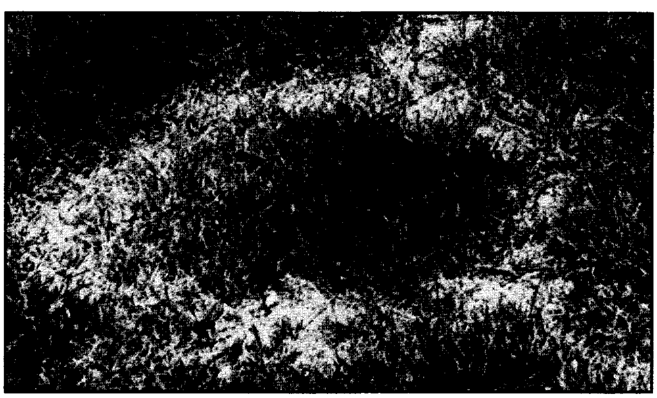
Leafspot and Melting-Out Diseases

Description. Leafspot diseases, formerly called Helminthosporium diseases, are caused by a variety of fungi: *Bipolaris, Drechslera, Exserohilum.* Leafspot diseases can develop during most of the year, but become most active in Michigan during the cool, moist weather of spring and fall. The leafspots first appear as small, purple to black lesions on the leaf blades. As more spots develop, they join together to form large, elongated areas of infection. Severely infected blades wither and die. During periods of drought stress, the fungi may spread to and blight the crowns and roots causing "melting-out." Infected areas turn yellow and may brown-out and die. Because dead or badly diseased plants often lose the characteristic symptoms described, drying-out or insect damage is often blamed as the cause of injury. Leafspot is mainly a problem on creeping bentgrass and fine leaf fescues, while melting-out injures mostly Kentucky bluegrass.

Management. Check for resistant turf varieties when establishing new lawns. For established turf, reduce leafspot and melting-out by (1) mowing at a high height of cut to limit stress; (2) not promoting excessive lush growth in the spring; (3) limiting moisture on the foliage by avoiding evening and night waterings and (4) promoting air circulation. A number of fungicides are effective when applied during wet weather in the spring and fall, when temperatures are optimum for development. While spray programs are effective, they are time-consuming and expensive.

Necrotic Ring Spot

Description. Necrotic ring spot is caused by the fungus *Leptosphaeria korrae* and is a serious disease of Kentucky bluegrass. Symptoms of necrotic ring spot become obvious in midsummer, when turf is drought stressed. Wilted, dying or dead turf in spots 2 to more than 12 inches wide appear first. The straw-colored patches may grow together, forming streaks, crescents, or circles in the turf. Healthy grass is surrounded by a ring of dead turf creating a characteristic "frog eye" pattern. Necrotic ring spot is favored by periods of warm, wet weather followed by periods of heat and drought. This disease is often associated with turf in hot, compacted areas along driveways or sidewalks.



Characteristic "frog eye" pattern shown by turf infected with necrotic ring spot.

Management. Use resistant Kentucky bluegrass varieties (see Disease Resistance chart.) Avoid stressing turf with inadequate nitrogen fertilization, low mowing height, and inappropriate irrigation. Since drought stress favors Necrotic ring spot, infected lawns should receive light, daily irrigation during the summer months. Keeping thatch at a minimum also helps prevent drought stress and reduce disease severity. Fungicides can be used to protect valuable turf at the first sign of symptoms.

Nematodes

Description. Nematode-infested turfgrass is thin, lacks vigor, and is frequently pale yellow, stunted and slow-growing. Usually the grass does not respond to water and fertilizer. Severely-affected plants wilt during midday, and later die in irregular patches. Apparently healthy grass blades are found with blades dying back from the tip. The roots are coarse and shallow, and may have swollen areas or galls. Roots may appear bushy or stubby with enlarged tips, and often have dark, sunken lesions.

Management. Professional diagnosis is necessary to confirm a nematode infestation. Limit the number of nematode pests by using only top-quality planting material and maintaining vigorous turf. Frequent, light watering at midday may prevent infested turf from wilting. If established turf is severely damaged, it may be necessary to apply a nematicide.

Powdery Mildew

Description. Powdery mildew of Kentucky bluegrass is common in the spring and fall when the nights are damp and cool and the days are mild and cloudy. White, powdery patches of mildew develop on grass leaves, especially in shaded or poorly-drained areas. Heavily infected turf appears dull white, as if dusted with flour. Diseased leaves often turn yellow, wither, and die. Plant growth is reduced, and heavily-infested plants may die.

Management. Avoid planting shady and wet areas with Kentucky bluegrass; use shade-tolerant grasses such as fine-leaf fescues.

Pythium Blight

Description. Pythium blight is a hot-weather disease that rapidly develops when daytime temperatures are in the 90's and night temperatures stay above 75°F. Since these conditions seldom occur in Michigan, pythium blight is confined to areas with poor drainage. Round to irregular, water-soaked, "greasy," sunken patches up to 12 inches wide are first to develop. In the early morning, when the humidity is high, a fluffy white mold growth may be seen associated with leaf lesions. Diseased areas quickly fade from reddish-brown to straw-colored as the grass dies. Pythium blight often appears in elongated streaks following water drainage or mowing patterns.

Management. Pythium can largely be managed in Michigan by improving soil drainage. Avoid over-watering, thick thatch, compaction, and excessive nitrogen fertilization. When pythium outbreaks occur, fungicide can be applied.

Red Thread

Description. Irregular to circular, "ragged," light tan to pinkish patches of 2 to 12 inches wide develop during prolonged humid weather. The spots may merge to form large bleached-tan or yellowish "scorched" areas. Fungal "threads" around one-quarter inch long protrude from the leaves. The threads are initially coral-pink and gelatinous, and later turn dry, brittle, and dark red.

Management. Maintain turf vigor with proper fertilization. Remove clippings to reduce inoculum.

Rhizoctonia Brown Patch

Description. Rhizoctonia brown patch attacks all types of turfgrass in Michigan when day temperatures reach the middle 70's. Symptoms are often disguised by actively-growing turf. Infected turf almost immediately shows damage during hot, moist, overcast weather. Brown patch has a "slimy" appearance when it occurs on perennial ryegrass. On high-cut grasses, the light brown patches are up to 2 feet wide. On closely cut bentgrass, the patches are 2 to 3 feet wide, roughly circular, and light brown. When moist, a grayish-black "smoke" ring of wilted and blighted grass may be evident on the patch edge.

Management. Avoid high nitrogen levels, since nitrogen increases rhizoctonia brown patch. Removing dew early in the morning and increasing air circulation helps reduce turf injury. Several fungicides are available for management of brown patch. Since infection begins long before symptoms are obvious, fungicides are used as a preventive treatment.

Rust

Description. All types of turfgrass are susceptible to one or more species of rust fungi, but in Michigan it is primarily a problem of bluegrass and ryegrass. Rusts are only a problem during warm to hot, dry periods when the grass growth slows or stops. Heavily-infected turf becomes reddish-brown to yellow-orange because of the large number of fungi pustules growing on grass blades. The rust material easily rubs off onto fingers, shoes, and clothing. A severe rust infection results in thin, weakened turf that is more susceptible to winterkill, drought, and other diseases.

Management. Use resistant varieties of bluegrass and ryegrass. Maintain vigorous, growing turf during dry periods of weather.

Slime Mold

Description. Slime molds are harmless fungi that feed on decaying organic matter. They live on the soil, thatch, or the surfaces of grass foliage. During warm weather, white, gray, black, or cream slimy masses grow over grass blades following heavy rain or watering. Slime molds develop in streaks or small patches that smother, rather than consume, otherwise healthy turf. The masses soon dry to form unsightly ash-gray crusty mats.

Management. Slime molds soon disappear, and rarely occur more than once a season. Raking, brushing or spraying the mold with a stream of water will remove the mold from the grass blades. Chemical control for slime molds is not recommended.

Stripe Smut

Description. Stripe smut is a major cool-weather disease of Kentucky bluegrass and creeping bentgrass in Michigan. Because the symptoms are subtle and difficult to detect, the disease is often not recognized until extensive damage occurs. Turf infected with stripe smut is stunted and slow to start growing in the spring. Infected grass blades are pale green with long black streaks of pustules along the veins. These streaks are not apparent on short-mowed turf. As pustules open, shoes and clothes become coated with black spores. Later, infected blades fray, twist, and turn white. The foliar symptoms virtually disappear in the summer, making diagnosis difficult if not impossible.

Long, black streaks of spore-filled pustules are a sign of striped smut.

Management. Use a blend of turfgrass varieties resistant to smut. Once established turf becomes infected with stripe smut, control is difficult and temporary at best. Chemical control only suppresses smut for a short time. Follow good cultural practices throughout the growing season. Apply moderate levels of nitrogen, and light, frequent waterings to reduce smut injury. Do not allow stripe smut-infected grass plants to go dormant in the summer as they will die.

Typhula Blight (Gray Snow Mold)

Description. Typhula blight is an important disease where snow cover remains on the ground for three months or more without melting. As the snow melts, circular gray to dark brown spots appear in the turf. The spots range from 3 to 24 inches, but most are 6 to 12 inches in diameter. Grayish-white fungal strands can be seen on the spot margins. Typhula blight is most severe when snow falls on unfrozen turf, and when turf is lush going into the winter.

Management. Avoid fall nitrogen applications that encourage new, tender growth. Use resistant turfgrass varieties when possible. A fungicide treatment may be necessary to protect valuable, susceptible turf when conditions favor Typhula blight.

Predicting Disease Activity

There are several indicators in the landscape that can help you predict disease outbreaks. These indicators concern host turfgrass variety susceptibility and pathogen biology.

Grass blades covered with gray snow mold fungal strands and fruiting bodies.

1. **Host Susceptibility**
   It is widely known that some species of plants are more disease-prone then others. Turf varieties and cultivars differ in disease susceptibility. For instance, the Kentucky bluegrass variety 'Adelphi' is resistant, and 'Enoble' is susceptible, to all of the major turf diseases (see Disease Susceptibility table.) As a part of your pest management program, keep an inventory of the stands composed of disease-prone grass varieties.

2. **Weather Conditions**
   Turf disease development depends greatly

Disease Susceptibility of Kentucky Bluegrass Varieties

Kentucky bluegrass variety	Leafspot/ melting-out	Leaf smuts	Leaf and stem rust	Necrotic ring spot	Dollar spot	Typhula blight
A-20	resistant	resistant	resistant	—	resistant	—[a]
A-34	resistant	resistant	resistant	—	—	—
Adelphi	resistant	resistant	resistant	resistant	resistant	resistant
Baron	resistant	resistant	resistant	—	resistant	resistant
Bonnieblue	resistant	resistant	resistant	—	—	resistant
Cheri (Golf)	resistant	resistant	resistant	—	resistant	—
Enmundi	resistant	—	resistant	resistant	resistant	—
Enoble	resistant	—	—	—	—	—
Fylking	resistant	resistant	resistant	—	—	—
Geronimo	resistant	—	—	—	resistant	—
Glade	resistant	resistant	resistant	—	resistant	—
Majestic	resistant	resistant	resistant	—	resistant	—
Monopoly	resistant	resistant	—	resistant	—	—
Nugget	resistant	resistant	resistant	—	—	resistant
Parade	resistant	resistant	resistant	—	resistant	—
Plush	resistant	resistant	—	—	resistant	—
Rugby	resistant	—	resistant	—	resistant	—
Sydsport	resistant	resistant	resistant	—	resistant	—
Touchdown	resistant	resistant	—	—	—	—
Vantage	—	resistant	—	—	resistant	—
Victa	resistant	resistant	resistant	resistant	resistant	—

[a]no consistent data available

Adapted from "Illinois Pesticide Applicator Training Manual 39-1."

upon weather conditions. Rainfall, length and frequency of dew, air and soil temperatures, and soil moisture are all factors influencing pathogen activity. Most turf managers can recall a particularly bad year for one disease or another. Monitoring these factors will help you to predict disease development and schedule control activities.

3. **Microclimate**
   A microclimate is a relatively small area with growing conditions different from those of the surrounding land. Examples of microclimates include low-lying areas with heavy dew or fog, the southern exposure of hills and buildings, and the borders of roadways exposed to heat and compaction. Microclimates can be created by management practices. For instance, the environment in the crowns of turf mowed at a low height of cut is hotter and dryer than that of a turf cut high. Small differences in growing conditions can result in dramatic variation in the degree of disease infection among areas of a turf stand.

Infectious Disease Management

There is no way as yet to entirely eliminate disease inoculum from the landscape or reliably remove or kill pathogens infecting turf. Disease management efforts therefore focus on preventing disease from occurring or lessening the effects of disease. There are three strategies to protect turf from disease injury:

1. **Resistance.** This strategy focuses on the host plant rather than the pathogen. Select turfgrass species and varieties that are resistant to disease infection or damage. Use turfgrasses that are best suited to the site.
2. **Avoidance.** Manipulate the landscape environment or microclimate through cultural controls to avoid conditions that favor disease development.
3. **Protection.** This strategy renders the pathogen ineffective before it can infect the plant. Most fungicides are protectants. Good record keeping of past infections are important, as protectant fungicides are applied before disease injury is obvious.

Because of the difficulty in managing most turf diseases, applicators must, by necessity, use IPM techniques including non-chemical tactics and careful timing of pesticide applications. Use the alternative methods summarized in the Disease Management table accompanying this section. Refer to the Extension bulletin #E2178 "Insect, Weed and Disease Management for Commercial Turfgrass" for pesticide recommendations used to manage turf diseases. Remember, no matter what reference manuals recommend, *you are responsible for checking the product label for the legal uses of the pesticide.*

Review Questions—Chapter 8

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

1. Define **disease.**

2. What is the difference between infectious and noninfectious diseases? Name three causes of noninfectious disease.

3. How do fungi enter plants? Describe a way fungi spread from plant to plant?

4. Describe how nematodes injure turf. How can you tell for certain that turf is infested with nematodes?

5. What is the disease triangle? Why is it important to disease management?

6. Why is turf disease diagnosis difficult?

7. What type of grass does anthracnose fungi infect?

8. What are the "spiny cushions" produced by anthracnose fungi?

9. Describe the turf injury characteristic of dollar spot?

10. Which of the snow molds must have snow cover to develop?

11. Explain why turf is susceptible to leafspot/ melting-out throughout the growing season.

12. The "frog eye" pattern is characteristic of what disease?

13. Bushy or stubby roots with sunken lesions indicate infection by what disease?

14. Why is pythium blight mostly confined to turf with poor drainage in Michigan?

15. Removing clippings is a management tactic for which disease, as recommended in this chapter?

16. Rust is a fungal disease which becomes a problem when conditions are hot and dry. *(True or False?)*

17. Which disease does not consume turf, but rather smothers it?

18. How can you predict the occurrence of disease by taking note of turf stand microclimates?

19. Name two disease management tactics that use the resistance strategy.

20. Most fungicides are a tactic of which management strategy?

Key to Turfgrass Diseases*

This key is organized according to the temperature ranges at which the disease is first visible.

Cold-Weather Diseases (32°-45°F)

Round patches of dead grass appear as the snow melts:

- patches are usually less than 1 foot wide, and the wet grass is covered with a bright pink mold . . . . Fusarium patch (pink snow mold)
- patches are up to 2 feet or more wide, and the wet grass is covered with a white to bluish-gray mold . . . . Typhula blight (gray snow mold)

Cool-Weather Diseases (45°-60°F)

Round to arc-shaped, dark-green patterns in the turf after the grass turns green; mushrooms may appear in rings following wet periods . . . . Fairy rings

Surfaces of the grass blades covered with a powdery mold:

- mold is in black streaks; blades are split into ribbons and twisted; grass later dies in irregular patches; affects Kentucky bluegrass and bentgrass . . . . Stripe smut
- mold is milky white to gray, easily rubbed off, and always occurs in the shade; affects bluegrass and fescues . . . . Powdery mildew

Patches of weak, thin grass; Kentucky bluegrass crowns and roots are reddish-brown to black . . . . Melting-out

Warm-Weather Diseases (60°-75°F)

More or less round, bleached, straw-colored spots about 1-6 inches wide; blades have gray lesions with a reddish-brown border . . . . Dollar spot

Scorched patches, usually 2-12 inches wide; light coral-pink to bloodred threads bind leaves together . . . . Red thread

Dark purple or brown leaf spots; leaves may wither, die, and drop in large, irregular areas on the turf; leaf sheath may rot . . . . Leafspot/melting-out

Surface of grass blades is powdery; leaf spots usually not present:

- bright yellow to orange or reddish brown pustules occur on bluegrass and ryegrass during extended dry periods . . . . Rust
- turf is slimy or "greasy" . . . . Slime mold
- mold is milky white to gray, easily rubbed off, and always occurs in the shade; affects bluegrass and fescues . . . . Powdery mildew

Hot-Weather Diseases (over 75°F)

Irregular patterns of weak, thin, wilted, dead or dormant grass. Turf lacks vigor.

- roots are shallow, often swollen, stubby, bushy, coarse, or with dark lesions . . . . . . Nematodes
- leaves of annual bluegrass are spotted to blighted and yellow-bronze in irregular patches; black spiny lesions on grass blades can be seen with a hand lens . . . . Anthracnose
- leaves have dark-reddish to purplish-black spots and may wither and die back . . . . Leafspot

Round pattern of dead grass appears:

- patches are up to 12 inches wide, may occur in streaks; blades are matted . . . . Pythium blight
- patches are straw-colored and up to 2 feet wide; patches may develop a "frog eye" pattern; often appear during dry periods . . . . Necrotic ring spot
- patches are light brown, up to 3 feet wide, often with a smoke ring, and appear during wet periods; grass blades usually not matted . . . . Rhizoctonia brown patch

Surface of grass blades becomes powdery:

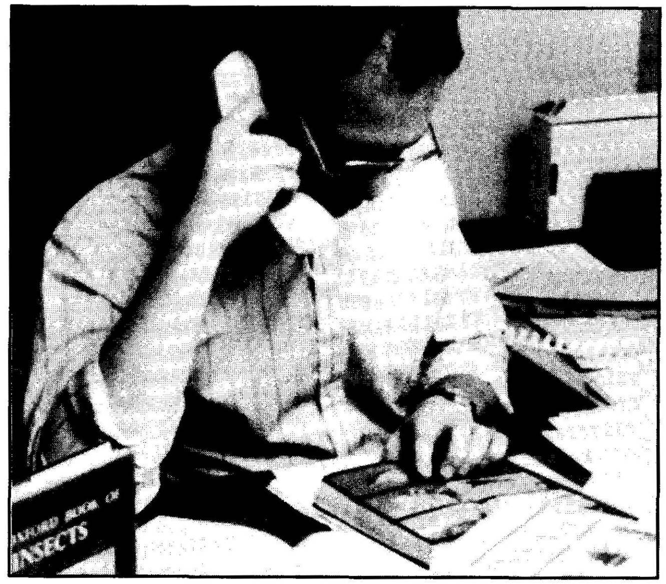
- bright yellow-orange or reddish-brown pustules occur during extended dry periods . Rust
- turf is slimy or "greasy"; then a bluish-gray, creamy-yellow, or black powder develops that is easily wiped off . . . . Slime mold

*Adapted from "Illinois Pesticide Applicator Training Manual 39-1."

CHAPTER 9

INSECT AND VERTEBRATE PESTS

Two groups of animals commonly injure Michigan turfgrass: insects and vertebrates. Insects eat turf roots, stems, leaves and sap. Unlike insect pests, vertebrates do not consume turf, but rather tear up patches and severe roots while searching for food. The major animal pests of Michigan turf and strategies to manage them are described in this chapter.


Accurate pest ID and understanding pest biology is essential for successful pest management, and may require some research.

Insect Pests

As with any pest problem, the first step in managing turfgrass insects is accurate identification. There are hundreds of insect species found in turf; only a handful are of concern to turf managers. Some beneficial insects resemble insect pests. For example, the big-eyed bug, an important predator of turf pests, looks like the chinch bug. To be certain what pest is damaging turf, you must become familiar with adult and immature stages of important insect pests, and understand their life cycles.

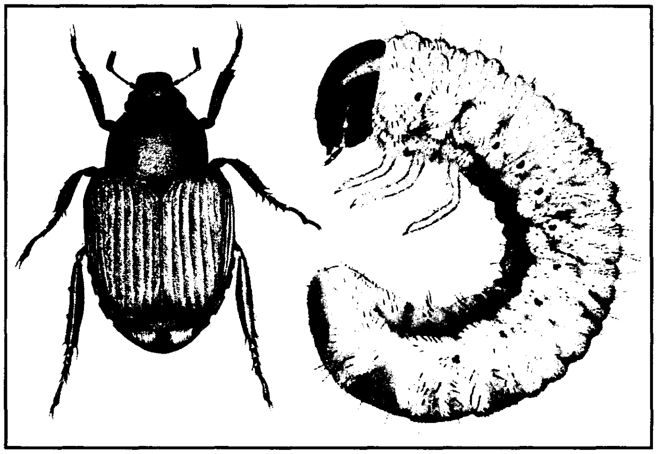
Almost all of the insect damage to Michigan turf is caused by seven pests:

Key Insect Pests of Michigan Turf

Type of Damage	Insect	Golf Courses	Home Lawns	Distribution (as of 1991)
root-feeding grubs	Japanese beetle	x	x	Found in localized pockets anywhere south of a line between Grand Rapids and Flint. Greatest populations are around Detroit, Monroe, Jackson, Battle Creek and Kalamazoo.
	European chafer	x	x	Most common in greater Detroit area, Jackson, and Grand Rapids, but range is expanding.
	Black ataneius	x		Widespread across the state, but more of a problem on certain golf courses.
sap and stem feeders	Hairy chinch bug		x	Widespread throughout the state.
	Bluegrass billbug		x	Widespread throughout the state.
	Black cutworm	x		Widespread across the state. Only a problem on tees and greens.
nuisance pest	Ants	x		Widespread across the state. Only a problem on tees and greens.

Created by Dave Smitley, Michigan State University.

Insect pests can be grouped into those that feed on turf roots, those that feed on the grass blades or stems, and nuisance pests. Damage symptoms reflect how insects feed and at what time of year they are active. The following descriptions of the important insect pests of Michigan turfgrass include their appearance, life cycle, injury, action thresholds, and management.



Japanese beetle adult and grub.

Japanese Beetle

Damage: Larvae **(white grubs)** feed on turf roots in May, early June and again in September and October. Damaged turf may turn brown in patches if it is not frequently watered.

Appearance: White C-shaped larvae are ½ to 1″ long by late September.

Threshold: 20-30 grubs per square foot on daily-irrigated turf.

Japanese beetle adults are a dark metallic green color, stout-bodied and approximately one-half inch long. They emerge in July and early August, feed on the foliage and flowers of flowering fruit trees, roses, basswood and wild grape before mating and depositing their eggs in turf in July and early August. Tiny larvae (1/16″) hatch from eggs in August and begin feeding on turf roots. By late September the larvae will grow to one-half to 1 inch long. Heavily-infested turf suffers from root pruning damage; the turf cannot absorb sufficient amounts of water and dies. In October when soil temperatures begin to drop, the C-shaped larvae (white grubs) move deeper into the soil to overwinter. The following April or May they move closer to the surface and begin feeding again. Sometime in June the larvae quit feeding and pupate. They stay in a white pupal form, which is an inactive, non-damaging stage, for several weeks. In late July adult beetles emerge.

Turf managers usually discover Japanese beetle grubs in May or September when grub feeding and root injury is at a peak. Patches of turf may be ripped up by animals such as skunks and racoons that are feeding on grubs during these times. Vertebrate damage is often observed before managers are aware of large grub populations.

Irrigated turf has a tremendous ability to recover from insect injury. Even so, turf with more than 20 grubs per square foot will likely suffer from water stress. More than 10 grubs per square foot may result in brown patches in unwatered turf. Determine the level of grubs in late August or September where skunks are active or where turf is damaged. Roll back the turf in several one-foot square sec tions and count the number of grubs.

If more than 20 grubs per square foot are found, apply insecticide as spot treatments in late August and early September. Early morning or evening is the preferred application time for insecticide sprays. Water-in insecticide sprays according to product label recommendations. Check the label for the reentry period, but be sure not to allow people on the treated turf until after the irrigated turf is dry.

The degree of control is highly variable from site to site and year to year, but insecticides usually provide 50-80% control of Japanese beetle grubs. Three weeks after the application, evaluate the treatment by sampling for grubs where the original samples were taken. Be sure to record the results for future reference.

Adult Japanese beetles are highly attracted to beetle traps. Traps are useful for monitoring adults, but they are not useful for Japanese beetle control. Milky spore disease has consistently been a poor control. Do not rely on the currently-available milky spore products to effectively suppress grubs. Parasitic nematodes formulated into grub control products have not provided good grub control in the past. This is largely due to the use of an inappropriate strain of nematode. Applying nematodes on turf with environmental conditions not favorable to them also reduces the level of grub control. A fall application of the "HP-88" strain of *Heterorhabditis bacteriophora* on silty, irrigated soil has provided consistently good results.

European Chafer

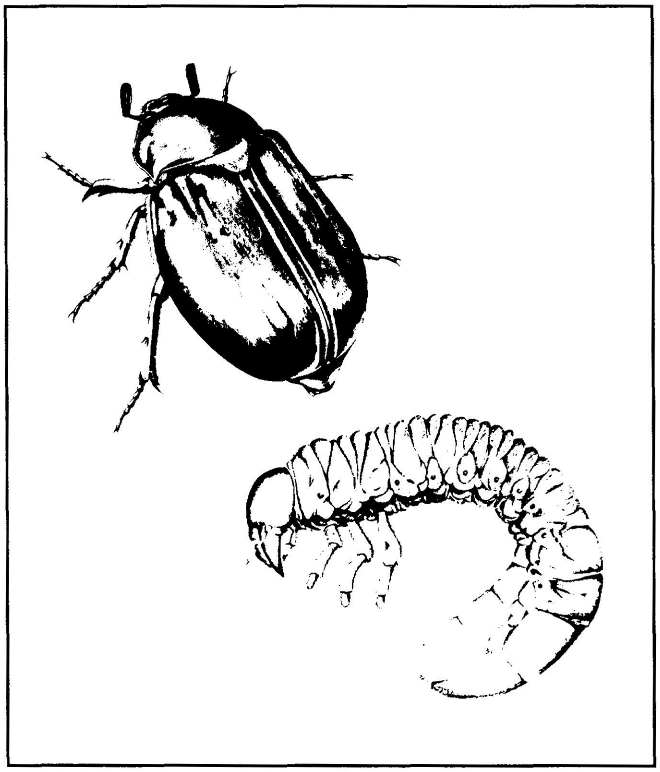
Damage: Larvae (white grubs) feed on turf roots in May and early June, and again in September and October. Damaged turf may turn brown in patches if it is not frequently watered.

Appearance: White C-shaped larvae are ½ to 1″ long by late September.

Threshold: 20-30 grubs per square foot on daily irrigated turf.

European chafer adults are uniformly light brown, stout-bodied, have clubbed antennae, and are about one-half inch long. They emerge in late June and July which is about two weeks earlier than the Japanese beetle. The life cycle is similar to that of the Japanese beetle. However, European chafer grubs will feed longer in the fall (early November) and will return to the surface earlier in the spring (early April.)

European chafer injury and damage thresholds are the same as for Japanese beetle. Management strategies are also similar with the exception that European chafer grubs are more difficult to control with insecticides. Frequent irrigation to protect injured turf from water stress is the best way to prevent turf damage. Insect-parasitic nematode products have been as effective as insecticides. For the best results, apply nematodes in early morning or evening. Do not apply nematodes to dry turf; water turf lightly (a quarter of an inch) before and after application.



June (May) beetle adult and grub.

June Beetle

Damage: Larvae feed on turf roots from May until October. Damaged turf may turn brown in patches as it dries out. Vertebrates often uproot turf looking for the large grubs.

Appearance: The larvae are large, C-shaped, white grubs. They grow from ¼" at egg hatch to a maximum size of about 2 inches long.

Threshold: Because June beetle grubs are larger than Japanese beetle and European chafer grubs the threshold is lower. Turf injury is likely if more than 10 grubs per square foot are found on daily-irrigated turf, or if more than 5 per square foot are found on low-maintenance turf.

Several species of June beetle, or May beetle as some call them, are numerous in Michigan: *Phyllophaga rugosa, P. hirticula* and *P. fusca*. The first two usually emerge in June and the third in April or May. The adult beetles are shiny, robust, reddish-brown in color, and nearly 1 inch long. June beetles are most active from 7:00 to 9:00 at night. People are quick to notice these beetles because the adults are highly attracted to lights and frequently fly into windows and screen doors.

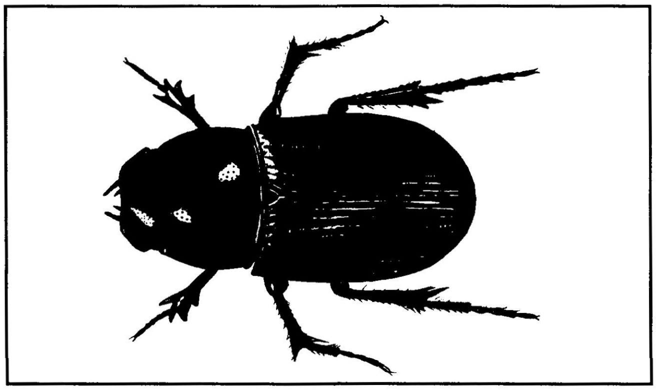
June beetles are active for about two weeks during which time they feed on tree leaves, mate and deposit their eggs in grassy soil. Eggs hatch in three to four weeks. The small larvae feed on organic matter and turf roots until September, and then move deep into the ground to overwinter. The larvae cause the most damage in their second year when they feed heavily from May through September. In the third year they feed briefly in the spring and early summer. In late summer they pupate. The adult beetles emerge in fall, but overwinter in the soil until the following May or June to complete a 3-year life cycle. The most serious injury associated with June beetles occurs in rural areas as skunks turn over sod to feed on the large grubs.

Because many natural enemies attack June beetles, insecticides usually are not necessary. Should a June beetle population warrant chemical control, time applications to correspond with susceptible stages of the grubs. The third-year, large grubs (1½–2 inches long) stop feeding in July, and are therefore almost unaffected by insecticides in July and August. Do not apply insecticides at that time.

Black Turfgrass Ataenius

Damage: Larvae feed on turf roots in July and August. Golf course fairways may turn brown in patches, where a heavy infestation of grubs have chewed off all the roots. Damage is uncommon on home lawns.

Appearance: These small black beetles (one-quarter inch long) give rise to a white



Black turfgrass ataenius.

grub that reaches a maximum length of 3/8″

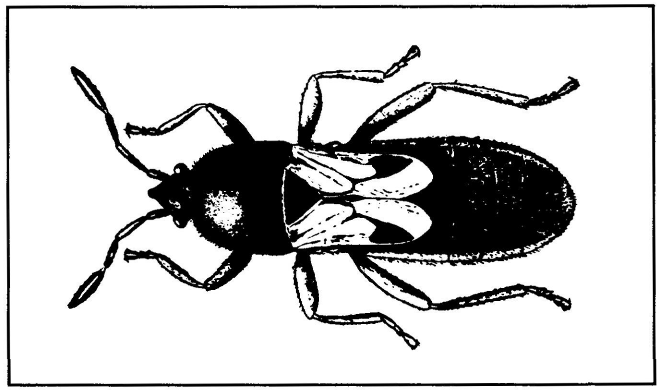
Threshold: From 60 to over 100 larvae per square foot of turf.

Overwintering adult Ataenius beetles become active in May. Large numbers of small (3/8″) black beetles, that are most active from 7:00 to 9:00 p.m., are the first indicator of a potential problem with Ataenius. Adults lay eggs in the soil that hatch into root-feeding grubs. Injury from grub feeding is not evident until early July when the grubs are nearly full grown. At that time some wilting or brown patches may be seen on tees, greens, or fairways. A second generation of beetles emerges in late July and more grub injury can occur in August. Second generation adult beetles emerge in September and seek sheltered sites for overwintering. Because beetle emergence is spread out over several weeks, some Ataenius grubs may be found all summer. Injured turf may support from 100 to 500 grubs per square foot. Damage rarely occurs when less than 100 grubs per square foot are found.

Golf courses where some Ataenius damage occurs every year may choose to apply an insecticide in the middle of May when the beetles are emerging and laying eggs. This strategy is designed to kill the adults before they deposit eggs. However, because populations of Ataenius fluctuate from place to place and from year to year, it is more prudent to wait until early July and sample fairways to determine if an insecticide is needed. If more than 60 grubs per square foot are found feeding on the roots of valuable turf, then a soil insecticide can be applied.

Hairy Chinch Bug

Damage: Large populations of chinch bugs may cause turf to turn brown in large patches in July or early August. The damage looks similar to drought stress.



Adult chinch bug.

Appearance: Adult chinch bugs are black with white wing markings and are about 3/16″ long.

Threshold: Twenty adult or larvae bugs in two minutes of monitoring several areas of the stand using the visual inspection technique (see Chapter 2) or 15 bugs per flooded coffee can.

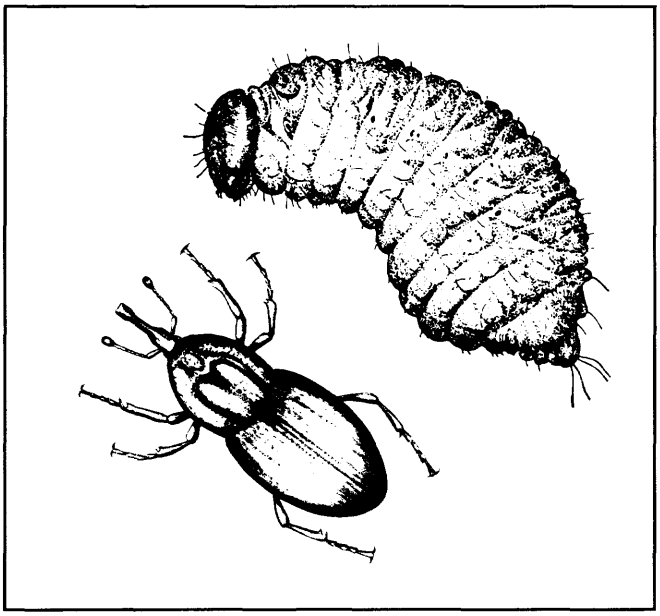
Adult chinch bugs are small black bugs 3/16″ long with white wings. The wingless larvae are smaller than the adults. The youngest larvae are brick red in color with a white band that crosses on the back; older larvae are mostly black. There are two generations of chinch bugs per year. In areas of Michigan north of Lansing, only one generation occurs. Adults overwinter in protected areas near lawns. Overwintering adults emerge in May, and the second generation of adults are present in July and August. Adults mate and lay eggs in the leaf sheaths of grass plants. Larvae require approximately four to six weeks to develop to the adult stage. First generation larvae occur in late June to July, and second generation larvae are present in mid-August.

Both chinch bug larvae and adults suck out sap. Their saliva contains substances toxic to the plant and the puncture wounds often block water movement. Chinch bug injury can be serious when warm, dry conditions induce water stress in grass plants. Their damage is most frequently observed in July in central Michigan or in late summer or early fall in southern Michigan and is often attributed to some other agent. Chinch bug injury is characterized by irregularly-shaped yellow patches two to three feet in diameter. These patches often turn brown and die. Clumps of clover and other non-grass weeds may survive in these areas. This injury looks like drought or heat stress, but is not eliminated by applying water.

Heavy rainfall in June and early July during egg hatch will reduce larvae survival. Much of this mortality is due to a naturally-occurring fungus *(Beauveria sp.)* that attacks the bugs during cool, wet conditions. The fungus is ineffective during hot, dry periods when chinch bug population buildup occurs.

Research on chinch bugs in Michigan revealed that chinch bugs are widespread, but rarely are abundant enough to cause damage. A survey of Lansing area showed that less than 5% of the lawns had damaging levels of chinch bugs.

Since chinch bugs are usually not a problem in well-irrigated turf, regular watering of turf during hot, dry weather will help prevent chinch bug problems. If chinch bug populations exceed threshold levels, an insecticide application may be necessary.



Grub and adult bluegrass billbug.

Bluegrass Billbug

Damage: Small legless grubs destroy the crowns of grass plants, sometimes causing brown patches of turf in late July.

Appearance: White legless grubs are about ¼" long.

Threshold: Irrigated turf recovers quickly if less than one-third of the crowns are destroyed. Lawns with greater damage can be targeted for management the following year.

Adult billbugs are dull grey to black beetles, ⅜" long, with a snout or bill. Billbug larvae are white, legless, ⅝" long, humpbacked grubs with a yellow to brown head capsule that is harder in texture than the soft white body.

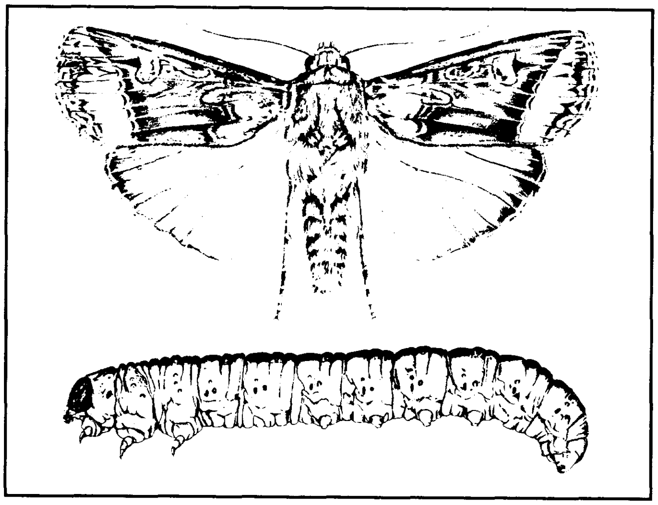
Billbugs overwinter in the soil as adults and become active as temperatures begin to warm in April. Although some eggs are laid in grass stems in early May, most are deposited in early June. Egg hatch occurs in one to two weeks. The larvae tunnel down through the grass stems into the crown or around the roots. Mature larvae frequently feed across the plant crown cutting off the root system, and then pupate in the soil. Larvae may be present in June or August, but peak density occurs in mid-July. Old adults (those that overwintered and laid eggs) may persist all summer but the new generation of adults (who lay eggs the following spring) begin to emerge in late August or early September. Soon after emergence, new adults seek sheltered areas to spend the winter and can be seen walking around driveways, patios, and near ground cover. There is only one generation per year.

The bluegrass billbug is almost always found attacking Kentucky bluegrass *(Poa pratensis)* but can sometimes be found in fescue and perennial rye grass lawns. The bluegrass varieties Merion and Nugget are especially susceptible to billbug injury. Damage is evident in late July and is characterized by circular to irregularly-shaped dead patches of turf scattered throughout the lawn. Damage caused by large numbers of billbugs is similar to that caused by white grubs. However, grub-damaged turf can be pulled up like a carpet to reveal the C-shaped larvae. Billbug damage is usually more localized and may first appear near curbs or driveways. Damage from necrotic ringspot is also similar to billbug injury, but the diseased areas are larger and usually have live patches of green grass in their centers.

The following signs can be used to diagnose billbug injury:

- Circular to irregular patches of dead grass, especially near side walks or curbs.
- Grass in dead areas of lawn pulls easily and has hollow stems.
- A white, legless, humpbacked larva present in or under the plant crown or in the soil as deep as 1 inch.
- Brown sawdust-like frass in the root zone.
- Adult billbugs present in adjacent grass.

Generally, small damaged areas of lawn will recover with proper water and fertilization but larger areas may not. Examine lawns for billbug injury in late July and early August. By late August it is almost impossible to determine if billbugs were responsible for the damage observed. Lawns examined in late July that suffered patches of heavy damage or where more than ⅓ of the plants examined were damaged, can be targeted for an insecticide application to control adults the following May. Home lawns heavily damaged from billbug are very unusual, and therefore, preventive insecticide applications are not recommended.



Moth and caterpillar stages of the black cutworm.

Black Cutworm

Damage: Small holes (¼" diameter) in tees and greens with closely-clipped grass spreading outward one inch from the holes.

Appearance: The dark-brown caterpillars vary from ¼ to 2" long as they grow from eggs to pupae.

Threshold: Depends upon the importance and use of the turf.

Cutworms are the caterpillar stage of dull-colored moths. Black cutworm caterpillars reach a length of 2 to 3 inches when fully grown. The adult moths are inactive by day and may be attracted to lights at night. The first cutworms are usually found in early July, and some may be found all summer long with peaks of activity in July and late August. Although black cutworms are frequently found on home lawns, natural enemies effectively control them and damage is rare. Black cutworms are primarily a problem of golf course greens, where tolerance levels are low.

Careful examination of areas suspected of cutworm activity should show green fecal pellets and clipped grass associated with the cutworm feeding. Disclosing solutions (see Monitoring section, Chapter 2) can also be used to detect cutworms.

Home lawns and golf course fairways are tolerant of cutworm feeding and rarely need treatment. However, golf course greens may require an insecticide application when cutworms are detected. The bacterial pathogen Bt and insect-parasitic nematodes are effective against cutworms. When applying parasitic nematodes, keep in mind that insecticides may render the nematodes inactive.

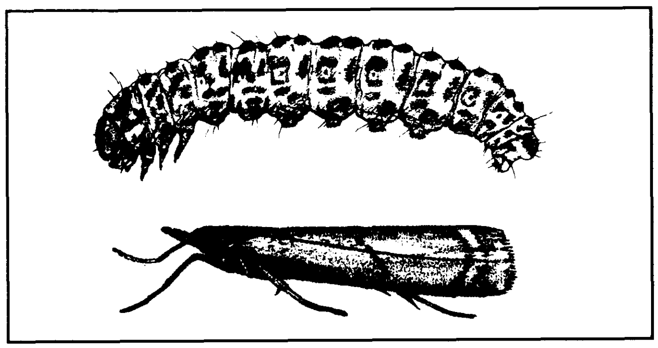
Sod Webworm

Damage: Small, brown patches of turf where grass blades have been clipped at the base. Small patches may grow together to form larger, irregular-shaped patches of dead turf.

Appearance: The ivory white caterpillars with small black spots grow from ¼" just after egg hatch to 1" long before the caterpillars pupate.

Threshold: Depends upon the importance and use of the turf.

Sod webworms, the caterpillar stage of lawn moths, are infrequent pests of bluegrass lawns in Michigan. The caterpillars overwinter in the soil and resume feeding in the spring (late April to early May) as temperatures begin to rise. Occasionally, damage will occur in the spring from large numbers of overwintered webworms. Adults begin to emerge in late May and early June and can be seen flying across lawns at dusk or late evening. They are dirty white in color with black, round spots. Adult moths rest during the day in deep grass, ground cover, or in shrubbery. Females drop up to 200 eggs into the grass while in flight. Eggs hatch in 5 to 10 days and the young larvae begin eating grass blades. After a short time the larvae become large enough to chew small portions of the grass blade so that the damaged leaves may appear notched. Later, the more mature larvae construct silk-lined burrows in the thatch and begin to chew the grass blades off just above the thatch line and pull them into their tunnels to eat. Injury thus appears as small circular (quarter size) areas of closely clipped grass and exposed brown thatch.



Sod webworm caterpillar and moth.

Most turfgrass varieties are susceptible to webworms, but bluegrass and bentgrass lawns appear to be favored. Pupation takes place in late June to early July and second generation adults are usually observed shortly afterwards. Eggs are deposited and second generation larvae reach peak activity in mid to late August. Most of the damage is caused by the second generation of caterpillars. As the temperatures drop in the fall, webworm larvae burrow deeper into the soil to overwinter. There are only two generations a year.

When sod webworm injury is suspected, check for the following:

(1) Brown patches where grass blades are missing and not simply dead.
(2) Piles of green fecal pellets (frass) in the thatch.
(3) Webworm caterpillars in the thatch living in silk-lined tubes.

Larvae in the lawn can frequently be brought to the surface by drenching the infested turf with a disclosing solution (see Monitoring Techniques, Chapter 1.) Mark off two to three sections of lawn 2 ft x 2 ft square in both damaged and undamaged areas of the lawn and evenly pour 1-2 gallons of the solution over each section. If more than 4-6 larvae per 4 ft^2 of turf surface are found, treatment is advisable.

Sod webworms have many natural enemies that usually keep populations under control. Webworm damage is most likely to occur on lawns where predators and parasites have been suppressed by pesticide use. One of the most effective natural enemies is a small wasp that lays eggs inside of webworm larvae. In larvae where these wasps are active you may see a group of small white cottony cocoons in the thatch next to a dead webworm.

Ants

Damage: Ants build small soil mounds ½ to 2″ in diameter that are undesirable on golf course tees and greens.

Appearance: Depending upon the species, black, brown or red ants that are 1/16 to ¼″ long.

Threshold: Depends on the tolerance of the superintendent or clientele.

There are many species of ants living in turfgrass. Ants are beneficial insects in home lawns and golf course fairways because they consume a broad range of food including insect eggs and larvae. They help keep populations of turf insect pests under threshold levels.

While ants do not injure grass plants, ant mounds ruin surface uniformity. In a dense lawn ant mounds are not visible. They only become a problem when grass is cut very short, as it is on a golf course green. Golf courses with sandy soils suffer the greatest damage. Ants become active in May and mounding is usually a problem from June through September.

Ant colonies often recover quickly from insecticide applications. Even the most effective products only provide control for two to four weeks. To limit the risk to non-target organisms insecticide baits should be used. However, effective bait formulations may not be available.

Insect Management

Vigorous, dense turf can tolerate insect injury by producing new growth. For instance, turfgrass temporarily thinned in patches by a Japanese beetle invasion can quickly recover once the grubs complete their life cycle and stop feeding. Vigorous turf can withstand feeding injury from two or three times the number of beetle larvae that would seriously injure turf under drought stress.

Healthy turf is best grown without the use of insecticides. Insecticides may be the most effective "manufactured" management tool, but they are ranked a distant second to the natural enemies of insect pests. Insecticides destroy both insect pests and beneficial insects. Insecticide use also limits organisms, such as earthworms, important for thatch decomposition. The best approach to insect pest control is to (1) grow healthy turf and (2) limit pesticide applications.

If an insect pest is causing unacceptable injury that cannot be adequately managed through non-chemical methods, then the infested section of turfgrass can be treated with an insecticide. Remember that proper use of insecticides requires you to:

1. Monitor the turf frequently. Apply insecticides only when and where needed.
2. Protect beneficial insects and mites. Killing all insect pests is not necessary to prevent turf injury. A small insect pest population is needed to maintain beneficial insects.
3. Carefully time insecticide applications to coincide with susceptible pest life cycle stage(s). Frequently monitor pest activity to time the applications.
4. Avoid preventive treatments except when intolerable damage is certain to occur.
5. Take advantage of low-toxicity insecticides to manage pests while limiting the effect on non-target organisms.
6. Record and evaluate the results of insecticide applications.

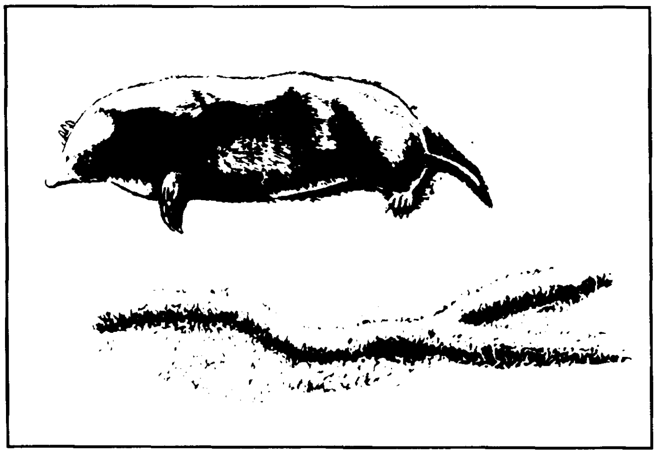
Specific product recommendations for insect problems are made on product labels and in reference publications such as "Insect, Weed and Disease Management for Commercial Turfgrass," Extension bulletin #E2178. Remember, *it is your responsibility to be certain that any pesticide you use is* *registered for use in Michigan and is applied as specified by the label.*

Vertebrate Pests

Vertebrates have backbones, and are large animals compared to insects. Several species feed on organisms living in turfgrass. Vertebrates that eat turf pests could be considered beneficial, except that they tend to injure turf in the process.

Several species of **birds** puncture pencil-thick holes in the turf with their beaks as they search for grubs and caterpillars. They also use their feet to rake away turf to expose prey. The blackbird family, including starlings, redwing blackbirds, and grackles, cause the most injury to turf.

Skunks, opossums, and **raccoons** likewise tear back sod to uncover grubs and other organisms living in the soil. Their activity is often the first sign of a large grub population. **Moles** also consume great numbers of grubs. These small mammals inhabit underground burrows. They resemble shrews and mice, but have greatly enlarged front feet for tunneling through the soil. Moles lack external ears and have very tiny eyes. As moles travel near the soil surface, they create upheaved ridges. These mole tunnels make mowing difficult and ruin the turf surface uniformity. Their activity makes moles a significant pest of high-maintenance turf.



The ridges caused by tunneling moles are difficult to mow over and ruin surface uniformity.

Vertebrate Management

Some people view vertebrate feeding as a valuable biological control of turf pests. More people, however, have a low tolerance of the resulting injury to turf. The easiest way to reduce vertebrate feeding injury on turf is to remove the source of food through IPM techniques. This tactic will not produce immediate results, but is a useful long-term vertebrate management option.

Various barriers and repellents have been marketed for vertebrate management on turf. These devises rarely provide an acceptable level of control for turf suffering from vertebrate activity. They may be useful, however, in preventing pests from becoming established near valuable turf stands.

Trapping is an effective way to remove established vertebrate pests. Trapping requires a fair amount of labor and knowledge about pest habits. Traps of various sizes and types are available to suit all types of wildlife pests. Remember, before trapping vertebrates, you must obtain a Wildlife Damage Investigation and Control Permit from your district office of the Department of Natural Resources. Mice (voles), rats, moles and chipmunks are the only vertebrates exempt from DNR regulation.

There are relatively few pesticides marketed to control vertebrates because they are hazardous to desirable wildlife, pets, and humans. Use poisonous products only when alternative measures fail to limit vertebrate damage to an acceptable level. Be especially cautious to place poisonous baits in a manner and during a time which avoids or limits exposure to nontarget organisms.

Review Questions—Chapter 9

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

1. Which of the key insects is mostly a problem on high-maintenance turf of golf courses?

2. Which turf insects could you expect to be a problem on home lawns in the upper and lower peninsulas of Michigan?

3. Which life cycle stage of Japanese beetle injures turf? Describe the injury and how to diagnose it.

4. For what purpose are adult Japanese beetle traps useful?

5. What is the best way to protect turf from European chafer in jury?

6. How do June and May beetles differ? Should populations require insecticide control, at what time of the year are insecticides effective?

7. Can turf support, without injury, more or less black Ataenius grubs than Japanese beetle grubs?

8. What stage(s) of the hairy chinch bug damages turf?

9. Describe the turf injury caused by chinch bug feeding.

10. Very few Lansing area lawns develop damaging levels of chinch bug. *(True or False?)*

11. Which stage of the bluegrass billbug injures turf? What type of grass do they usually attack?

12. How can you distinguish billbug damage from white grubs and necrotic ringspot?

13. What type of turf suffers the most injury from black cutworms?

14. Sod webworm caterpillars prefer which two types of grass?

15. Webworm damage is most likely to occur where predators and parasites have been suppressed by pesticides. *(True or False?)*

16. Describe the turf injury caused by ants. How does turf benefit from ants?

17. Why can healthy turf withstand more insect injury than stressed turf?

18. Name two reasons not to attempt to kill all insect pests in turf.

19. When should you use preventive treatments for insect pests?

20. Why do some people view vertebrate feeding beneficial to turf? How can it damage turf?

21. What type of animals tear up patches of sod in search of soil organisms? Name two ways to manage these animals.

22. Moles injure turf by eating grass roots. *(True or False?)*

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).

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.

Farm Chemicals Handbook. Richard T. Meister, editor.

Herbicide Handbook of the Weed Science Society of America.

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

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.

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

Pesticide Use and Safety

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

The New Pesticide User's Guide. Bert L. Bohmont.

The Mathematics of Turfgrass Maintenance. Published by the Golf Course Superintendents Association of America.

Pesticide Usage Reference Manual. Published by the Golf Course Superintendents Association of America.

Pesticide Emergency Information. Extension bulletin #AM37.

SARA Title III. Extension bulletin #E2173.

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

Grass Plant Identification

Diagnostic Services
101 Center for Integrated Plant Systems
Michigan State University
East Lansing, MI 48824
517-355-4536

Turf Care and Maintenance

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

Lawn Care: A Handbook for Professionals. Henry F. Decker and Jane M. Decker.

Turf Management for Golf Courses. James B. Beard.

1990 Recommended Turfgrass Cultivars for Michigan, B.E. Branham and M. Collins. MSU Department of Crop and Soil Science, File #22.4.

N-P-K Fertilizers. Extension bulletin #E0896.

Lime for Michigan Soils. Extension bulletin #E0471.

Environmental Education Specialist
Dr. Greg Lyman
584B Plant and Soil Sciences Bldg.
Michigan State University
East Lansing, MI 48824
517-353-0860

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

The Green Industry Resource Center
MSU Cooperative Extension Service of Oakland
1200 North Telegraph Rd
North Office Building, Second Floor
Pontiac, MI 48053
313-858-0887

Turfgrass Information Center, MSU Libraries
W212 Main Library
Michigan State University
East Lansing, MI 48824-1048
517-353-7209

Pest Management—General

Cooperative Extension Service 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 order, write or call:

Crop Advisory Team (CAT) Alert, Landscape Edition
B18 Food Safety & Toxicology Bldg.
Michigan State University
East Lansing, MI 48824
517-353-4951
www.msue.msu.edu/ipm

For diagnostic services, write or call:
Diagnostic Services
101 Center for Integrated Plant Systems
Michigan State University
East Lansing, MI 48824-1312
517-355-4536
www.cips.msu.edu

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

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

Controlling Turfgrass Pests. Malcolm C. Shurtleff.

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

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

Insect, Weed and Disease Management on Commercial Turfgrass. Extension #E2178.

Weeds of Turf

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

Problem Perennial Weeds of Michigan. Extension bulletin #E0791.

Annual Broadleaf Weed Identification. Extension bulletin #NCR090.

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

Dandelion Control in Lawns. Extension bulletin #E1452.

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

Weed Seedling Identification Video Tape. Extension video tape #VT026.

Turfgrass Diseases

Compendium of Turfgrass Diseases. Richard W. Smiley.

Management of Turfgrass Diseases. Joseph M. Vargas, Jr.

Smut of Turfgrass. Extension bulletin #E1329.

Rhizoctonia Brown Patch. Extension bulletin #E1537.

Typhula Blight (Gray Snow Mold). Extension bulletin #E1538.

Helminthosporium Melting-out and Leafspot of Grasses. Extension bulletin #E1539.

Dollar Spot of Turfgrass. Extension bulletin #E1540.

H.A.S. Decline of Annual Bluegrass (Anthracnose). Extension bulletin #E1541.

Fusarium Blight in Kentucky Bluegrass. Extension bulletin #E1542.

Fusarium Patch (Pink Snow Mold). Extension bulletin #E1543.

Fairy Ring. Extension bulletin #E1544.

Pythium Blight in Michigan. Extension bulletin #E1545.

Insects of Turf

Turfgrass Insects of the United States and Canada. H. Tashiro.

Sod Webworm: Biology and Control. Extension bulletin #E1480.

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

Garden's Alive (Natural Gardening Research Center)
Highway 48
P.O. Box 149
Sunman, IN 47041
812-623-3800

Mellinger's
2310 W. South Range Road
North Lima, OH 44452
800-321-7444

Praxis
Box 134
Allegan, MI 49010
616-673-2793

Professional Publications

Golf Course Management
1617 St. Andrews Drive
Lawrence, KS 66047-1707
913-841-2240

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

Landscape Management
7500 Old Oak Blvd.
Cleveland, OH 44130

Professional Organizations

Golf Course Superintendents Association of America
1617 St. Andrews Drive
Lawrence KS 66047-1707
913-841-2240

Lawn Service Association of Michigan
4463 Burssens
Warren, MI 48092
313-751-1190

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

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

Professional Lawn Care Association of America (PLCAA)
1225 Johnson Ferry Road, NE
Suite B-220
Marietta, GA 30067

Answers to Chapter Review Questions

Chapter 1

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. Resistant turf varieties, cultural practices, natural enemies, mechanical controls, and pesticides.
3. (1)Detection of agents injuring turf; (2)Identification of agents injuring turf; (3)Economic significance; (4)Selection of methods; (5)Evaluation.
4. Action can be taken before turf is seriously injured, and low level pest populations are often more easily managed than those at outbreak levels.
5. Turf insects. Close, careful visual inspection. Turf roll-back.
6. The time of the calendar year during which temperatures needed for pest development occur varies a great deal between years. Degree days is a precise measurement of the occurrence of threshold temperatures.
7. Soil conditions; exposure to sunlight; irrigation; fertilization; level of wear (also mowing height; compaction; exposure to road salt or chemicals.) These non-pest conditions affect turf health and vigor, which in turn affects the susceptibility of the turf to pest injury.
8. True.
9. Many turfgrass disorders are directly associated with a specific species or variety of grass.
10. Dull mowers crimp and tear grass blades. Leaf tips have a white cast then brown out. (See "Brown Spot" chart.)
11. Hot, dry weather induces natural dieback (the grass goes dormant.)
12. Most turf pests affect only grasses, or one type of grass. Chemical burn affects all types of grasses and other plants.
13. (1)Cost of replacing killed turf; (2)Loss of aesthetic quality or use; (3)Increased maintenance costs due to interference.
14. See page 8.
15. (1)Clients' tolerance of pest damage; (2)Visibility of the turf stand; (3)Action of natural controls. See page 10.
16. See page 10.
17. Was the turf protected from pest injury? Did unacceptable environmental contamination result? Were secondary (other) pest problems created? Was the program impractical or too expensive?

Chapter 2

1. A vigorous stand resists pest attacks and requires less pesticides. The root system reduces ground water contamination by holding onto pollutants, dust, and other particles in snow and rain. Healthy turf also efficiently breaks down pesticide.
2. True. See page 15.
3. For growth and tissue maintenance and to cool themselves (transpiration.
4. Warm/hot grasses cannot survive Michigan winter temperatures.
5. Photosynthesis is the food-making process in plants. At high temperatures (>75°F), the rate of photosynthesis decreases as oxygen use (respiration) increases, stressing the plant.
6. False. Some grass varieties tolerate shady conditions better than others.
7. An ideal soil has both nutrient/water holding capacity and air-filled pores (good characteristics of different particle sizes.)
8. High soil pH renders some nutrients insoluble and therefore unavailable to plants.
9. Nitrogen (N).
10. Too much nitrogen results in a thin root system relative to top growth, increased occurrence of disease, and reduced drought and wear tolerance.
11. A micronutrient is an element which is used by plants in a relatively small amount. Manganese, copper, boron, and zinc.
12. They contribute to the soil's organic matter and fertility. See page 18.
13. There is more genetic variation in blends and mixes. Such stands better resist pests and adapt to different environmental conditions.
14. Endophyte fungi are a biological control for turf insects. Grass containing endophytes should not be eaten by livestock.
15. False. New, tender grass plants could be injured by herbicide.
16. Apply a small amount ($\frac{1}{10}$-$\frac{2}{10}$") of water daily during the afternoon. See page 22.
17. Mowing lower than preferred by the grass species or variety reduces root growth and plant vigor.
18. Only when required for the use of the turf, or as a disease management tactic.
19. A complete fertilizer contains nitrogen, phosphorus, and potassium.
20. See the eight ways on page 25.
21. Air, beneficial organisms, and good drainage.
22. A light layer of thatch reduces soil compaction, moderates soil temperature, and limits evaporation of soil water.
23. See page 26.
24. (1)Grasses are plants that prefer full sun and may not receive enough light; (2)areas under trees can be droughty; (3)areas shaded by buildings may be too wet. See page 26.

Chapter 3

1. Short-term suppression techniques provide immediate pest control, but do not have a lasting impact. Long-term maintenance controls help to create a turf stand where pests are kept below injury threshold levels.
2. True.
3. True.
4. False. Ryegrass and tall fescue containing endophyte fungi repel or kill insect pests.
5. Proper mowing, irrigating, and fertilizing. Others include aerating, raking, and dethatching.
6. Slime mold; sod webworm,

chinch bugs, or cutworms, (see page 30).
7. Mice (voles), rats, moles and chipmunks.
8. Natural enemies require some pest individuals to live on. Their survival and population growth is directly related to the availability of pests.
9. Big-eyed bugs, ground beetles, damsel bugs, spiders, and ants.
10. Limit the destruction of beneficials by applying pesticides only when and where needed. Avoid broad-spectrum and highly toxic pesticides whenever possible.
11. Bt. Armyworm, cutworm, sod webworm, and other caterpillars.
12. Microbials are generally most effective as a long-term maintenance tactic. See page 32.

Chapter 4

1. True.
2. (1)labeled for the pest; (2)produces the desired level of control; (3)least disruptive to the environment; (4)not phytotoxic to turf; (5)economically practical; (6)compatible with other management practices; (7)acceptable to the public.
3. Type of pest controlled; pesticide chemistry; mode of action; formulation.
4. Less toxic pesticides have fewer regulations governing their use and less liability associated with pesticide accidents.
5. Fungicide. Rodenticide.
6. False. Broad-spectrum pesticides kill beneficial as well as pest organisms.
7. 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 perennial weeds because they will kill the underground plant portions.
8. Unmixed dry formulations are not as affected by temperature extremes. Liquid formulations are more easy and safe to handle when mixing.
9. WP; F or L; G.
10. True.
11. As nozzles wear the orifice size increases. Lessen wear by using hardened stainless steel, chrome-plated brass, or ceramic nozzle components. Nozzle screens also reduce wear.
12. Nozzle screens filter out the larger particles that cause nozzles to wear. Screens may change the rate of output.
13. Spot treatments; small area applications; treating areas inaccessible to larger units.
14. False.
15. (1)suction screen plugged; (2)suction hose cracked. See Common Sprayer Problems chart.
16. The delivery rate is not uniform the entire width of the swath. Overlapping ensures uniform distribution of material.
17. Trimming is a technique used to apply spray on the edges of turf stands at the desired rate. See page 42.
18. See page 42. Three years. One year.

Chapter 5

1. Area of a circle = pi (3.14) r^2.

$$3.14 \times (50')^2 = 7{,}850 \text{ sq ft}$$

$$\frac{x \text{ acre}}{7{,}850 \text{ sq ft}} = \frac{1 \text{ acre}}{43{,}560 \text{ sq ft}} \quad \text{OR}$$

$$x \text{ acre} = \frac{7{,}850}{43{,}560} = .18 \text{ acre}$$

2. Lot area = 25,000 sq ft
House area = 1,800 sq ft
Lawn area = 25,000 sq ft − 1,800 sq ft = 23,200 sq ft

3.

$$\frac{8 \text{ oz per}}{1{,}000 \text{ sq ft}} \times \frac{23.2}{1{,}000 \text{ sq ft units}} = \begin{matrix}185.6\\ \text{ounces}\end{matrix}$$

4. Multiply the distance between offsets by the width of the stand:

$$60 \text{ ft} \times 1{,}200 \text{ ft} = 72{,}000 \text{ sq ft}$$

$$x \text{ acres} = \frac{72{,}000 \text{ sq ft}}{43{,}560 \text{ sq ft per acre}} = 1.65 \text{ acres}$$

5.

E 250 − 160 = 90	I 250 − 90 = 160
F 250 − 150 = 100	J 250 − 70 = 180
G 250 − 140 = 110	K 250 − 70 = 180
H 250 − 120 = 130	L 250 − 90 = 160
	M 250 − 30 = 220
	offset length total 1,330 ft

Multiply the offset length total by the distance separating the offset lines (40 ft) to find the area of the pond.

$$1{,}330 \text{ ft} \times 40 \text{ ft} = 53{,}200 \text{ sq ft}$$

The total area of the field is:

$$1{,}000 \text{ ft} \times 500 \text{ ft} = 500{,}000 \text{ sq ft}$$

The area to be treated therefore is:

$$500{,}000 \text{ sq ft} - 53{,}200 \text{ sq ft} = 446{,}800 \text{ sq ft}$$

6. First find the average "radius" of the stand:

$$\frac{2{,}174 \text{ ft}}{36} = 60.39 \text{ ft}$$

To find the total area of the stand, figure the area of the "circle":

$$3.14 \times (60.39)^2 = 11{,}451 \text{ sq ft}$$

7a. Area of the test course:

$$50 \text{ ft} \times 7 \text{ ft} = 350 \text{ sq ft}$$

7b. your application rate (per 1,000 sq ft) is:

$$\frac{2.5 \text{ lb}}{350 \text{ sq ft}} \times \frac{1{,}000}{\text{sq ft}} = \frac{7.1 \text{ lb per}}{1{,}000 \text{ sq ft}}$$

7c. 5% of the label rate of 8 pounds is:

$$.05 \times 8 \text{ lb} = .4 \text{ lb}$$

The acceptable range is from 7.6 lb to 8.4 lb per 1,000 sq ft. Your application rate is just below the acceptable rate.

8a. your application rate (per 1,000 sq ft) is:

$$\frac{3.5 \text{ lb}}{500 \text{ sq ft}} \times 1{,}000 = \frac{7 \text{ lb per}}{1{,}000 \text{ sq ft}}$$

$$.05 \times 5 \text{ lb} = .25 \text{ lb.}$$

The acceptable range of delivery rates is from 4.75 to 5.25 pounds per 1,000 sq ft. Your application rate is too high.

8b. your application rate (per 1,000 sq ft) is:

$$\frac{2.6 \text{ lb}}{500 \text{ sq ft}} = 5.2 \text{ lb}$$

This delivery rate is within the acceptable range and you are ready for the application.

9. your output (per 1,000 sq ft) is:

$$\frac{1.3 \text{ gal}}{800 \text{ sq ft}} \times 1{,}000 = 1.63 \text{ gal}$$

your output (per acre) is:

$$\frac{1.3 \text{ gal}}{800 \text{ sq ft}} \times 43{,}560 = 70.8 \text{ gal}$$

10a. your output (per 1,000 sq ft) is:

$$\frac{.8\text{ gal}}{400\text{ sq ft}} \times 1{,}000 = 2\text{ gal}$$

10b. total pesticide for the job is:

$$30\text{ fl oz} \times \frac{2.8}{1{,}000\text{ sq ft units}} = 84\text{ fl oz}$$

11a. Using the "ounce method," your output with this equipment is 54 gallons per acre.

11b. area covered by one tankful is:

$$\frac{100\text{ gal}}{54\text{ gal per acre}} = 1{,}85\text{ acres}$$

11c. pesticide added per tankful is:

$$\begin{matrix}1.85\text{ acres}\\ \text{per tankful}\end{matrix} \times \begin{matrix}3\text{ lb per}\\ \text{acre}\end{matrix} = \begin{matrix}5.55\text{ lb per}\\ \text{tankful}\end{matrix}$$

12. The average flow rate of the nozzles is:

$$\frac{30.0+30.5+29.0+32.0+28.0+30.5}{6} = \begin{matrix}30\text{ oz}\\ \text{per minute}\end{matrix}$$

5% of the average flow rate is:

$.05 \times 30\text{ oz} = 1.5\text{ oz}$

Nozzles which deliver at a rate less than 28.5 ounces per minute and those that deliver greater than 31.5 ounces per minute should be cleaned or replaced. These include nozzles #4 and #5.

Chapter 6

1. True.
2. False. You must comply with label recommendations.
3. Cholinesterase is an essential chemical in the nervous system. Exposure to cholinesterase-inhibiting pesticides can lower an applicator's cholinesterase below a healthy level.
4. The chemical class carbamates (including carbaryl and oxamyl) and organophosphates (including diazinon, dursban, malathion, acephate).
5. False. It may take hours or days for symptoms to develop.
6. Headache, blurred vision, pinpoint pupils, sweating. See page 59. Symptoms of Pesticide Poisoning chart.
7. You should know the brand and chemical name, formulation, and rate of the pesticide you are transporting and applying.
8. See page 60.
9. (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.
10. Pesticide product labels, Syrup of Ipecac, cat litter or other absorbent material, fire extinguisher, extra pair of gloves. See Checklist of Safety Materials.
11. Triple- and power-rinsing makes pesticide containers non-hazardous so that they can be easily disposed of or recycled.
12. Toys, sandboxes, pet dishes, fish ponds, etc. See page 63.
13. On the pesticide label. Generally, people may enter after pesticide sprays have dried and dusts have settled.
14. The fire department should be notified because chemical fires require special handling and may produce extremely toxic smoke.
15. (1)There is a great potential for liability; (2)Stored pesticides degrade; (3)Pesticides can be banned from use; (4)Pesticide packaging may deteriorate.
16. The best way to dispose of mixed pesticide is to use it in a manner consistent with its label. Return unopened pesticide to the dealer or manufacturer, or offer it to another qualified applicator.
17. Stop the spill, contain the spill, and clean up the spill.
18. False. Once Regulation 637 is enacted by MDA, commercial applicators must comply with its guidelines. The guidelines concern applicator service agreements, protective gear, mixing/loading operations, posting requirements and more. See page 66.
19. Clients who understand the importance of healthy turf to pest management usually are more willing to provide proper maintenance.
20. (1)Membership in professional organizations; (2)Workshops; (3)Industry journals.
21. To keep up to date with the latest requirements for conducting your business.
22. The more experience and training your employees have, the fewer problems on the job.

Chapter 7

1. A weed is any plant that grows where it is not wanted.
2. True. Weeds are a result of poor turfgrass performance.
3. Weeds compete with turf for growing space, water, nutrients, and sunlight.
4. (1)Many weed species are aggressive plants; (2)Many weeds have tremendous seed production; (3)Many weed species are adapted to poor growing conditions.
5. See page 72. Monocot: crabgrass, sedges, wild garlic. Dicot: dandelion, chickweed, ground ivy.
6. (1)Seedling stage; (2)Vegetative stage; (3)Seed production; (4)Maturity stage. The developmental stage of a weed affects how it responds to management tactics.
7. Summer annuals (crabgrass, prostrate knotweed, common purslane) germinate in the spring and complete their life cycle by winter. Winter annuals (henbit, common chickweed, annual bluegrass) germinate in summer, overwinter, and complete their life cycle the following spring.
8. Growth habit, leaf venation, leaf shape, rooting structure, flower type.
9. False. Weeds with very different biology and management can resemble each other.
10. Usually there is more then one common name for a species of plant, but there is only one scientific name. To avoid confusion use weed scientific names.
11. True.
12. Both are dicot weeds.
13. The stems of knotweed grow low to the ground to form a dense mat.
14. They like alike except that the leaves of hairy crabgrass are twice as wide and are covered with hair.
15. Wood sorrel.
16. Yarrow.
17. True.
18. (1)Eliminate weeds before the seed production stage; (2)Get rid of weed seed sources near by valuable

turf; (3)Do not introduce weed-infested compost, mulches, or top soil.
19. Most weeds require light for germination. Longer turf shades the soil.
20. See page 83.
21. False. Such a lawn will be healthy, but not totally free of weeds.
22. False. No herbicide is completely harmless to turf.
23. Preemergence herbicides retard or prevent weed seed from germinating.
24. Leaf shape, leaf hairs, life cycle stage, etc. See page 85.
25. Heavy rain can cause soluble herbicides to leach through the soil or run-off the site. Light rain can carry a root-absorbed herbicide through the soil to the roots.

Chapter 8

1. A disease is a continual disturbance of normal plant function.
2. Infectious diseases are caused by microorganisms, such as fungi, and can spread between plants. Noninfectious diseases cannot be spread from plant to plant and are caused by non-living agents. Drought, soil compaction, nutrient deficiency, chemical burn.
3. Fungi enter plants through the outer "skin" or through wounds and natural openings. Fungi produce seed-like spores that are carried to other plants by wind, splashing water, and animals.
4. Nematodes consume plant cell contents. Nematode feeding impairs the ability of roots to absorb water and nutrients. Have the injured plant and surrounding soil analyzed in a laboratory.
5. The disease triangle is the relationship between the three factors required for disease development. Disease control eliminates one of the disease triangle components.
6. The disease-causing agents are mostly microscopic and therefore injury symptoms must be used for diagnosis.
7. Annual bluegrass.
8. The part of the fungi where spores are produced.
9. The disease produces small bleached-out spots about the size of a silver dollar. These spots may merge to form large, irregular areas.
10. Gray snow mold.
11. Leafspot is a warm-hot weather disease and melting-out is a cool-warm weather disease.
12. Necrotic ring spot.
13. Some type of nematode.
14. Pythium prefers weather that rarely occurs in Michigan: day time temperatures in the 90's and night temperatures above 75°F.
15. Red thread.
16. True.
17. Slime mold.
18. The environmental conditions of a microclimate may stress grass or favor disease development. Small differences in growing conditions can result in dramatic variation of disease infection among areas of a stand.
19. (1)Use grass varieties resistant to serious diseases; (2)Plant grass varieties best suited to site conditions and use.
20. Protection.

Chapter 9

1. Black cutworm, black ataenius beetle, ants. See Key Insect Pest table.
2. Hairy chinch bug, bluegrass billbug.
3. Grub (larval stage.) See page 99.
4. The traps are useful for monitoring adults, but not for pest control.
5. Protect chafer-infested turf from water stress by frequent irrigation.
6. June beetles are called May beetles by some people. June, because large grubs stop feeding in July and therefore are not affected by insecticides after that time.
7. More. The threshold for black Ataenius is 60-100 grubs per square foot of turf compared to 20-30 Japanese beetle grubs per square foot.
8. Both immature and adult chinch bugs feed on turf sap.
9. Chinch bug injury is characterized by irregular yellow patches, 2-3 feet wide, where the grass eventually dies.
10. True. One survey showed less than 5% of the lawns had damaging levels of chinch bug.
11. Grub (larval stage.) Bluegrass billbugs usually attack Kentucky bluegrass.
12. See page 102.
13. The closely-mowed grass of tees and greens.
14. Most grass varieties are susceptible, but bluegrass and bentgrass lawns are favored by sod webworm.
15. True. Webworm damage is most likely to occur where pesticides are used.
16. Ants are the natural enemies of turf pests, but build mounds that ruin turf surface uniformity.
17. Healthy turf can recover from injury more quickly and completely.
18. Killing all insect pests is not necessary to prevent turf injury. A small pest population is needed to maintain beneficial insects.
19. Use preventive treatments only when intolerable insect damage is certain to occur.
20. Vertebrates eat great numbers of turf pests, but injure turf in the process. See page 105.
21. Starlings, grackles, redwing blackbirds, skunks, raccoons, and opossums. (1)Remove the source of food; (2)Trapping.
22. False. They eat soil organisms including grubs.

PESTICIDE EMERGENCY INFORMATION

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

Current as of February 2002

Human Pesticide Poisoning

POISON CONTROL

From anywhere in the United States, call

1-800-222-1222

Special Pesticide Emergencies

Animal Poisoning

Your veterinarian:

____
Phone No.

or

Animal Health Diagnostic Laboratory (Toxicology) Michigan State University:

(517) 355-0281

Pesticide Fire

Local fire department:

____
Phone No.

and

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

(517) 322-1924

Traffic Accident

Local police department or sheriff's department:

____
Phone No.

and

Operations Division, Michigan State Police:

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

Environmental Pollution

District Michigan Department of Environmental Quality (MDEQ) Office Phone No.

____
Phone No.

and

MDEQ Pollution Emergency Alerting System (PEAS):

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

also

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

Michigan Department of Agriculture Spill Response

Pesticide Disposal Information

Michigan Clean Sweep, Michigan Department of Agriculture Environmental Stewardship Division.

Monday– Friday: 8 a.m.–5 p.m.

(517) 335-6529

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

National Pesticide Information Center

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

7 days a week; excluding holidays

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

1-800-858-7378

FAX: 1-541-737-0761

Revised by Carolyn J. Randall, *Pesticide Education Program, Michigan State University Extension*

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