Field Crop Pest Management A Guide for Commercial Applicators Category 1A
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Field Crop Pest Management

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A Guide for Commercial Applicators
Category 1A

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Bode, L.E., S. L. Pearson, D. Anderson, M. D. McGlamery, K. Steffey, H. W. and Kirby (eds). *Illinois Pesticide Applicator Training Manual Field Crops 39-2.* University of Illinois Urbana-Champaign, IL.

Iowa State University, University Extension. *Agricultural Crop Disease Management. Category 1C. Iowa Commercial Pesticide Applicator Manual.* Iowa State University Extension CS-11. May 1994. Ames, IA.

Iowa State University, University Extension. *Agricultural Insect Control. Category 1B. Iowa Commercial Pesticide Applicator Manual.* Iowa State University Extension CS-10. June 1995. Ames, IA

Minnesota Extension Service. Pesticide Applicator's Training Manual for Categories C and D. Agricultural Herbicides, Fungicides and Insecticides. University of Minnesota. St. Paul, MN.

Section of Communications and Technology in the College of Food, Agricultural, and Environmental Sciences, The Ohio State University. *Ohioline* < http://ohioline.ag.ohio-state.edu/lines/acrop.html >

Field Crop Pest Management

INTRODUCTION

How to Use This Manual

This manual contains the information needed to become a certified commercial applicator in Category 1A, Field Crops. This manual is intended for use in combination with the *Pesticide Applicator Core Training Manual* (Extension bulletin E-2195), available through the Michigan State University Bulletin Office. However, this manual would also be useful to anyone interested in learning more about field crop pest management.

Category 1A, Field Crops, covers the management and control of common pests in alfalfa, corn, dry beans, soybeans, small grains, and sugarbeets. The manual presents basic scientific information on pest life cycles and emphasizes protecting non-target organisms and preventing the development of resistance in pests.

The Category 1A certification exam is based on information found in this booklet. Each chapter begins with a set of learning objectives that help you focus on what you should understand from each chapter. The table of contents helps you identify important topics and understand how they relate to one another through the organization of headings and subheadings. As you prepare for the exam, read each chapter and answer the review questions. These questions are not on the certification exam. They are provided to help you prepare for the exam. Questions on the exam will pertain directly to the learning objectives.

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

This certification manual benefits the applicator and the general public. By learning how to handle pesticides correctly, applicators can protect themselves, others, and the environment from pesticide misuse. For more specific information on how to become a certified applicator in Michigan, refer to the beginning of the core manual (E-2195) or the Michigan Department of Agriculture's Web site, <http://www.mda.state.mi.us>, or call the MDA at 1-800-292-3939.

CHAPTER 1

INTEGRATED PEST MANAGEMENT

LEARNING OBJECTIVES

After completely studying this chapter, you should:

- Be able to define integrated pest management.
- Understand the importance of an economic threshold.
- Know the basic principles of field scouting.
- Know the three ways that cultural control methods work.
- Be able to define and give examples of a natural enemy.
- Understand the various types of pesticides.
- Understand the importance of preharvest interval, residues, reentry interval, phytotoxicity, and pesticide resistance.

Field crops are vulnerable to attack by pests. Pest damage can range from slight damage that has no effect on the value of the harvested product to severe damage that kills plants, significantly reduces yield of the crop, or reduces its market value. Field crop pests include insects and mites, weeds, diseases, and nematodes.

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

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

INTEGRATED PEST MANAGEMENT (IPM)

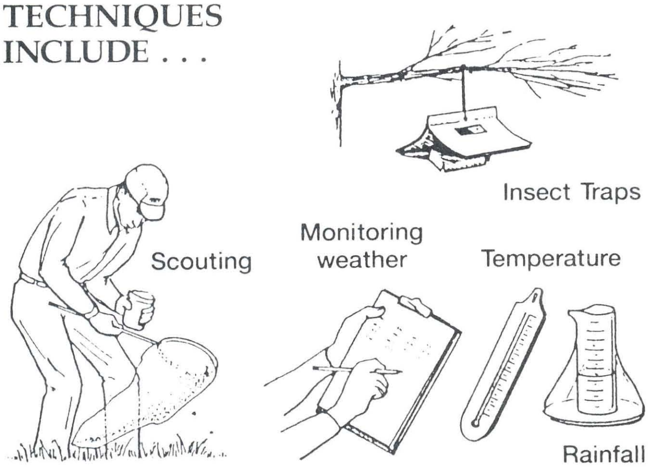
The goal of IPM is to use all appropriate tools and tactics to keep pest populations below economically damaging levels and to avoid adverse effects to humans, wildlife, and the environment. These tools include cultural, biological, and chemical control methods. Management decisions are based on information gathered about the pest problem and crop. Then you use a combination of control measures that best suits the problem.

What are these IPM tools and how are they used?

FIELD SCOUTING, MONITORING

Field scouting is an important part of any IPM program because it helps define the pest problems. Correct identification and location of each pest in a crop are necessary for a successful pest management program. These can be accomplished by regularly scouting fields. A scouting trip through a field reveals what pests are present, the growth stage of the pests and the crop, the location of the pest in the crop, whether the pests are parasitized or diseased, the pest population, if the population is increasing or decreasing, and crop condition. A scouting program should include accurately written records of field locations, field conditions, previous pest infestations, and control measures. Using this information, you can decide what control measures are needed and will be the most effective.

PEST MONITORING TECHNIQUES INCLUDE . . .



Remember the following basic principles when scouting:

- Take samples from several areas of the field.
- Select sample sites at random unless field conditions suggest uneven pest distribution.
- DO NOT sample in border rows or field edges unless indicated to do so for a particular pest.

Insect pests can be monitored in several ways. The most common methods are directly counting the number of insects present and/or estimating the amount of insect damage. Insect counts are usually expressed as the number of insects per plant or plant part (e.g., number of insects per leaf); insect crop damage is often expressed as percentage of the plant damaged (for example, percent leaf defoliation). Other scouting methods include collecting insects with a sweep net, shaking crop foliage and counting dislodged insects, and trapping insects.

ECONOMIC THRESHOLDS

An **economic threshold** is defined as the pest density at which action must be taken to prevent the pest population from increasing and causing economic damage. Economic thresholds are constantly changing. They vary between fields, varieties, and crop growth stages. Economic thresholds are a function of crop value and cost of control. In general, a high-value crop will have a lower economic threshold; less pest damage will be accepted and control measures must be taken sooner. If the control measures are expensive, the economic threshold is usually high. High control costs mean it takes more crop loss to justify the control action.

Economic thresholds are often referred to as **action thresholds**. When the pest population reaches the threshold, action is taken to reduce the population. For insects, an economic or action threshold is typically expressed as the number of insects per plant or the amount of crop damage.

CONTROL STRATEGIES

CULTURAL CONTROL

Cultural control uses farming practices to reduce pest populations. Implementing a practice such as tillage or crop rotation at the correct time can kill or reduce pest numbers or slow pest development. Like all other control strategies, cultural control requires an understanding of the pest and the crop. Cultural control measures are usually applied at the weakest stage of the pest's life cycle. Generally, cultural control methods are preventive actions rather than curative actions.

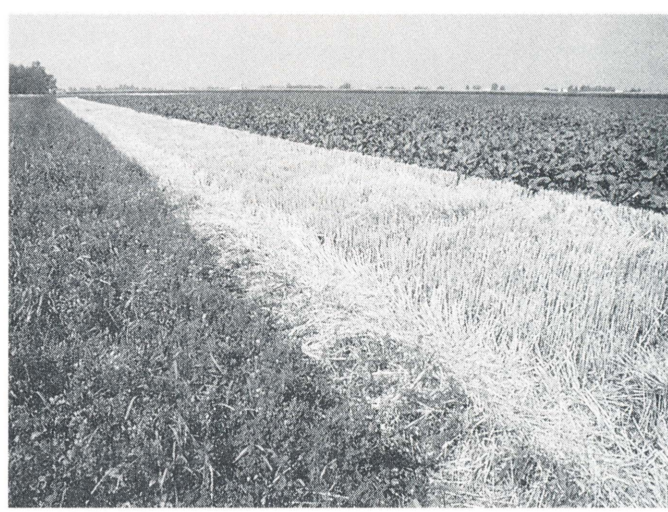
Cultural control methods work in three ways:

1. Prevent the pest from colonizing the crop or commodity.
2. Create adverse conditions that reduce survival of the pest.
3. Reduce the impact of pest injury.

PREVENTING COLONIZATION

Control measures that prevent colonization physically exclude the pest, reduce pest populations, prevent the pest from finding the crop, or disrupt the timing between the pest and the crop.

A. Trap crop—planting a small area with a preferred host to attract the pest away from the crop. Once in the trap crop, the pest can be destroyed or controlled.



Alfalfa and wheat strips border a sugar beet field.

B. Physical barriers—separating a pest and host with an object such as a wall to stop the pest from infesting. Example: in grain bins, it is extremely important to fill in all cracks and crevices with approved caulking material to prevent colonization by pests such as insects and rodents.

C. Crop rotation—a cycle in which different crops are planted in a field every year; the longer the rotation, the better the pest control. A crop rotation system helps control host-specific pests. A classic example of crop rotations is a corn-soybean rotation to control corn rootworms.

D. Delayed planting (timing)—changing the planting date so that the host is not available when the pest is present. Example: changing the planting date of winter wheat can control the Hessian fly. The adult fly is short-lived and requires wheat at a specific vegetative state for egg laying. Delaying the fall planting of winter wheat until after the Hessian fly adults have died offers year-round control of this pest. Another example is planting oats before May 15 to reduce the crop's exposure to aphids carrying barley yellow dwarf virus when the plants are young and more susceptible.

Red clover cover crop growing in spelt stubble.

E. Cover crops—utilizing plant competition by planting a secondary crop to prevent weeds from becoming established. Example: cereal grain cover crops provide a suitable environment for soybean seedling establishment while suppressing weeds.

CREATING ADVERSE PEST CONDITIONS IN THE CROP

Pests require specific living conditions. Cultural control methods can disrupt ideal pest conditions and so decrease pest pressure. Adverse pest conditions can be created by destroying the host plant, physically moving the soil, changing water management practices and spatial arrangement, and the plant's natural defense mechanisms.

A. Destroy crop residue, alternate hosts, and volunteer crops—eliminating the pest or pest habitat found in crop residue, or destroying alternate hosts of the pest found near or in the crop. Example: planting wheat into corn residue increases the risk of wheat scab because the pathogen infects both hosts.

Pests, particularly plant pathogens, can survive in a field on volunteer crops and alternate hosts. The survival of these pathogens provides a source of inoculum for the field. For example, wheat streak mosaic virus and its mite vector survive on volunteer wheat. Many fungi and bacteria build up on volunteer crops early in the season and surround and infect the crop later in the season.

B. Tillage—physically moving the soil around the crop. Tillage can destroy an insect, create physical and chemical changes in the soil that reduce pathogens, and destroy a weed's roots and disrupt nutrient uptake. All of these factors can reduce pest populations.

C. Water management—manipulating water to control a pest. For example, fungal pathogens that infect pests such as the velvetbean caterpillar in soybeans are easily spread by overhead sprinkler irrigation. Water management can also be used to promote healthy crops, which are better able to compete with weeds. Overwatering can increase the potential for plant diseases.

D. Spatial arrangement (seeding rate and row spacing)—changing the spatial arrangement of the crop to reduce pest populations. Example: when plant spacing and row width are reduced, soybeans outcompete weeds. On the other hand, close spacing may provide a favorable environment for disease to develop—for example, white mold in soybeans and dry beans.

E. Allelopathy—one plant species eliminates a competing plant species through the release of toxic chemical agents. Allelopathy has great potential in weed management. For example, in a conservation tillage system, leaving rye residues can reduce the number of weeds.

REDUCE PEST INJURY TO CROP

Cultural controls also utilize a plant's defense mechanisms to minimize pest damage. Planting pest-resistant crops, maintaining a healthy crop, timing harvest to reduce pest damage, and practicing pest-reducing storage techniques can reduce pest injury.

A. Host-plant resistance—the host plant's ability to tolerate pest pressure. Plants have defense mechanisms that allow them either to affect the pest or withstand the pest's damage.

B. Plant health—maintaining strong, healthy plants that are better equipped to out-compete weeds, fight disease, and withstand insect damage.

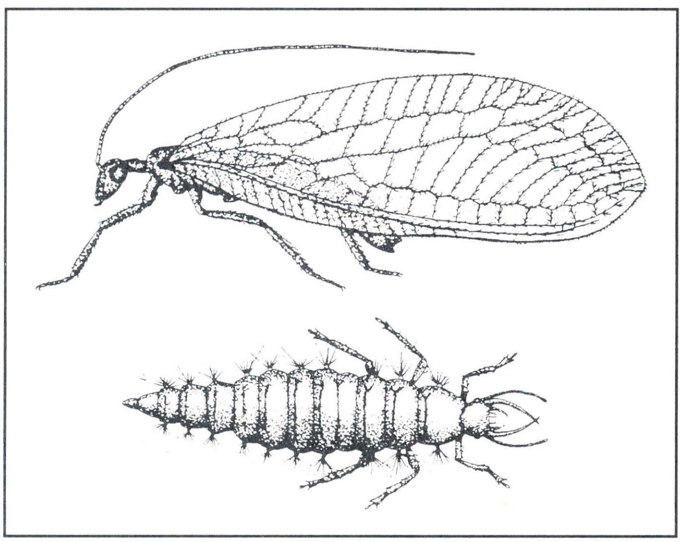
C. Harvest timing—changing the time when a crop is harvested to reduce pest impact on yield. For example, cutting alfalfa early can reduce the effects of alfalfa weevil or leafhopper damage. Cutting too early, however, weakens the roots and can make the plant more susceptible to root diseases.

D. Storage practices—handling, curing, and storage practices to prevent the spread of disease during storage. For example, low temperature and good ventilation are essential to minimize losses in potatoes.

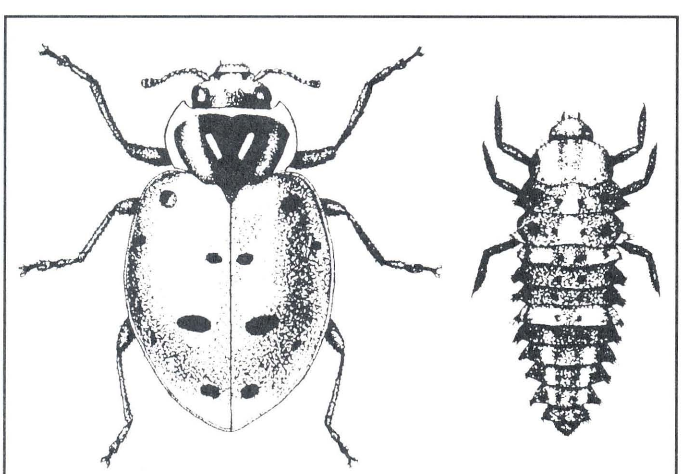
BIOLOGICAL CONTROL

Biological control is the use of living **organisms** to reduce a pest population. These beneficial (good) organisms are referred to as natural enemies. Predators, parasitoids, and pathogens are the most common natural enemies.

- **Predators**—other organisms that eat the pest. Predators are usually not specific about what they eat—they will eat a variety of pests.

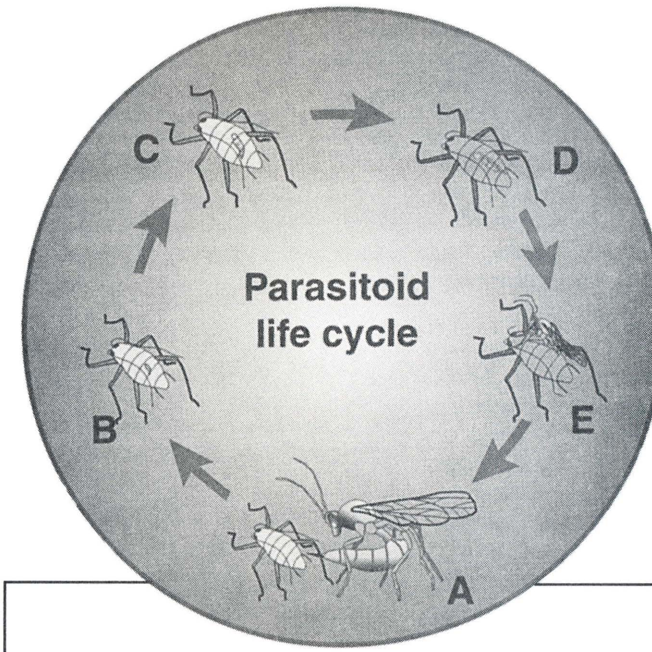


Green lacewing adults and larvae eat a variety of insects.



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

- **Parasitoids**—organisms that must live in or on another organism to develop. A parasitoid is usually an insect that develops and feeds inside another insect. An adult parasitoid lays an egg in or on a host insect. When the parasitoid egg hatches, the larva feeds on the host insect. Eventually, the developing parasitoid kills the host insect by eating it from the inside out. Common parasitoids include tiny wasps and flies. They are usually host specific.



A. Wasp lays egg in host (for example, an aphid).
B., C. As the host feeds and grows, so does the wasp larva.
D. Parasitoid kills then pupates within dead host.
E. An adult parasitoid emerges from the dead host.

- **Pathogens**—disease-causing organisms such as bacteria, viruses, and fungi that infect and kill the pest. Environmental conditions such as high humidity or high pest abundance allow naturally occurring pathogens to multiply and cause disease outbreaks (**epizootic**) that reduce a pest population. Some insect pathogens are manipulated to control specific pests. For example, the soil bacterium *Bacillus thuringiensis* (commonly known as Bt) can kill a variety of insects, including many caterpillars and mosquito and beetle larvae.

amples of insect biological control agents (natural enemies).

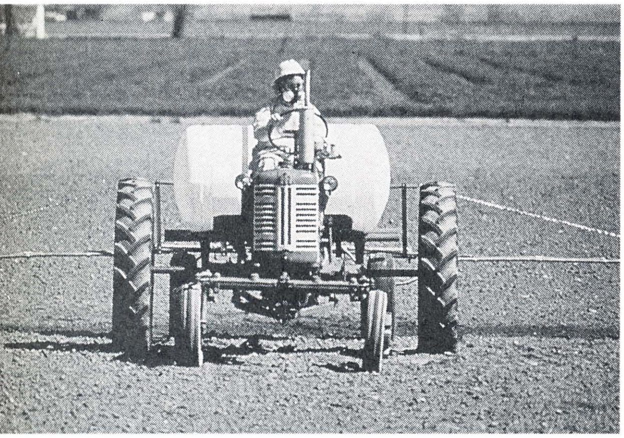
Natural Enemy	Pests Controlled
PREDATORS	
lady beetles	aphids, scale insects
green lacewings	aphids, mites, others
spined soldier bug	Colorado potato beetle, Mexican bean beetle
minute pirate bug	corn earworm eggs, mites
PARASITOIDS	
tachinid flies	beetles, caterpillars
ichneumonid wasps	caterpillars, leafrollers, weevils, others
braconid wasps	caterpillars, beetles, aphids
Trichogramma wasps	eggs of moths, such as European corn borer
PATHOGENS	
Bacillus thuringiensis	caterpillars, some beetle larvae
nuclear polyhedrosis viruses (NPV)	caterpillars
Beauveria bassiana (fungus)	caterpillars, grasshoppers, aphids
Nosema (protozoan)	caterpillars, beetles, grasshoppers

EMICAL CONTROL

Chemical control reduces a pest population through application of pesticides. The decision to use a pesti- e as part of an IPM program should be based on a uting program, pest identification, economic thresh- s, and the crop/pest life stage. When used properly, ticides provide effective and reliable control of most t species.

PES OF PESTICIDES

Pesticides used to control field crop pests are applied ier to the soil or to the plant foliage.



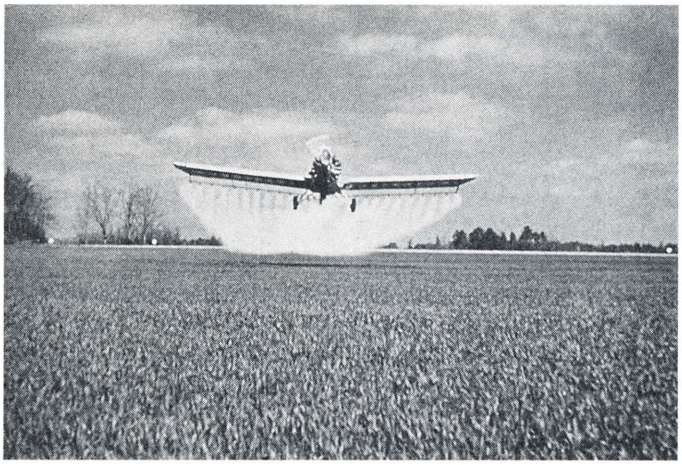
Soil-applied pesticides

Chemigation—applying a pesticide or fertilizer to the soil by injecting it into the irrigation system.

Insecticides—applied to prevent insect damage to the roots of corn and other crops. Insecticides can be applied by broadcast soil applications and soil incorporation before planting, applied in the seed furrow at planting, or broadcast before or after crop emergence.

Herbicides—applied to the soil surface and mixed into the soil before planting (**preplant incorporated**) or applied after planting but before crop emergence and not incorporated (**preemergence**).

Soil fumigants or nematicides—applied to the soil to control nematodes.



Foliar-applied pesticides

Most foliar applications are broadcast liquid pesticides applied directly to the crop or pest. They can be applied before damage occurs (**preventive**) or in response to damage (**curative**).

Insecticides—generally applied to control insects feeding aboveground on the crop.

Herbicides—applied to the weed foliage after the crop and weeds have emerged (**postemergence**).

Fungicides—can be applied to the crop before the disease appears (**protectant**) or to remove the disease after it appears (**eradicant**).

The following are special considerations to remember when using a pesticide to control your pest problem:

Preharvest interval—the minimum number of days needed between the last pesticide application and harvest. The Environmental Protection Agency (EPA) requires that all pesticide labels state the preharvest intervals for each crop. The preharvest interval is based partly on how long it takes the pesticide to break down. Observing the preharvest interval reduces pesticide residue on the commodity.

Residues—the pesticide that remains on the crop after an application. Ideally, a pesticide is present only long enough to kill the pest and then breaks down. Unfortunately, many pesticides do not break down completely before harvest. Therefore, for each pesticide registered for use on a food or feed crop, the EPA sets the amount of acceptable residue (tolerance) permitted on the harvested crop. The amount of residue relates to the preharvest interval and the pesticide application rate. Harvesting a crop during the preharvest interval or applying more pesticide than the label stipulates increases the potential for residues to exceed legal tolerance levels.

Reentry interval (REI)—the amount of time required after a pesticide application before a person can reenter a field without personal protective equipment (PPE). The reentry interval prevents unnecessary pesticide exposure. Only workers trained for early entry under the Worker Protection Standards (WPS) and wearing proper PPE may enter a treated area during the reentry interval. Refer to the Worker Protection Standards (WPS) for the regulations on informing workers about pesticide applications.

Phytotoxicity—when a pesticide damages the crop to which it is applied. Pesticide drift, excessive rates, mixing incompatible pesticides, and improper calibration can all cause phytotoxicity. Weather conditions can increase the degree of damage caused by phytotoxicity. For example, cooler weather followed by a period of bright, hot, dry weather can increase the likelihood of plant damage. Even using pesticides in accordance with the label can result in some phytotoxicity. Applying pesticides within recommended rates and following label instructions for mixing and applying help avoid this problem.

Pesticide resistance—the genetically acquired ability of an organism to tolerate the toxic effects of a pesticide (for example, malathion-resistant Indian mealmoths, atrazine-resistant common lambsquarter, and ALS-resistant ragweed). Resistance develops from overuse of the same pesticide or from overuse of a class of pesticides with a common mode of action (for example, organophosphates or ALS herbicides). Therefore, it is important to use pesticides only when necessary.

CHAPTER 1

Review Questions

Chapter 1: Integrated Pest Management

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

1. Define integrated pest management.

2. List three control strategies and give an example of each.

3. Define economic threshold.

4. A high-value crop will usually have a high economic threshold.

   A. True

   B. False

5. Field scouting is important because it helps determine pest:

   A. Presence.

   B. Location.

   C. Life stage.

   D. All of the above.

6. When scouting a field, you should sample only from:

   A. Border rows.

   B. One small area of the field.

   C. Randomly picked locations throughout the field.

   D. The edge of the field.

7. List three ways that cultural controls work.

8. Which of the following is an example of a biological control?

   A. Parasitoid

   B. Cover crop

   C. Pesticide

   D. Tillage

9. Host plant resistance is a form of:

   A. Biological control.

   B. Chemical control.

   C. Cultural control.

10. When plant species eliminate other plants by releasing toxic chemicals, it is called:

    A. Phytotoxicity.

    B. Allelopathy.

    C. Sanitation.

    D. Carryover.

11. After the growing season, destroying or removing crop residue can help reduce potential insect and disease problems the following year.

    A. True

    B. False

12. Pesticides are NOT part of an IPM program.

    A. True

    B. False

13. Herbicides that are applied and mixed into the soil before crop planting are called ______________ herbicides.

    A. Preemergence

    B. Postemergence

    C. Preplant incorporated

    D. Broadcast

14-18. Match the following scenarios with the type of pesticide application you would perform to combat the problem.

A. Preventive

B. Curative

14. ___ Very weedy cornfield; the corn is knee-high.

15. ___ A neighboring field is infected with a disease and you don't want it in your field.

16. ___ The MSU Crop Advisory Team alerts you to potential pest outbreaks in your area.

17. ___ You apply a fungicide to get rid of a disease.

18. ___ When scouting a field, you find that the potato leafhopper population is above the economic threshold.

19. How are tolerance and pesticide residues related?

20-23. Match the following with their definitions.

A. Predators

B. Biological control

C. Pathogens

D. Parasitoids

20. ___ Typically a fly or tiny wasp that develops inside another insect.

21. ___ Generalist (organisms that eat almost anything).

22. ___Using living organisms to control a pest.

23. ___ Viruses or bacteria.

24-27. Match the following words with their definitions.

A. Pesticide resistance

B. Reentry interval

C. Preharvest interval

D. Phytotoxicity

24. ___ Reduces unnecessary pesticide exposure to workers.

25. ___ Damage to a crop caused by pesticide application.

26. ___ Avoids harvesting pesticide-contaminated crops.

27. ___ Results from the continued use of the same pesticide.

CHAPTER 2

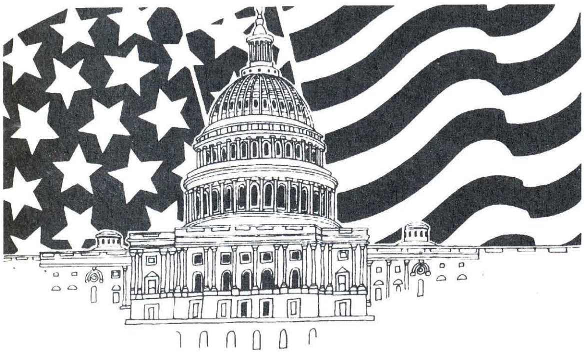
MINIMIZING PESTICIDE IMPACT

LEARNING OBJECTIVES

After completely studying this chapter, you should:

- Understand pesticide labeling.
- Understand the difference between point and non-point source pollution.
- Understand management practices to reduce ground-water contamination.
- Understand how to protect non-target organisms from pesticides.
- Understand how pesticide resistance develops and how to delay or prevent resistance.

STATE AND FEDERAL LAWS



The *Pesticide Applicator Core Training Manual* (E-2195) discusses federal and state laws governing the use and handling of pesticides. These federal laws include the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), the Occupational Safety and Health Act (OSHA), the Endangered Species Act, and the Worker Protection Standard (WPS). Michigan pesticide laws include the Natural Resources and Environmental Protection Act (Act 451, P.A. 1994, Part 83, Pesticide Control), Regulation 636, Regulation 637, and the Michigan Occupational Safety and Health Act (MIOSHA). Pesticide applicators and technicians should keep up-to-date copies of the laws and review their contents periodically. Copies of these laws can be obtained from Michigan Department of Agriculture (MDA) regional offices. Refer to the core manual (MSU Extension bulletin E-2195) to learn more about these and other laws affecting pesticide use.

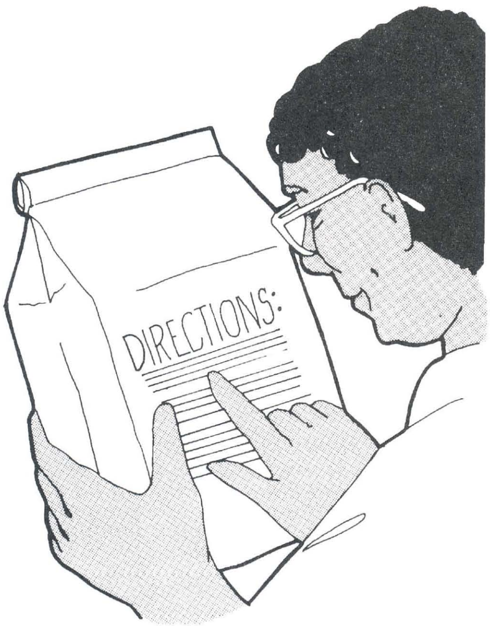
GUIDELINES FOR SELECTION AND USE OF PESTICIDES

The most important law regulating pesticide registration, distribution, sales, and use in the United States is the Federal Insecticide, Fungicide, and Rodenticide Act, or FIFRA. The Environmental Protection Agency (EPA) and the Michigan Department of Agriculture (MDA) administer FIFRA.

Pesticide labels provide use information such as safety precautions, application rates, sites where the pesticide can be applied, and target pests. They contain information to protect the applicator, the environment, and the crop while maximizing pest control. Pesticide labels are legal documents that must be followed. Always read the entire label and all supplemental labeling before using a pesticide. **Supplemental labeling** includes any information you receive from the manufacturer about how to use the product. Supplemental labeling is considered part of the pesticide label and may be supplied at the time of purchase or requested from the dealer. If an applicator applies a pesticide according to a supplemental label, a copy of the supplemental label must be in the applicator's possession at the time of application. Supplemental labels include special local needs labels (24c), emergency exemption labels (section 18), and use information issued by the pesticide manufacturer.

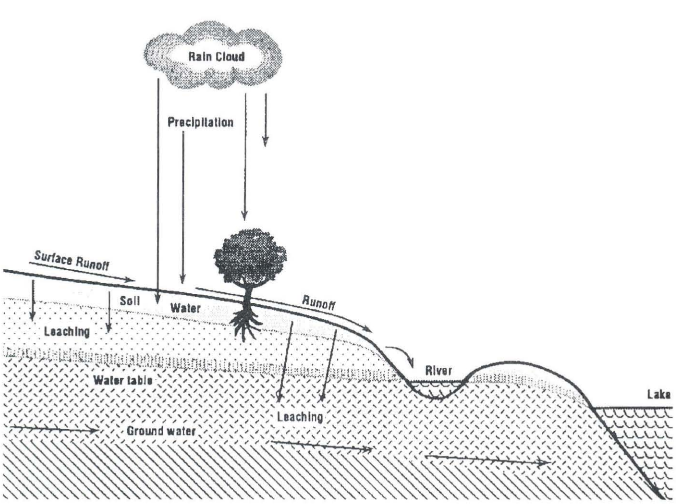
Always:

- Select pesticides labeled for use on your crop.
- Read and understand the label instructions and limitations before each use.
- Follow the application directions on the pesticide label.
- Contact your county MSU Extension office if you have questions or concerns about a particular pesticide.



PROTECTING OUR GROUNDWATER

Groundwater is the water beneath the earth's surface. It is found in the cracks and pores of rocks, and in the spaces between sand grains and other soil particles. Many people living in rural Michigan get their drinking water from wells. It is easy to see why you should be concerned about keeping pesticides out of groundwater.



Groundwater is always moving. Eventually, it reaches the earth's surface at natural places such as lakes, springs, and streams. Sometimes it is pumped to the surface from wells. Every year rain and snow seep into the soil, replenishing the groundwater. The depth at which you first find groundwater is referred to as the **water table**. The water table depth changes during the year, depending on the amount of water added and removed from the ground.

Both **surface water**—visible bodies of water such as lakes, rivers, and oceans—and groundwater are subject to contamination by point and non-point source pollution. When a pollutant enters the water from a specific source, it is called **point source pollution**. For example, a factory that discharges chemicals into a river is a point source. **Non-point source pollution** refers to pollution from a generalized area or weather event, such as land runoff, precipitation, acid rain, or percolation rather than from discharge at a single location.

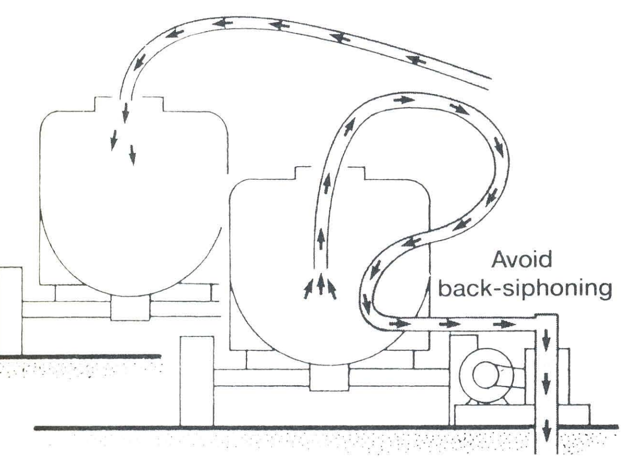
Keeping Pesticides Out of Groundwater and Surface Water

A pesticide that has not become a gas (volatilized), absorbed by plants, bound to soil, or broken down can potentially migrate through the soil to groundwater. Groundwater movement is slow and difficult to predict. Substances entering groundwater in one location may turn up years later somewhere else. A difficulty in dealing with groundwater contaminants is discovering the pollution source when the problem is occurring underground, out of sight. Also, microbial and photodegradation (by sunlight) do not occur deep underground, so pesticides that reach groundwater break down very slowly.

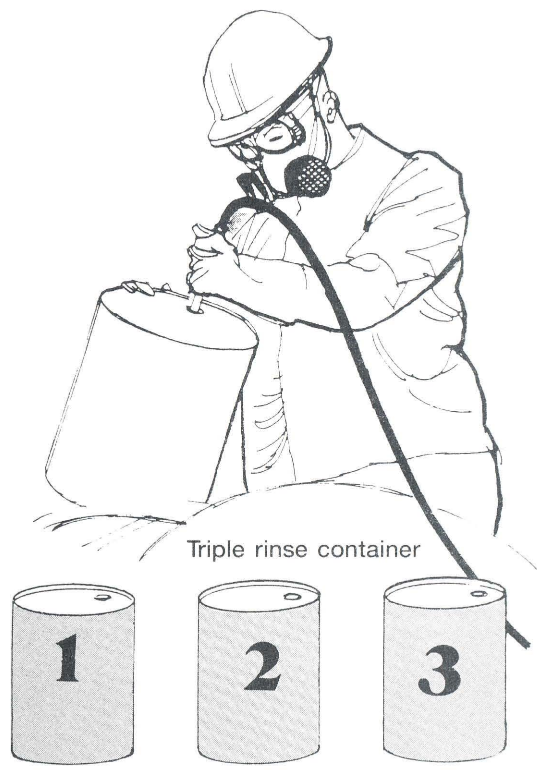
Cleaning contaminated groundwater or surface water is extremely difficult. Following certain practices can reduce the potential for pesticide contamination of groundwater and surface water:

- **Use integrated pest management.** Minimize pesticide use by utilizing other pest management practices to reduce or eliminate pesticide use.
- **Consider the geology of your area** when locating wells, mix/load sites, or equipment washing sites. Be aware of the water table depth and how fast water moves in the geological layers between the soil surface and the groundwater.

- **Select pesticides carefully.** Choose pesticides that are not likely to leach (move downward) in the soil into groundwater or run off into surface water. Pesticides that are very water soluble and not easily bound to soil tend to be the *most likely* to leach. Read pesticide labels carefully, consult the MSU Extension pesticide application guides, and/or seek advice from an MSU specialist or a pesticide dealer to choose the best pesticide for your situation.
- **Follow pesticide label directions.** Container and supplemental pesticide labels are the law. Labels provide crucial information about application rates, timing, and placement of the pesticide. Consult all labels before using the pesticide.
- **Calibrate accurately.** Calibrate equipment carefully and often to avoid over- or underapplication.
- **Measure accurately.** Carefully measure concentrates before placing them into the spray tank. Do not "add a little extra" to ensure that the pesticide will do a better job.
- **Avoid back-siphoning.** Make sure the end of the fill hose remains above the water level in the spray tank at all times. This prevents **back-siphoning** of the pesticide into the water supply. Use an anti-backflow device when siphoning water directly from a well, pond, or stream. Do not leave your spray tank unattended.



- **Consider weather conditions.** If you suspect heavy rain will occur, delay applying pesticides.
- **Mix on an impervious pad.** Mix and load pesticides on an approved impervious mix/load pad where spills can be contained and cleaned up. If mixing in the field, change the location of the mixing area regularly. A portable mix/load pad is required if you fill at the same location ten or more times per year.
- **Dispose of wastes and containers properly.** All pesticide wastes must be disposed of in accordance with local, state, and federal laws. Triple-rinse containers. Pour the rinse water into the spray tank for use in treating the labeled site or crop. After triple rinsing, perforate the container so it cannot be reused. Recycle all metal and plastic triple-rinsed containers. Otherwise, dispose of them in a state-licensed sanitary landfill. Dispose of all paper containers in a sanitary landfill or a municipal waste incinerator. Do not burn used pesticide containers. Burning does not allow for complete combustion of most pesticides, resulting in pesticide movement into the air; it is also a violation of state regulations administered by the Michigan Department of Environmental Quality. Contact your regional MDA office or local county Extension office for more information on pesticide container recycling in your area.



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

PROTECTING NON-TARGET ORGANISMS

Insecticides can kill **bees and other pollinating insects**. To reduce the chance of bee poisoning:

- **Select the least hazardous pesticide formulation for bees**. Dusts are more hazardous to bees than sprays. Wettable powders are more hazardous than emulsifiable concentrates (EC) or water-soluble formulations. Microencapsulated pesticides are extremely dangerous to bees because the very small capsules can be carried back to the hive. Granular insecticides are generally the least hazardous to bees.

- **Do not apply pesticides that are toxic to bees if the site contains a blooming crop or weed.** Remove the blooms by mowing before spraying.
- **Minimize spray drift** by selecting appropriate nozzles, adding an adjuvant, or postponing the application to a less windy time.
- **Time pesticide applications carefully**. Evening applications are less hazardous than early morning ones; both are safer than midday applications.
- **Do not treat near beehives.** Bees may need to be moved or covered before you use pesticides near hives.

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

Pesticides can also be harmful to **vertebrates** such as fish and wildlife. Fish kills may result when a pesticide (usually an insecticide) pollutes water or changes the pH of the water. Pesticides may enter water via drift, surface runoff, soil erosion, and leaching.

Pesticides may result in bird kills if birds ingest granules, baits, or treated seed; are exposed directly to the spray; drink and use contaminated water; or feed on pesticide-contaminated prey.

Endangered and threatened species are of special concern. Under the federal Endangered Species Act, every pesticide posing a threat to an endangered or threatened species or to its habitat must have a warning statement on the label. The warning provides instructions on how to safeguard the species when using the pesticide within its habitat.

POTENTIAL FOR PESTICIDE RESISTANCE

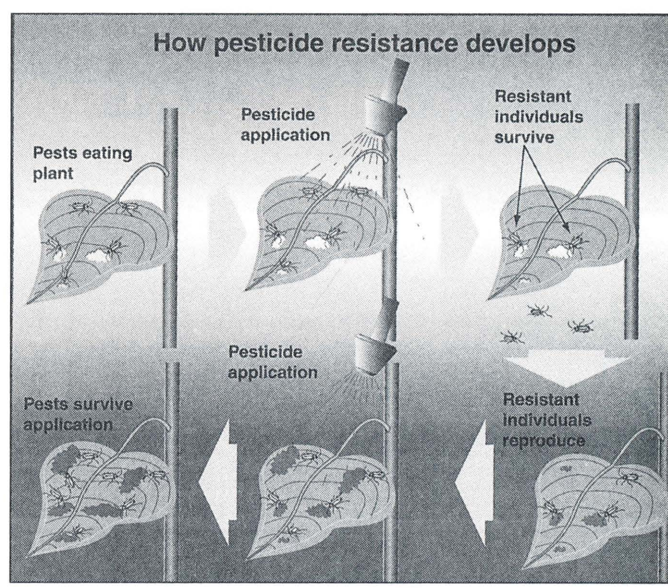
Pesticide resistance is a measurement of a pest's ability to tolerate the toxic effects of a particular pesticide. As the number of resistant individuals increases in a pest population, the original application rate or spray frequency no longer provides adequate control.

The Development of Resistance

Repeated applications of the same pesticide or of pesticides with a common mode of action give a pest population a chance to develop resistance. **Resistance** is an individual's (weed, crop, insect, etc.) ability to survive a specific pesticide application. There are four mechanisms of resistance. Resistant individuals:

1. Change the site of action so that the pesticide no longer functions.
2. Metabolize the pesticide. **Metabolism** is a biochemical process that modifies the pesticide to less toxic compounds.
3. Remove the pesticide from the site of action.
4. Break down (detoxify) the pesticide.

Resistant individuals survive when the pesticide is applied, and their offspring inherit the pesticide resistance. With each generation, more individuals in the population are resistant. Because the pesticide kills most of the non-resistant individuals, the resistant organisms make up an increasingly larger percentage of the surviving pest population. With each use of the pesticide, this percentage increases until the chemical is no longer effective against the pest.



In most cases, pests that are resistant to one pesticide will show resistance to chemically related pesticides. This is called **cross-resistance**. Cross-resistance occurs because closely related pesticides kill pests in the same way—for example, all organophosphate insecticides kill by inhibiting the same enzyme in the nervous system, cholinesterase. If a pest can resist the toxic action of one pesticide, it can often survive applications of other pesticides that kill same way.

Resistance Management

Resistance management attempts to prevent, delay, or reverse the development of resistance. A resistance management program includes:

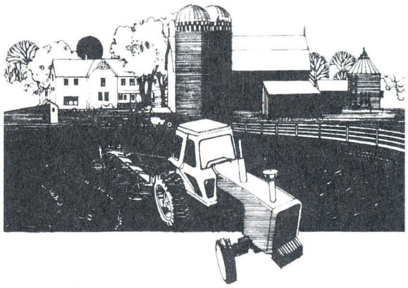
- **Using integrated pest management.** Combine cultural, mechanical, biological, and chemical control measures into a practical pest control program. For example, crop rotation can reduce the buildup of pests in a particular crop, reducing the number of pesticide applications needed. This reduces the advantage that resistant individuals have over non-resistant individuals and delays or prevents the buildup of resistance in a population.

- **Using pesticides from different chemical families with different modes of action.** Try to do this whether you apply pesticides against a pest once a year or several times within a treatment season. Generally, pests resistant to the first pesticide will be killed by the second.

- **Using pesticides only when needed, and using only as much as necessary.**

NOTIFYING NEIGHBORS

Good public relations are extremely important when applying pesticides. It is the joint responsibility of landowner and applicator to see that neighboring landowners are not subjected to acts of trespass or exposed to spray drift. As a matter of courtesy, it is a good idea to inform adjacent landowners, neighbors, and beekeepers in advance of any large-scale pesticide application.



If off-target pesticide drift is expected, Michigan Regulation 637 requires a pesticide applicator to have a drift management plan. A drift management plan should contain:

- A map of all areas where pesticide applications occur.

- A list of pesticide-sensitive sites located near an application area—for example, schools, day care facilities, or sensitive crops.

- Pesticide label and mandated restrictions that relate to setback provisions from sensitive areas.

- Information for persons in sensitive areas regarding the type of pesticide used, the method of application, and the applicator's plan to minimize pesticide drift.

A drift management plan should be used by private and commercial applicators as a communication tool to minimize adverse effects of off-target drift. For more information on drift management plans, contact the Michigan Department of Agriculture.

CHAPTER 2

Review Questions

Chapter 2: Minimizing Pesticide Impact

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

1. A pesticide label is a legally binding document.
   A. True
   B. False

2. What is supplemental labeling? Give an example.

3. A certified pesticide applicator may apply a pesticide labeled for use on alfalfa to soybeans only if:
   A. The same pest is present on both crops.
   B. Use for soybeans is also on the pesticide label.
   C. A lower rate is applied to the soybeans.
   D. The pest density is above the economic threshold.

4. Which of the following is NOT true about groundwater?
   A. It is always moving.
   B. It is measured by the water table.
   C. It is found at the earth's surface.
   D. It is used as drinking water.

5. When applying a pesticide according to the instructions on a supplemental label, you should have
   A. A Michigan Department of Agriculture official with you.
   B. The dealer's phone number with you.
   C. A copy of the Michigan pesticide laws with you.
   D. The label with you.

6. The part of the government that regulates pesticides in the United States is the:
   A. Environmental Protection Agency (EPA).
   B. Food and Drug Administration (FDA).
   C. U.S. Department of Agriculture (USDA).
   D. Occupational Safety and Health Administration (OSHA).

7. The least hazardous pesticide formulation for bees and other pollinating insects is:
   A. Emulsifiable concentrates.
   B. Granular.
   C. Wettable powders.
   D. Dusts.

8. The water table depth changes:
   A. In the summer.
   B. In the winter.
   C. Never.
   D. Throughout the year.

9. Rain and melting snow do NOT affect the water table.
   A. True
   B. False

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

11. List five ways you can reduce the risk of pesticides contaminating groundwater.

12. Which of the following is true about back-siphoning?

A. It does not occur with an IPM program.

B. It helps minimize pesticide drift.

C. It can lead to contamination of water.

D. It occurs when pesticides volatilize.

13. Which of the following is a proper method of disposing of an empty pesticide container?

A. Burn it.

B. Rinse and dispose in a licensed landfill.

C. Use it to hold other pesticides.

D. Bring to your local MDA office.

14. The impact of pesticides on bees and other pollinating insects can be reduced by applying:

A. Pesticides under favorable weather conditions.

B. When plants are in bloom.

C. Microencapsulated pesticides.

D. Broad-spectrum pesticides.

15. Pesticides are NOT harmful to fish and birds.

A. True.

B. False.

16. The ability of a pest to detoxify a pesticide and survive is:

A. Resistance.

B. Phytotoxicity.

C. Pollution.

D. Pesticide drift.

17. A resistance management program will __________ the development of pesticide resistance.

A. speed up

B. slow down

18. The ability of a pest to develop resistance to similar pesticides is called:

A. Mechanical control

B. Cross-resistance.

C. Cholinesterase.

D. Resistance management.

19. In Michigan, a drift management plan is required if off-target pesticide drift is likely to occur.

A. True.

B. False.

20. List four items to include in a drift management plan.

CHAPTER 3

APPLICATION EQUIPMENT

LEARNING OBJECTIVES

After completely studying this chapter, you should:

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

METHODS OF APPLICATION

The method you choose to apply a pesticide will depend on the nature and habits of the target pest, the site, the pesticide, available application equipment, and the cost and efficiency of alternative methods. Some common application methods are described below.

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

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

Foliar application directs pesticide to the leafy portions of a plant.

Spot treatment is application of a pesticide to small, discrete areas.

Soil application places pesticide directly on or in the soil rather than on a growing plant.

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

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

TYPES OF SPRAYERS

When selecting a sprayer, be certain that it will deliver the proper rate of pesticide uniformly over the target area. Most pesticide applications in field crops are done with a hydraulic sprayer at either high or low pressures.

Hydraulic Sprayers

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

Low-pressure Sprayers

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

Low-pressure sprayers do not deliver sufficient volume to penetrate dense foliage. They are most useful in distributing dilute pesticide over large areas.

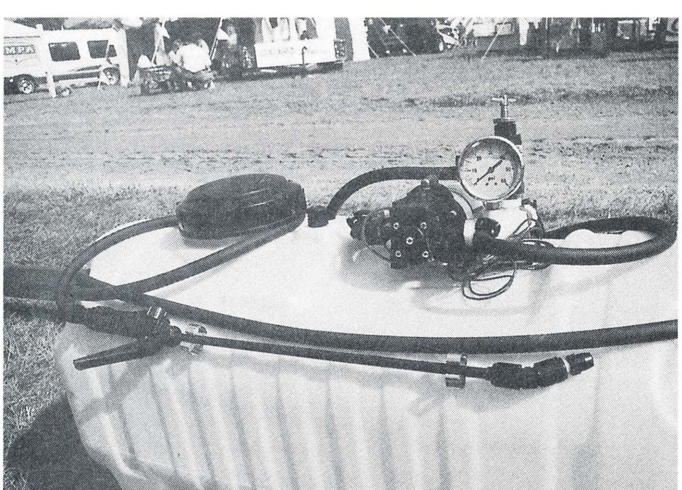
High-pressure Sprayers

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

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

PARTS OF A SPRAYER

To properly select, maintain, and operate your sprayer, you need to know its parts. The major components of a sprayer are tank, pump, agitator, flow control, and nozzles.



Sprayer tank, wand, pump and gauge.

Tanks

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

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

Agitators

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

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

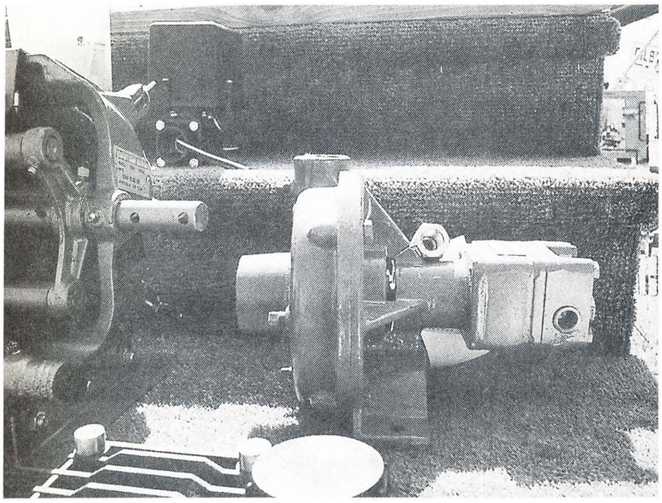
A mechanical agitator consists of a shaft with paddles and is located near the bottom of the tank. The shaft is driven by an electric motor or some other device powered by the tractor. This system is more costly than jet agitation. Mechanical agitators should operate at 100 to 200 revolutions per minute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

Pumps

The pump must deliver the necessary flow to all nozzles at the desired pressure to ensure uniform distribution. Pump flow capacity should be 20 percent greater than the largest flow required by the nozzles.

When selecting a pump, consider resistance to corrosive damage from pesticides, ease of priming, and power source availability. The materials in the pump housing and seals should be resistant to chemicals, including organic solvents.

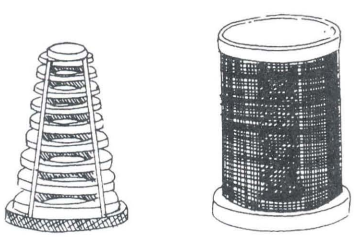
Pesticide sprayers commonly use roller, piston, diaphragm, and centrifugal pumps. Each has unique characteristics that make it well adapted for particular situations. Choose a pump that best fits your pesticide application program.



Centrifugal Pump.

Strainers

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



Strainers.

Hoses

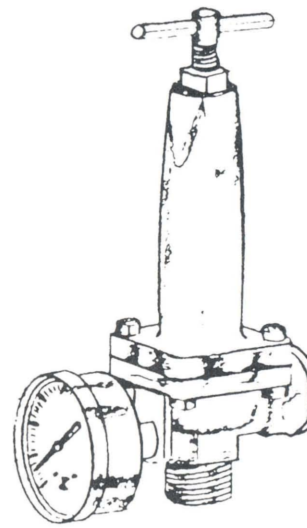
Use synthetic rubber or plastic hoses that have a burst strength greater than peak operating pressures, resist oil and solvents present in pesticides, and are weather resistant.

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

Pressure Regulators

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

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

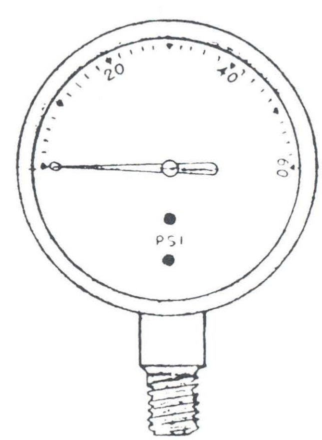


Pressure regulator.

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

Pressure Gauge

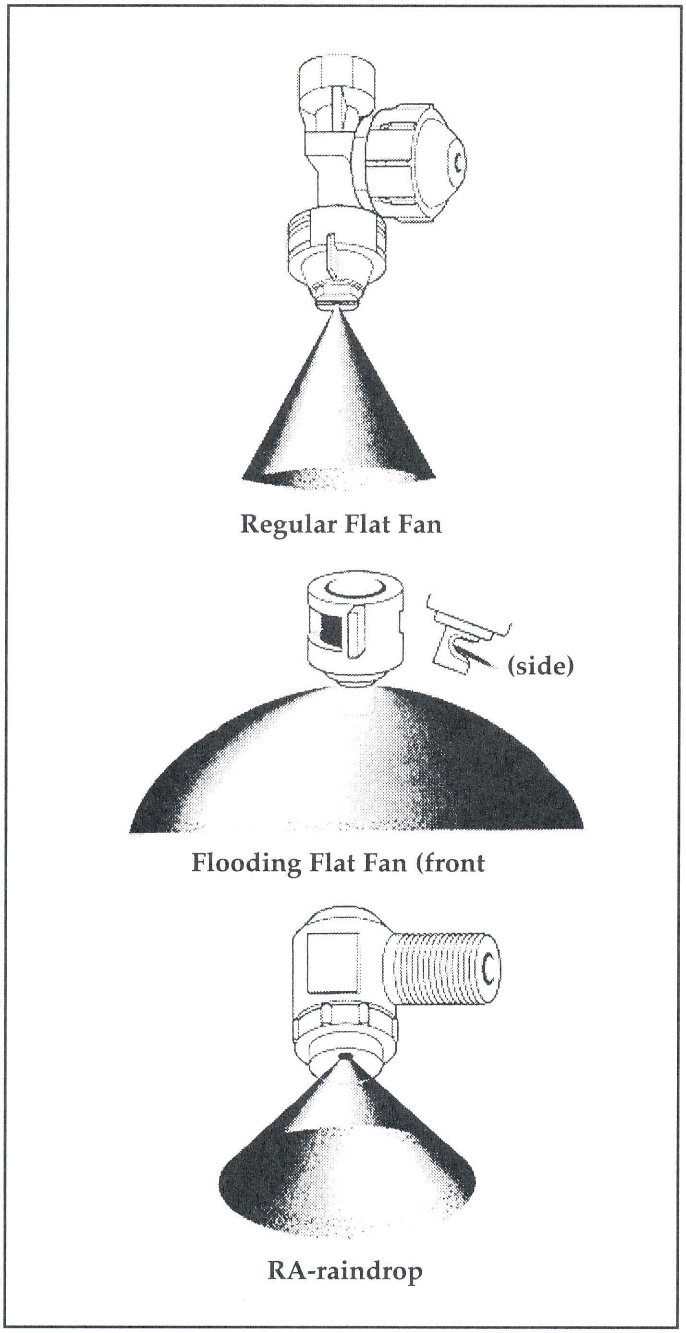
A pressure gauge is essential to every sprayer system to correctly indicate the pressure at the nozzle. Pressure directly affects the application rate and spray distribution. Pressure gauges often wear out because they become clogged with solid particles of spray material. A glycerine-loaded diaphragm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



Pressure guage.

Nozzles

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



Types of nozzles.

Regular Flat-fan Nozzle

Regular flat-fan nozzles are designed for broadcast applications and are sometimes used on high-clearance and pickup sprayers. They are typically used for foliar applications and require a 30 to 50 percent pattern overlap to obtain uniform coverage. Flat-fan nozzles are recommended for herbicides and insecticides where foliage penetration and complete coverage are not necessary.

Regular flat-fan nozzles produce a narrow oval pattern and medium droplets at pressures of 15 to 20 psi. Drift potential increases at pressures above 30 psi.

Flooding Flat-fan Nozzle

Flooding flat-fans are the most commonly used nozzles. They produce a wide-angle pattern that varies with pressure. At high pressure, the pattern is heavier in the center and tapers off toward the edges; at low pressures, they produce a uniform pattern.

Pressure also affects droplet size. Flooding flat-fan nozzles produce large spray droplets at low pressure and small droplets at high pressure. To control drift, flooding nozzles should be operated at between 8 and 25 psi.

Hollow-cone whirl chamber nozzle

The hollow-cone nozzle is used primarily to penetrate foliage for effective pest control when drift is not a concern. These nozzles produce small droplets at pressures of 40 to 80 psi that penetrate plant canopies and cover the undersides of leaves more effectively than spray from other nozzles.

Whirl chamber nozzles have two pieces. The first part is the whirl chamber, which squirts the material as it moves through the second piece, a disk. This results in a circular hollow-cone spray pattern.

Raindrop Nozzle

Raindrop nozzles are designed to reduce drift. This nozzle produces large droplets in a hollow-cone pattern when operated between 20 and 50 psi. The large droplets aid in drift control but may result in poor coverage by some foliar pesticides.

Nozzles are available in a variety of materials. Brass nozzles are inexpensive but wear rapidly. Stainless steel, nylon, and other plastic nozzles are wear resistant when used with corrosive or abrasive materials. Nozzles made of hardened stainless steel are the most wear resistant and expensive.

OPERATION AND MAINTENANCE OF SPRAYERS

Proper operation and maintenance of spray equipment will lead to safe and effective pest control, significantly reduced repair costs, and prolonged life of the sprayer.

Before Spraying

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

Fill the tank with water that does not have silt or sand in it. Keep the tank level when filling to make sure the quantity in the tank is correctly indicated.

Calibrate the sprayer before using. (Calibration is discussed in Chapter 4 of this manual.)

During Spraying

Frequently check the pressure gauge to make sure the sprayer is operating at the same pressure and speed used during calibration. Operate the sprayer at speeds appropriate for the conditions. Bouncing and swaying booms can cause application rates to vary. Periodically check hoses and fittings for leaks, and check nozzles for unusual patterns. If you must make emergency repairs or adjustments in the field, wear the protective clothing listed on the label as well as chemical-proof gloves.

After Spraying

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

GRANULAR APPLICATIONS

Granular applicators are designed primarily for soil applications and are available in various styles and sizes. Drop-through spreaders and rotary spreaders are the most common types of applications.

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

Drop-through Spreaders

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

Rotary Spreaders

Rotary spreaders distribute the granules to the front and sides of the spreader, usually by means of a spinning disk or fan. Heavy granules are thrown farther than lighter ones. A 6- to 8-foot swath width is common. Both power- and hand-driven rotary spreaders are available.

FIELD OPERATIONS

Pest control with pesticides relies on uniform application of the correct amount of product at the most efficient time. Clogged or worn nozzles, overlapping, and deviations in swath width can double applications or create skips in the treated area.

Dripping nozzles can cause crop damage during turns or when the sprayer is stopped for any reason. Use a positive shutoff, such as a high-capacity diaphragm check valve, to avoid dripping nozzles. Hydraulic and air-activated shutoff systems are more reliable but much more expensive.

GLOBAL POSITIONING SYSTEM (GPS) AND GEOGRAPHICAL INFORMATION SYSTEM (GIS)

Global positioning system (GPS) and geographical information system (GIS) technology has helped increase the accuracy of pesticide applications. This technology combines a tracking and guidance system with precise field mapping. Global positioning systems are based on the triangulation of worldwide satellite signals to determine exact field location. Geographic information systems are computer systems that interpret, manipulate, and display GPS information about a specific location. For example, a grower using a global position system can record the exact location of weedbeds in a field. A geographic information system can interpret this information and produce a map of the weed bed locations. This map can be used to apply pesticides directly to the weed beds the following year.

Geographic information systems can also be linked directly to application equipment and used to turn spray nozzles on and off. This results in pesticide applications only where necessary. Global positioning and geographical information systems are more often used with herbicide and fungicide applications.

CHAPTER 3

Review Questions

Chapter 3: Application Equipment

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

1. Which of the following methods of application mixes the pesticide into the soil?

   A. Soil treatment

   B. Soil application

   C. Soil fumigation

   D. Soil incorporation

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

3. What is one reason to use a directed-spray pesticide application?

   A. To minimize contact with beneficial insects.

   B. To get an evenly distributed application.

   C. To avoid back-siphoning.

   D. All of the above.

4. Pesticides can corrode certain materials from which spray tanks are made.

   A. True

   B. False

5. A spray tank should have:

   A. An opening for filling.

   B. A shutoff before the pump.

   C. A drain plug at the lowest point.

   D. All of the above.

6. To compensate for pump wear, pump flow capacity should ______________ the largest flow required by the nozzles and hydraulic agitation.

   A. Be less than

   B. Be equal to

   C. Be greater than

   D. Not affect

7. All spray pumps are resistant to the corrosive effects of pesticides.

   A. True

   B. False

8. Which of the following formulations requires the most agitation?

   A. Wettable powders

   B. Solutions

   C. Emulsions

   D. Liquids

9. Hydraulic agitation is accomplished by a shaft with paddles in the spray tank.

   A. True

   B. False

10. With paddle agitation, foaming can result if the shaft motor is operated:

    A. Too slow.

    B. Too fast.

    C. Too long.

    D. Too little.

11. With hydraulic agitation, foaming can result if the jet is:

A. Not operating.

B. Above the liquid level in the tank.

C. Below the liquid level in the tank.

D. All of the above.

12. As liquid moves from the spray tank to the nozzle, the strainer mesh should:

A. Remain the same.

B. Become larger.

C. Become smaller.

D. Not matter.

13. Strainers within the spray system are cleaned automatically by the movement of the spray solution.

A. True

B. False

14. The burst strength of spray system hoses should be greater than the:

A. Peak operating pressure.

B. Volume of spray delivered.

C. Length of the hose.

D. Temperature during the application.

15. What does the pressure regulator do?

16. Relief valves and pressure unloaders are two types of:

A. Pressure gauges.

B. Nozzles.

C. Pressure regulators.

D. Hose fittings.

17. Nozzle types are specific to the types of applications.

A. True

B. False

18. Low-pressure sprayers and high-pressure sprayers are most efficient if they have the same type of pump.

A. True

B. False

19. Low-pressure sprayers are very useful for:

A. Penetrating dense foliage.

B. Delivering dilute pesticide over large areas.

C. Spot treatment.

D. All of the above.

20. High-pressure sprayers can:

A. Provide high volume at high pressure.

B. Penetrate dense foliage.

C. Increase spray drift.

D. All of the above.

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

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

A. True

B. False

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

A. Sprayed on any site as long as it has plant material growing on it.

B. Sprayed on any bare soil.

C. Sprayed on a site that appears on the pesticide label.

D. Stored.

24. Granular applicators are designed primarily for:

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

25. How can global positioning systems and geographical information systems aid a pesticide applicator?

CHAPTER 4

CALIBRATION

LEARNING OBJECTIVES

After completely studying this chapter, you should:

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

INTRODUCTION

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

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

In this chapter, we provide formulas that are designed to make calibration easier for you. Some of these formulas have constants–i.e., numbers that remain the same whenever you use that formula. To make calibrations easier for you, we provide you with the constants.

CALIBRATION OF SPRAYERS

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

- The amount of product the sprayer delivers per acre.
- The number of acres you can spray per tank.
- The recommended rate of pesticide application.
- The amount of pesticide to add to the spray tank.

Variables That Determine the Spray Rate

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

Nozzle Flow Rate

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

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

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

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

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

Ground Speed of the Sprayer

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

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

To determine the new output after changing speed:

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

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

Precalibration Check of Nozzle Output

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

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

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

The average nozzle output is 40 ounces (240÷6).

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

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

Spray Pattern Uniformity

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

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

Broadcast Sprayer Calibration

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

1. Fill the sprayer tank approximately half full with water.
2. Determine the nozzle spacing or band width in inches and stake out the appropriate distance in the field according to the following table:

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

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

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

In this formula, 4,080 is a constant.

For example, if your nozzle spacing is 38 inches:

$$\text{Travel distance} = \frac{4080 = 107 \text{ feet}}{38}$$

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

3. With the sprayer turned off, drive the distance using the exact throttle setting and gear you plan to use during spraying. Be sure to *note the throttle setting and gear;* don't rely on a speedometer. Start the spray rig about 25 feet before the staked area so that you will be at typical field speed at the beginning of the measured distance. *Record your travel time in seconds.*
4. Adjust the pressure to the desired setting. Use slightly higher pressure when you use nozzle check valves and nozzle strainers.
5. With the sprayer stationary, collect and record the output (in ounces) from at least four nozzles for the travel time recorded in step 3. Because we already determined that the output of all nozzles is within 5 percent of one another in the precalibration check, it is not necessary to collect output from all nozzles.
6. *Determine the average nozzle output in ounces.*
7. The spray rate in gallons per acre is equal to the average nozzle output in ounces. For example, if the average nozzle output for the recorded travel time is 20 ounces, the spray rate is 20 gallons per acre.
8. If the spray rate is not reasonable for your particular spraying job, you can change output by one of three methods: adjust pressure, change speed, or replace nozzle tips. If only a minor change in output is needed, simply make an adjustment in pressure and determine the new average nozzle output. (Remember that operating pressure must be kept within the recommended range for the nozzle type so that the spray pattern is not distorted.) If a large change in output is necessary, make a change in travel speed. However, you must drive the designated field distance and determine the new travel time before calculating the average nozzle output. If it is impossible to obtain the desired output at an appropriate pressure and ground speed, you will need to change nozzle tips; in this case, you must repeat the precalibration check of nozzle output.

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

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

1. Fill the sprayer tank approximately half full with water.
2. The appropriate travel distance for 40-inch nozzle spacing is 102 feet; measure and mark this distance in the field.
3. Using the throttle setting and gear you plan to use during spraying, you find that it takes 14 seconds to drive 102 feet.
4. Adjust the pressure to the desired setting within the recommended pressure range of 15 to 30 psi for regular flat-fan nozzles; your chosen setting is 25 psi.
5. With the sprayer stationary, you collect the following outputs from four nozzles in 14 seconds:

Nozzle	Output (ounces per 14 seconds)
1	15.5
2	16
3	15.5
4	16
	Total = 63 ounces

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

$$\frac{63 \text{ ounces}}{4 \text{ nozzles}} = 16 \text{ ounces}$$

7. The spray rate, therefore, is equal to 16 gallons per acre.
8. The spray rate is lower than the recommended range of 20 to 30 gallons per acre stated on the label. The major change in output required should not be attempted by increasing pressure. You'll need to either decrease travel speed (in which case you'll also need to determine the new travel time) or increase nozzle tip size. Then determine the new average output.

Amount of Pesticide to Add to the Tank

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

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

You just learned how to determine the output of your sprayer.

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

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

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

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

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

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

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

Amount per tank = 10 x 2 = 20 quarts.

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

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

1. Calculate the area to be treated as follows:

   150 x 180 feet = 27,000 square feet, which is equal to 0.62 acres (27,000 ÷ 43,560)

2. Calculate the amount of water needed to cover 0.62 acres, using this formula:

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

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

   Cross-multiplying:

   (Y x 1) = (40 x 0.62) = 24.8 gallons to treat 0.62 acre

3. With a 4-gallon tank, we will need more than six loads of solution; let's plan to mix seven loads.

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

4. If we were spraying an acre, we would need 12 pounds of pesticide per 40 gallons of water (the per-acre output of our sprayer). However, we will be spraying only 3.54 gallons at a time. To determine the amount of pesticide to add per tank load, use the following formula:

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

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

Liquid Application on a Percentage Basis

Occasionally pesticide recommendations are expressed as amount of product per a specified volume of water. Such rates are expressed as "volume/volume" equivalents or as a percentage of product in the spray solution.

Example: Rate expressed as volume per volume. Pesticide C is recommended as a sanitary bin spray to control stored grain insects. Four gallons of product are recommended per 100 gallons of water. You want to prepare 75 gallons of solution. How much Pesticide C do you mix with the 75 gallons of water?

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

By cross multiplying:

100 x Y = 75 x 4

100 x Y = 300

Y = 3 gallons of Pesticide C per 75 gallons of water

GRANULAR APPLICATOR CALIBRATION

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

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

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

Drop-through Spreaders

Drop-through spreaders usually are calibrated using catch pans. Chain or wire catch pans beneath the spreader to collect granules as they are discharged. After covering a distance equivalent to 1/50 acre (871 sq. ft.), weigh the granules collected in the catch pan to determine the application rate. Use the table below to select the appropriate travel distance for your spreader.

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

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

$$\text{travel distance in feet} = \frac{871}{\text{swath width in feet}}$$

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

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

The step-by-step procedure for calibrating a drop-through spreader is:

1. Before starting, calculate how much material should be applied in the calibration area. You need to know only the recommended rate per acre and multiply this value by 1/50 (remember you will cover 1/50 acre in the calibration exercise).
2. Measure out the travel distance as determined by the swath width of the spreader.
3. Securely attach a collection pan to the spreader.
4. Set the feeder gate control to the setting recommended in the owner's manual or on the product label.
5. Calibration must be done with the same granules you intend to use during application.
6. Operate the spreader in the premeasured calibration area at the speed you intend to use during application.
7. Weigh the amount of granules in ounces in the collection pan. Be sure to use a scale that can accurately measure to the nearest ounce.
8. Compare the amount of product collected in the calibration area with the amount calculated in Step 1 above. If they are within 5 percent of each other, the applicator is properly calibrated; if not, you need to adjust the feeder gate control and recalibrate.

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

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

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

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

   19.2 ounces x 0.05 (5%) = 0.96 ounces

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

Review Questions

CHAPTER 4

Chapter 4: Calibration

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

1. Why is calibration of various spray systems essential?

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

3. What happens to the flow rate if you increase the nozzle pressure or use a larger nozzle tip opening?
   A. Has no effect of the flow rate.
   B. Increases the flow rate.
   C. Decreases the flow rate.

4. To double the flow rate, you must increase the pressure:
   A. Twofold.
   B. Threefold.
   C. Fourfold.
   D. Fivefold.

5. If the throttle setting remains constant, and the speed doubles, the amount of spray per acre:
   A. Remains constant.
   B. Doubles
   C. Is reduced by half.
   D. Is reduced by one quarter.

6. Measuring and comparing the output of each nozzle to the average output of all the nozzles allows you to determine if:
   A. The pump is functioning properly.
   B. Any nozzle is worn or clogged.
   C. It is the right nozzle for the job.
   D. The pressure is accurate.

7. If the spray pattern is not uniform, you should:
   A. Check the boom height.
   B. Check the spacing and alignment of the nozzles on the boom.
   C. Check the operating pressure.
   D. Do all of the above.

8. You determine the distance to travel for calibration by:
   A. Using a formula with a constant and the nozzle spacing.
   B. Reading it from the pesticide label.
   C. Reading it from the tractor handbook.
   D. Setting an arbitrary distance based on the type of pesticide.

9. Why is there an operating pressure range for each type of nozzle?
   A. To prevent nozzle clogging.
   B. To relieve strain on the pump.
   C. To keep the spray pattern from distorting.
   D. To calculate the travel distance.

10. In a broadcast sprayer calibration, if the nozzle spacing is 30 inches, what is an appropriate distance to stake out in the field?
    A. 101 feet
    B. 136 feet
    C. 256 feet
    D. 1 acre

11. In Question 10, it took 20 seconds to travel the appropriate distance. What does this travel time tell you?
    A. How long you should measure the output from nozzles.
    B. How long it will take to spray the entire field.
    C. How long it will take to empty the tank.
    D. Whether the sprayer is properly calibrated.

/hen calibrating a broadcast sprayer, you find that ie average nozzle output is 25 ounces for the record-d travel time. What is the spray rate in gallons per cre?

. 25 gallons per acre

30 gallons per acre

. 35 gallons per acre

. 40 gallons per acre

/hat can you do if your calibrated spray rate is less an the recommended rate stated on the label?

Increase the pressure.

Decrease travel speed.

Increase nozzle tip size.

B and/or C.

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

0.2 acres

0.5 acres

3 acres

5 acres

Question 14, how much pesticide will you need to ld per tank if the label recommends 4 quarts of oduct per acre?

10 quarts

20 quarts

30 quarts

40 quarts

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

A. Use a formula.

B. Read it off the spray tank.

C. Read the pesticide label.

D. All of the above.

17. The flow rate of dry granular pesticide products:

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

B. Remains constant from product to product.

C. Prevents accurate calibration.

D. Allows for less frequent calibration than liquid products.

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

A. 218 feet

B. 145 feet

C. 87 feet

D. 58 feet

CHAPTER 5

INSECT MANAGEMENT

LEARNING OBJECTIVES

After completely studying this chapter, you should:

- Understand how insects grow and develop.
- Understand the difference between simple and complete metamorphosis.
- Be able to identify general and major insect pests of alfalfa, corn, dry beans, soybeans, small grains, and sugar beets.
- Be able to describe the life cycles and habitats of the major field crop pests.

Insect damage reduces crop yield or quality, or contaminates the final product. Insects can also transmit plant diseases. To effectively control insect pests, you should understand how insects grow and develop.

GROWTH AND DEVELOPMENT

Growth

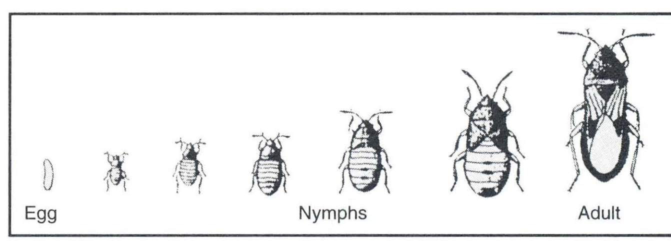
An insect's body is confined in a protective **exoskeleton**. This hard outer covering does not grow continuously. A new, soft exoskeleton is formed under the old one, and the old exoskeleton is shed—a process called molting. The new exoskeleton is larger and allows the insect to grow a little more. The new exoskeleton is soft and white at first, but it hardens and darkens in a few hours. After molting, which usually takes place in hiding, the insect resumes its normal activities.

Development

Insects are divided into groups according to the way they change during their development. The technical term for this change is ***metamorphosis***, which means "change in form." Pests of field crops undergo either simple or complete metamorphosis.

Group 1. Simple Metamorphosis

When insects that develop by simple metamorphosis hatch from their eggs, they resemble the adult insects except that the immatures, or ***nymphs***, do not have wings. Nymphs periodically molt, growing larger. After the final molt, nymphs become adults and generally have wings. Many pests of field crops such as potato leafhopper, sugarbeet root aphid, tarnished plant bug, and grasshoppers develop by simple metamorphosis. Nymphs and adults are often found together in the crop and usually eat the same food.

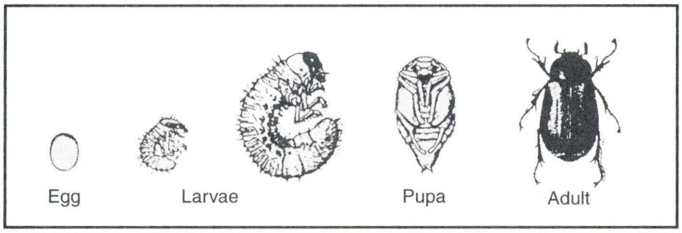


A plant bug is an example of an insect with simple metamorphosis.

Group 2. Complete Metamorphosis

Insects that develop by complete metamorphosis make a radical change in appearance from immature to adult. This major group includes beetles, moths, butterflies, flies, bees, and wasps.

In complete metamorphosis, newly hatched insects are called ***larvae***. Grubs, maggots, and caterpillars are types of larvae. The job of larvae is to eat and grow. Larvae molt four to six times and then change into ***pupae***. A pupa is an inactive stage of insect development. During pupation, the insect's body rearranges itself, resulting in a complete change in form from immature to adult insect. Insects undergoing complete metamorphosis have very different looking, larva and adult stages. Larvae and adults are often so different that they do not eat the same food and need different habitats.



A beetle is an example of an insect with complete metamorphosis.

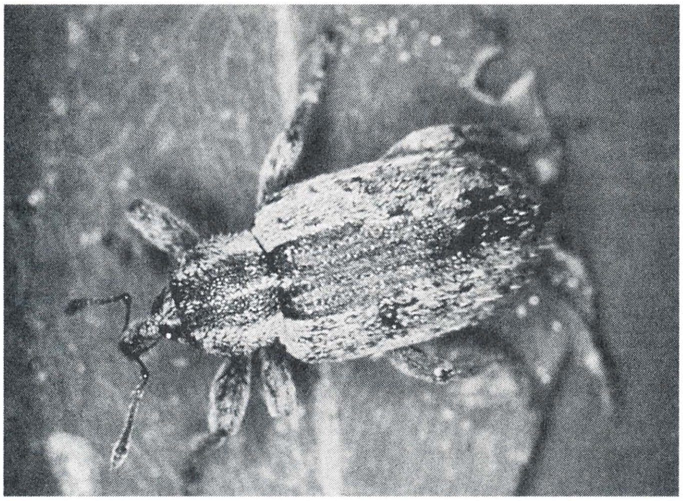
CONSIDERATIONS FOR PEST MANAGEMENT

The developmental stages of insects with complete metamorphosis support rather than compete with each other. It is as if they are two or three completely different animals with different needs and habitats, instead of a single species. The larvae feed and live in one habitat and sometimes leave that area to pupate a short distance away. The adult emerges and often eats a different food and lives in another area, returning to the larval feeding site only to lay eggs. An example is the European corn borer—the larva is a caterpillar living in corn; the adult is a moth. For this reason, species with complete metamorphosis are managed differently according to life stage, where each lives, and what each does. You will want to pay special attention to the following sections that discuss the life cycle and behavior of each insect pest.

INSECT PESTS OF ALFALFA

Alfalfa Weevil (*Hypera postica*)

Pest status: major pest.



Alfalfa weevil adult.

Characteristics and life cycle: This snout-nosed beetle was first found in Michigan in 1966. Adult weevils overwinter in alfalfa fields, fencerows, woodlots and other sheltered places. The adult is $^3/_{16}$ inch long with a broad, dark band down the middle of the back and chewing mouthparts at the end of a long, slender snout. Alfalfa weevils begin to feed on alfalfa in the spring as soon as growth starts. After two weeks of feeding, the female chews a hole and lays yellowish, brown eggs in the alfalfa stems. Eggs hatch in one to two weeks. The larvae are cream-colored to yellowish green with black heads and no legs and a distinct white stripe down the middle of the back. The larvae feed on leaf buds and terminal growing areas for three to four weeks. Full-grown larvae make cocoons on the leaves and pupate; adult weevils emerge between mid-June and mid-July. The new adults feed only a short time before preparing to overwinter and rarely cause much damage. There is one generation of alfalfa weevil per year.

Damage: Alfalfa weevil damage is a concern for the first cutting and the regrowth of the second cutting. Adults and larvae feed on leaves and stems. Small larvae feed on leaf buds and terminal growing areas. As larvae grow, they feed on the leaves, leaving only the veins. The majority of damage occurs between mid-May and mid-June. Severe infestations can affect regrowth and reduce yield, quality, and stand longevity.

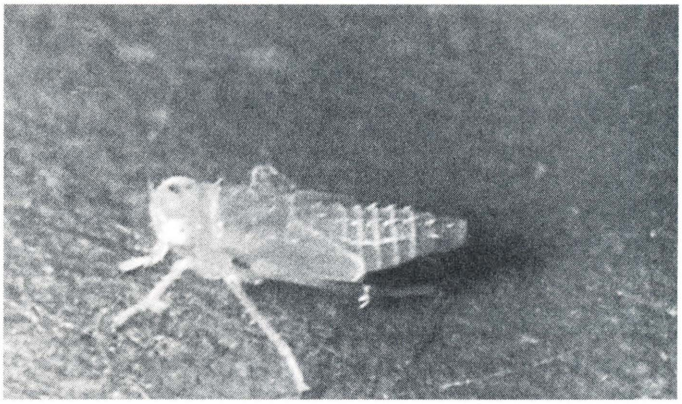
Control: *Cultural*—Cutting alfalfa at the bud stage will not only directly kill weevil larvae but also expose them to the environment and remove their food source.

Biological—In Michigan, at least three parasitic wasps attack adults and/or larvae. In most years, these biological control agents do an effective job of controlling alfalfa weevil, and pesticide applications are not necessary.

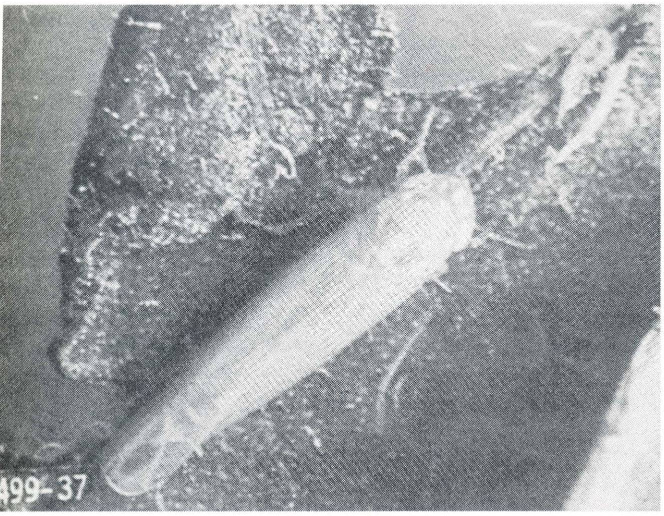
Chemical—Rarely required, a single insecticide application made at threshold will generally provide effective alfalfa weevil control. An insecticide application also kills the biological control agents, however, especially early in the season. Scouting methods and thresholds are available to make a management decision.

Potato Leafhopper (*Empoasca fabae*)

Pest status: key pest.



Potato leafhopper (nymph).



Potato leafhopper (adult).

Characteristics and life cycle: Potato leafhopper is the primary alfalfa pest each year. Adults migrate from the southern United States into Michigan in mid- to late May. The adult is a tiny, lime-green, translucent, wedge-shaped insect with sucking mouthparts. Eggs are laid in the stems and leaf petioles. A leafhopper nymph resembles an adult without fully developed wings. Potato leafhopper populations increase quickly, with a single generation taking only 21 days from egg to adult in a warm summer. There are multiple overlapping generations during the season.

Damage: Because potato leafhoppers migrate into the state, they usually attack only the second and third cuttings. Both adults and nymphs damage alfalfa by sucking plant fluids from the leaves. They inject a toxic substance as they feed that damages the plant cells and creates a characteristic V-shaped yellow marking on the leaf tip called "hopperburn." Heavy infestations cause leaves to yellow, curl, and die, may severely stunt plants, and reduce plant protein.

Control: *Cultural*—Establishing a healthy alfalfa stand is the first defense against the potato leafhopper. A number of potato leafhopper-tolerant and hairy alfalfa varieties show reduced symptoms. If potato leafhopper populations reach the economic threshold close to cutting time, the alfalfa may be cut to reduce nymph populations. Adults, however, are very active, strong flyers, and may fly away only to return later.

Biological—Generalist predators such as lady beetles and lacewings feed on potato leafhoppers. However, these biological control agents usually do not provide sufficient control to prevent damage under moderate to heavy potato leafhopper pressure.

Chemical—Early detection is the key to keeping potato leafhopper populations under control. Beginning in mid-June, sample fields using a 15-inch-diameter sweep net to determine infestation levels. If samples exceed the economic threshold (Table 5.1), insecticide treatment is justified or, if practical, the field can be cut immediately. Remember, don't wait until visible damage occurs to treat for potato leafhopper, because heavily damaged plants may not recover.

Table 5.1: Potato leafhopper economic thresholds

Plant height (inches)	No. leafhoppers/ 100 sweeps
Under 3	20 adults
3 to 8	50 adults
8 to 12	100 adults and/or nymphs
12 to 14	200 adults and/or nymphs

Alfalfa fields are home to a large number of insects, and blooming alfalfa fields attract honeybees. Typically, only alfalfa weevil and potato leafhopper are of concern in reducing alfalfa yield and quality. All of the insecticides used to control alfalfa weevil and potato leafhopper are highly toxic to honeybees. If an insecticide application is required, avoid application to a field in bloom, and do not allow drift onto blooming weeds or nearby beehives. Also, neighboring beekeepers should be notified when and where applications will take place.

INSECT PESTS OF CORN

Armyworm (*Pseudaletia unipuncta*)

Pest status: occasional.

Characteristics and life cycle: Each year adult armyworms migrate into Michigan. The adult armyworm is a gray-brown moth with a 1-inch wingspan and a white dot on the center of the forewing. Female moths prefer to lay eggs on grasses or grains. Full-grown larvae are 1½ to 1¾ inches long with two orange stripes along each side of the body and dark bands on the **abdominal prolegs** (the false, peglike legs on the abdomen of a caterpillar). There are two to three generations per year.

Armyworm damage in corn.

Damage: Armyworms feed on wild and cultivated grasses, especially corn and small grains. Severe defoliation results from larvae feeding on the leaves of seedlings and mature corn. Larvae may feed only on leaf margins or they may strip the plants, leaving only the stalks. Usually, the corn plant recovers from the damage as long as the growing tip has not been injured. Weedy corn or corn that has been no-tilled into pasture, fallow ground, or a cover crop is at greater risk for damage. Armyworms can also migrate in large numbers from small grain fields to adjacent cornfields after the grain has matured. These large larval migrations can destroy a cornfield in one to two days.

Control: *Cultural*—The elimination of grassy weeds from fields and field edges helps to reduce egg-laying sites and the potential for infestations and outbreaks.

Biological—In warm, dry weather, natural enemies usually keep armyworm populations under control.

Chemical—If armyworms deplete the grassy weed hosts and migrate , into a cornfield, an insecticide application may be necessary. Spot treatment of infested areas can provide sufficient control if the infestation is confined.

Fall armyworm (*Spodoptera frugiperda*)

Pest status: occasional.

Characteristics and life cycle: Native to the tropics, this late-season pest arrives from the Gulf Coast states. The adult moth is a mottled gray with a white spot near the tip of the forewing. Eggs are deposited in clusters on leaves and covered with hairs and wing scales from the female. The larvae vary in color but have three yellowish white lines from the head to tail and darker stripes on each side. Scattered along the body are black bumps (tubercles) with spines. A white inverted Y on the head capsule of the fall armyworm helps to distinguish it from other corn pests. Fall armyworm completes one to three generations per year and can not overwinter in areas where the ground freezes during the winter.

Damage: Fall armyworm causes more severe problems in late-planted corn. The larvae feed on developing leaves deep inside the whorl, occasionally killing the tassel before it emerges. Usually the plant will outgrow the damage if the tassel has not been injured. Larvae present late in the season feed on developing ears, causing damage similar to that of corn earworm.

Control: *Cultural*—Avoiding late plantings helps to reduce the risk of fall armyworm damage. Ear damage by fall armyworm can be more abundant in long-season hybrids.

Biological—Parasitoids and predators provide some suppression of fall armyworms.

Chemical—Chemical control is usually not an economical option.

Corn Flea Beetle (*Chaetocnema pulicaria*)

Pest status: common but rarely causes economic damage to field corn.

Characteristics and life cycle: This native beetle is very small (1/16 inch long), shiny, and black with enlarged hind legs. It jumps like a flea when plants are disturbed. Flea beetles overwinter in Michigan at the base of grasses along field edges. In the spring, they emerge and feed on other grasses and winter wheat if no corn is available. Eggs are deposited in the soil and the larvae develop in the soil feeding on corn roots.

Corn flea beetle (M. Rice, Iowa State University).

Damage: Adult corn flea beetles strip off the top layer of cells on a leaf, giving the leaf a scratched appearance. The most severe injury occurs during cold springs, when slow plant growth allows beetles more time to feed. The beetle also may transmit a bacterial disease, Stewart's wilt. Stewart's wilt can dramatically reduce yields on susceptible hybrids and lines of sweet corn, though it rarely causes a problem in field corn.

Control: *Cultural*—Avoid early planting of susceptible hybrids or plant resistant sweet corn hybrids.

Chemical—Seed corn producers can be affected by Stewart's wilt and may need to use insecticides to control corn flea beetles.

Corn Rootworm

Pest status: occasional to common, depending on species.

Characteristics and life cycle: Three species of corn rootworm beetles occur in Michigan.

1. **Northern corn rootworm** (*Diabrotica barberi*)

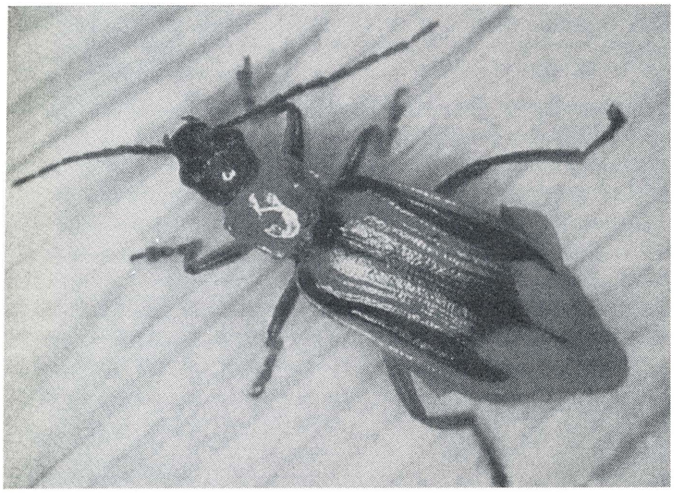
The $1/4$-inch-long adult is pale to dark green with no markings on the wing coverings.

2. **Southern corn rootworm** (*Diabrotica undecimpunctata howardi*)

Also known as the spotted cucumber beetle, the adult is yellow-green with 12 black spots on the wing covers. The southern corn rootworm is more commonly a garden pest.

3. **Western corn rootworm** (*Diabrotica virgifera virgifera*)

This is the most common and serious pest species of rootworm in Michigan. Western corn rootworm adults are light yellow to light green with three black stripes on the wing covers that tend to blend together toward the back of the beetle.



Western corn rootworm (adult).

The northern and western corn rootworms overwinter as eggs in the soil and begin hatching in late May, with peak hatch in June. The white larva has a brown head and three pairs of small legs behind the head. After feeding on corn roots, the larvae pupate in the soil, and adult beetles begin to emerge in late June, with peak emergence in August. Each female can deposit as many as 1,000 eggs in the top few inches of soil, primarily in cornfields. Egg laying goes on until the first frost. During dry years, western corn rootworms eggs may be laid up to 1 foot deep. Corn rootworms have one generation per year.

Damage: ADULT—The adult beetles are usually active during silking and eat (clip) silks and pollen. If the adults emerge before pollen shed and begin feeding on the silks, poor kernel fill can occasionally result. Typically, the adults do not cause economic damage in field corn.

LARVAL—Corn rootworm larvae feed on root hairs, layer roots, and growing tips. In young plants, the damage can reduce plant stand and plant vigor. Root destruction also causes plant stress, decreases plant stability, and creates entry wounds for plant pathogens. Economic loss due to corn rootworm larval feeding depends on the number of larvae, the size of the root mass, soil moisture, nutrients, hybrid, and weather conditions. Root regeneration and establishment of brace roots can be inhibited if moisture and heat stress are present during peak root feeding. This may result in severe lodging. After the larvae pupate and the lodged plants try to regenerate roots, the plants may then straighten, resulting in a "gooseneck" appearance. The end result may be extreme yield reduction and harvest complications.

Control: ADULTS: Adult corn rootworms rarely cause economic damage, and it is not common practice to control them.

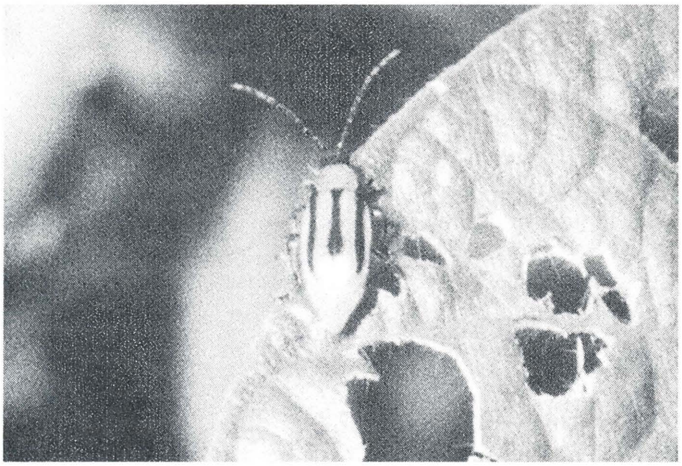
LARVAE: **Cultural**—In mid- to late summer, adult corn rootworms mate and lay eggs in the soil. These eggs overwinter, and the following spring, the larvae emerge and feed on corn roots. If no corn roots are available, the larvae will die in a few days. Crop rotation, therefore, is a very effective method of preventing economic loss from corn rootworm damage, and it eliminates treating first-year corn with soil insecticides.

Lodging caused by corn rootworm damage.

Chemical—Most growers who plant corn after corn apply a soil insecticide at planting. A product with a long residual, six to 10 weeks, is needed, because there is a four-to-six week time lapse between planting and corn rootworm egg hatch. Also, larvae feed for three to four weeks. Soil insecticide applications typically reduce larval survival by only 50 percent. Field scouting for adults the previous year will help to determine the corn rootworm pressure and whether a soil insecticide application will be needed the following year.

Western corn rootworm damage in first-year corn

A new behavior in the western corn rootworm, first noticed in Illinois, has also been found in Ohio and southwestern Michigan. The female western corn rootworm lays a portion of its eggs in other crops, such as soybeans. In strict corn-soybean rotations, the eggs hatch into corn the following spring and larvae feed on the roots. In parts of Illinois and Indiana, the rootworms cause extensive root injury, lodging, and yield reduction in rotated corn. To date, crop rotation is still an effective control option against corn rootworms in most parts of Michigan.



Western corn rootworm feeding on soybean (M. O'Neal, Michigan State University).

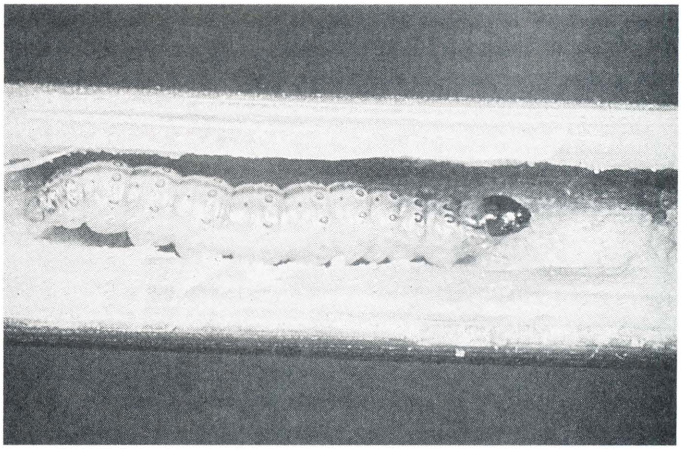
Field scouting and population sampling with yellow sticky cards placed just above the soybean canopy can indicate a potential problem for rotated corn. The mere presence of a few western corn rootworm beetles in soybeans does not mean that economic damage will occur if the field is rotated to corn. This is an emerging problem in Michigan; in 2000 it was confined to the southwestern part of the state. A soil insecticide may be needed in rotated corn if large numbers of beetles are trapped in the previous crop or if you are targeting other soil pests. Consult your county agriculture agent for updated information on scouting and treatment recommendations.

Yellow sticky card trapping corn rootworms in the soybean canopy (M. O'Neal, Michigan State University).

European Corn Borer (*Ostrinia nubilalis*)

Pest status: common.

Characteristics and life cycle: Introduced from Europe in the 1900s, the European corn borer has adapted to many hosts, including many agronomic and horticultural crops, and environmental conditions. European corn borers overwinter as full-grown larvae in corn debris and stubble on the soil surface. The larvae pupate in late April and May. Beginning in mid-June, adult moths emerge and mate in tall grasses. The female moth is 1 inch long with yellow-brown and medium brown, wavy lines on the wings, and a swollen abdomen when eggs are fully developed. The males have similar darker wing patterns and a hairy tuft at the tip of the abdomen. After mating, the female lays eggs on the undersides of corn leaves. Each egg mass contains 15 to 40 white eggs that overlap like fish scales. The egg mass darkens just before hatching, when the black heads of the larvae become visible ("black head" stage). The larvae hatch and feed on leaves, eventually moving to the whorl. Mature larvae are $^3/_4$ to 1 inch long with a medium to dark brown head and a creamy-white to gray body. As the larvae mature, they enter the stalk to feed, then pupate. Adult moths emerge in late July or early August to congregate and mate in grassy areas. The females then migrate to the cornfields and deposit their eggs on the leaves in the ear zone of the silking corn. This second generation of European corn borer feeds on the developing ears, causing kernel damage, or enters the stalk, ear shank or cob. Whether there are two or three generations per year depends on the temperature.



European corn borer in a cornstalk.

Damage: First generation European corn borer larvae feed primarily in the whorl and leaves, giving them a "shot-hole" appearance. Larger larvae feed within the leaf midrib and burrow into the stalk. Both of these activities disrupt normal movement of plant nutrients and water and have potential to reduce yield. Older fields with the tallest corn plants (i.e., early planted) are more likely to suffer first generation damage.

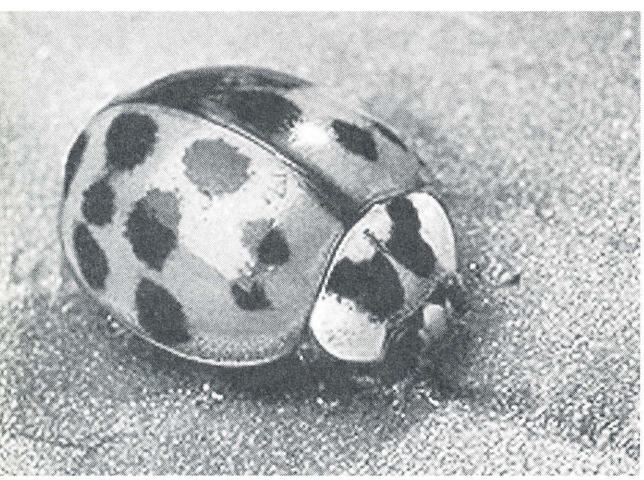
Second generation European corn borer larvae feed on the stalks, tassels, ear shanks, leaves, and kernels. Feeding on the ear shank causes the ear to drop, while stalk boring can lead to stalk breakage and harvesting difficulties and create entry wounds for stalk-rot fungi.

ounger fields with the shortest corn (i.e., late planted) e more likely to suffer second generation damage. rain reduction also occurs from kernel feeding.

ontrol: *Non-chemical*—Destruction of overwintering tes (cornstalks) in the fall kills many European corn orer larvae but does not reduce the population enough provide adequate control the following year. Resistant brids and early-season hybrids are all useful in man- ing European corn borer.

Because older corn is more attractive to egg laying rly in the season, there is often more first generation mage. Likewise, the second generation tends to attack e silking and pollen-shedding corn. Therefore, avoid tremely early and late plantings, or plant such fields th resistant hybrids. Concentrate scouting efforts on lds planted early and late.

A number of factors that are out of your control affect the tential economic loss caused by European corn borer mage. A series of cool evenings (below 65 degrees F) or a avy rain can reduce the number of eggs laid or the sur- val of small larvae. In addition, young larvae can dehy- ate and blow away on hot, windy days. Thus, conditions esent during European corn borer mating, egg laying, d development of eggs and small larvae are critical in termining the population from year to year.



dy beetle, *Harmonia axyridis* (H. Russell, Michigan State iversity).

Biological—Numerous natural enemies attack life stages of European corn borer. Generalist preda- s such as ladybeetle larvae and adults, lacewing lar- e, and minute pirate bugs feed on egg masses and all larvae. Other insects and birds eat large larvae and pae. In locations with large populations of predators, eir role in controlling European corn borer should be ken into consideration when determining a manage- ent strategy.

Though parasitoids were imported from Europe to ntrol European corn borer, only a few became success- lly established. The amount of control from these para- oids varies from year to year and depends on the loca- n and shape of each field.

Two main pathogens affect European corn borer popu- ions. *Beauvaria bassiana* is a naturally occurring fungus that usually kills overwintering larvae, giving dead larvae a white, furry appearance. Most epidemics of *B. bassiana* occur during and after periods of rainfall late in the season when temperatures are around 85 degrees F. *Nosema pyrausta*, a protozoan, reduces European corn borer egg laying, kills some larvae, and increases overwintering mortality. An increase in stress caused by other factors increases the mortality caused by *N. pyrausta*.

Chemical—A decision to treat for European corn borer depends on many factors, including percent infestation, stage of plant, larval life stage, expected yield, and availability of equipment. European corn borer populations are largely influenced by the weather, so it is difficult to predict pest pressure from year to year. Scout for first generation European corn borers by examining plants for shot-holing. Second generation European corn borers are scouted by looking for egg masses laid on the undersides of leaves, especially in the ear zone.

Insecticide applications to whorl-stage corn can be effective against the first generation. Research and field experience shows that granular insecticides, though not commonly used in Michigan, control first generation European corn borer more efficiently than liquid insecticides. Timing is critical because once the larvae enter the stalk, insecticide applications are not effective. Thus, scouting is crucial for first generation European corn borer. Second generation European corn borer are more difficult to control and the timing of the application becomes even more critical.

A common soil bacterium, *Bacillus thuringiensis* subspecies *kurstaki* (Berliner), usually known as Bt, produces spores and protein crystals that are toxic to European corn borer larvae. Commercial formulations of Bt applied by conventional methods are effective against whorl, sheath, and collar feeding. Bt kills European corn borer only when it is ingested, and it is more effective on smaller larvae. Therefore, once the larvae burrow into the stalk, Bt is not effective. Though Bt kills European corn borer and other caterpillars, it is much less toxic to other organisms (including beneficial insects and humans) than broad-spectrum conventional insecticides.

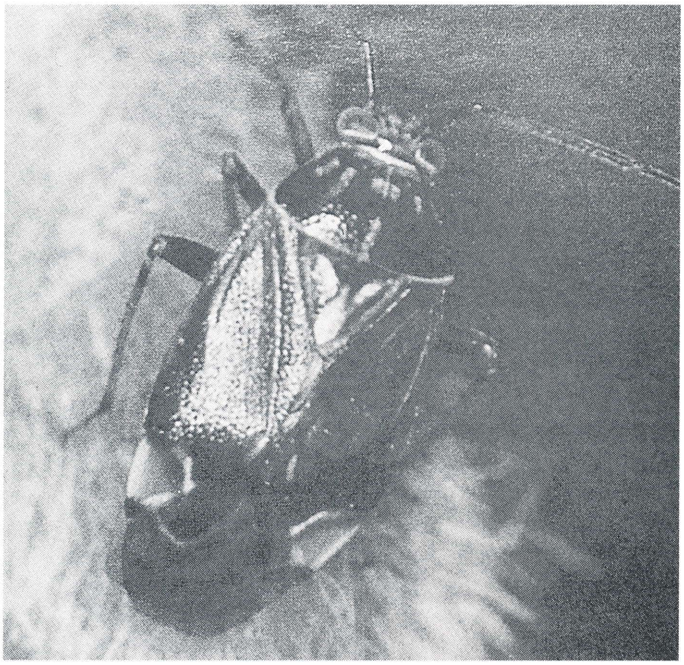
Another option for controlling European corn borer is planting transgenic Bt corn. The gene for the Bt insecticide protein was put into the genetic structure of the plant, allowing the plant to produce Bt protein. When larvae feed on transgenic Bt corn plants, they ingest the proteins and die. Like Bt insecticide applications, transgenic Bt corn is much less toxic to beneficial insects such as lady beetles than conventional insecticides and offers safety for the grower.

INSECT PESTS OF DRY BEANS

Tarnished Plant Bug (*Lygus lineolaris*)

Pest status: common.

Characteristics and life cycle: The tarnished plant bug overwinters as an adult in leaf litter. The adult is 1/4 inch long, light brown with a tarnished appearance, and relatively long antennae and legs. There is usually a white triangle between its "shoulders." Females deposit eggs into stems and midribs of plants. Nymphs are similar to the adult but smaller and without wings. Both nymphs and adults have sucking mouthparts.



Tarnished plant bug.

Damage: Tarnished plant bug adults and nymphs use their needlelike mouths to suck plant juices and inject toxic saliva. The saliva causes leaves to yellow and curl; severe damage may stunt plants. They can also feed on flowers and small pods so that beans shrivel.

Control: Scout fields from blossom to small pod development. A sweep net can be used to scout. The action threshold is one or more tarnished plant bugs per plant at the first flower to green pod stage.

Non-chemical—Tarnished plant bugs have a wide host range (dozens of crops and weeds), so there are no practical non-chemical control options at this time.

Chemical—Insecticide applications made to manage potato leafhoppers will also reduce tarnished plant bug populations. However, tarnished plant bugs are active and move about freely and thus avoid treatment. Therefore, feeding injury can resume soon after an insecticide application.

Potato Leafhopper (*Empoasca fabae*)

Pest status: common economic pest.

Characteristics and life cycle: Potato leafhopper adults migrate from the southern United States into Michigan in mid- to late May. The adult is a tiny, lime-green, translucent, wedge-shaped insect with sucking mouthparts. Eggs are laid in stems and leaf petioles. A nymphal leafhopper resembles an adult but lacks fully developed wings. Potato leafhopper populations increase quickly—a single generation takes only 21 days from egg to adult in a warm summer.

Damage: Adults and nymphs damage plants by sucking plant fluids from the leaves. They inject a toxic substance as they feed, creating a characteristic V-shaped, yellow marking on the leaf tip called "hopperburn." Heavy feeding causes leaves to yellow and curl, may severely stunt plants, and may kill plants.

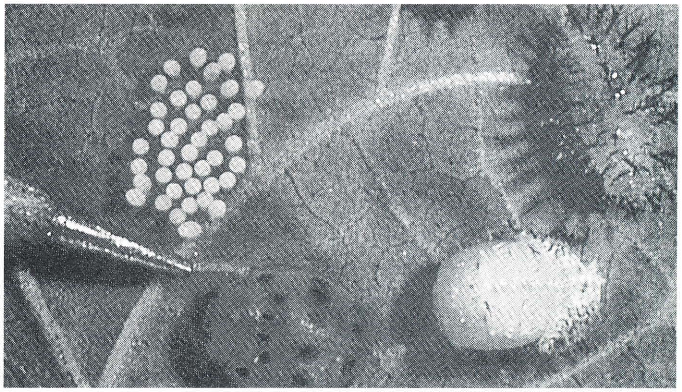
Control: *Cultural*—Promoting healthy, vigorous plants minimizes the impact of potato leafhopper damage in fields.

Biological—Potato leafhoppers are native to the United States so there is no foreign biological control agent to import. Native predators and parasitoids play only a minor role in controlling populations. A fungal pathogen controls potato leafhopper under cool, moist conditions later in the summer.

Chemical—Early detection is the key to controlling potato leafhopper populations. Fields are sampled by examining leaves to determine the number of potato leafhoppers per leaf. Fields should be scouted regularly, especially after nearby alfalfa fields have been cut. If samples exceed five or more adults and/or nymphs per leaf, insecticide treatment is justified. Full coverage is necessary. Remember, adults are very active and strong flyers; after a field is treated, adult potato leafhoppers can recolonize from neighboring areas.

Mexican Bean Beetle (*Epilachna varivestris*)

Pest status: occasional.



Mexican bean beetle life cycle.

Characteristics and life cycle: Adult beetles overwinter in plant debris, along field edges, and in fencerows. Mexican bean beetles are oval and orange to copper-colored with 16 black spots in three distinct rows. In early spring, the adults move into bean fields. The females deposit clusters of up to 50 yellow-orange, oval eggs on the undersides of leaves. Larvae are up to $^{3}/_{8}$ inch long, oval, and yellowish with prominent spines on the back that gives them a fuzzy appearance. Generally, there are two generations per year.

Damage: Adults and larvae have chewing mouthparts and defoliate plants. They eat irregularly shaped holes from the lower leaf surface. This gives heavily infested plants a lacy, skeletonized appearance. If the infestation is large when leaves begin to yellow, larvae and adults may begin to feed on stems and pods. Yield reductions are sually the result of defoliation, however, not pod feeding. conomic damage caused by Mexican bean beetle varies om year to year. Defoliation during flowering and pod evelopment poses the greatest threat for economic loss.

ontrol: *Non-chemical*—Avoid planting early—overvintering adults are attracted to early-emerging fields.

Biological—Many predators (such as stink bugs, abids, and minute pirate bugs) and some parasitic wasps duce Mexican bean beetle populations.

Chemical—Scout fields for larval and adult amage. Larvae are more damaging and harder to conol than adults. Reducing adult populations early can iminate the need for future applications.

NSECT PESTS OF SMALL GRAINS

phids

est status: common but usually not an economic problem.

haracteristics and life cycle: Aphids are small ($^1/_{16}$ to $^1/_8$ ch), pear-shaped, soft-bodied insects. They are found in variety of colors. Aphids have projections called cornies ("tailpipes") that extend from the rear of the body. hey live in colonies made up of both winged and wingss insects. Female aphids do not have to mate with ales to reproduce. They also produce live young (no ggs involved). This allows an aphid population to increase quickly.

Aphids on wheat.

Damage: Aphids use sucking mouthparts to remove plant juices from leaves and stems. If populations are large, their feeding causes plants to turn yellow and brown. They may feed on developing kernels. Aphids also vector a number of viruses, including barley yellow dwarf virus (see diseases of small grains).

Control: *Cultural*—Quick stand establishment and vigorous plants help to reduce the impact of aphid damage.

Biological—Many common predators—including ladybeetle adults and larvae, lacewing larvae, and syrphid fly larvae—feed on aphids, keeping the population under control. There are also a number of parasitic wasps. After the adult wasp emerges from an infested aphid, it leaves behind a hard shell of its host, a "mummy". When scouting fields for aphids, it is important to note the number of aphid mummies to determine the effectiveness of the natural parasitoid population.

Chemical—Aphids are usually noticed when the grain heads, though they have been present on the grain since earlier in the season. Begin scouting fields at tillering, randomly examining plants for aphids. A threshold of 12 to 15 aphids per tiller during seedling to boot stage is usually used. Consult current MSU Extension bulletins for sampling methods. Most years, a careful and proper scouting program shows that chemical treatments are not needed.

Cereal Leaf Beetle (*Oulema melanopus*)

Pest status: occasional.

Characteristics and life cycle: The cereal leaf beetle was discovered in the United States in Berrien County, Michigan, in 1962. Adult beetles overwinter in plant stubble, under tree bark, in small crevices, and in similarly sheltered places. When temperatures reach the upper 60s F, the overwintering adults emerge to feed and mate. Soon after mating, the female lays single oblong eggs or chains of eggs on the upper surfaces of grain leaves. After hatching, the larvae cover all but their heads with their own fecal material, giving them a sluglike appearance and protecting them from predators. Larvae feed for about two weeks. Full-grown larvae shed the fecal covering, typically in early June, and move to the soil to pupate. A new generation of adults emerges and feeds for about three weeks before preparing to overwinter. The cereal leaf beetle has one generation per year in Michigan.

Damage: Larvae and adults have chewing mouthparts and feed on leaves between the veins. The adults chew entirely through the leaves; the larvae feed on the upper layer of the leaf. This gives a severely infested field a frosted appearance. Feeding before the boot stage reduces plant vigor; after boot, feeding on the flag leaf may reduce seed set and grain test weight. Damage is more serious when it occurs during early heading than during tillering.

Control: *Cultural*—Hairy varieties are less desirable to cereal leaf beetle adults for egg laying and to larvae for feeding.

Biological—In the 1970s, a wasp egg parasitoid (*Anaphes flavipes*) was imported from Europe and distributed throughout Michigan. The spotted lady beetle (*Coleomegilla maculata lengi*) is an important predator that feeds on eggs early in the season. Larval parasitoids include three wasps, and a tachinid fly parasitoid attacks adults. In combination, the natural enemies of the cereal leaf beetle usually control this pest.

Chemical—Cereal leaf beetle infestations often start along field borders of winter grains, with adults moving to preferred spring grains. Begin looking for adult feeding damage in the spring after the first warm spell (above 60 degrees F). Check adult-damaged fields for eggs and larvae. The decision to manage cereal leaf beetle is based on plant stage and the number and stage of development of the larvae. (See MSU Extension bulletin E-2549, *Insect Management in Wheat and Other Small Grains*.) Timing of application is extremely important, and applications are more effective when small rather than large larvae are present.

INSECT PESTS OF SOYBEANS

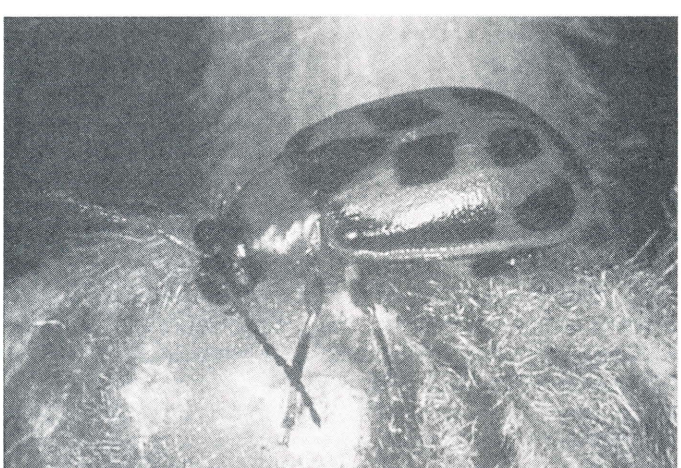
DEFOLIATORS

Many pests defoliate soybeans. Most are general feeders, capable of infesting many crops. High infestations of fall armyworms cause the most severe damage to soybeans. Fall armyworms prefer grass crops but can be a problem in weedy fields or when soybeans are double-cropped with small grains.

Taking whole-plant samples is best when you are scouting seedling-stage soybeans for defoliators. Sweep nets or ground cloths can be used for sampling larger plants. When making a management decision, it is important to consider all damage from all caterpillars (lepidopteran defoliators).

Bean Leaf Beetle (*Cerotoma trifurcata*)

Pest status: occasional.



Bean leaf beetle adult.

Characteristics and life cycle: Upon emergence in the spring, adult beetles feed on alfalfa. After the first alfalfa cutting and soybean emergence, bean leaf beetles move to soybean fields to lay eggs. Eggs are deposited in the soil and larvae feed on roots as they develop. Mature larvae build an earthen cell and pupate inside. Adult beetles emerge after approximately seven days. Usually peak emergence for this second generation is late August to mid-September. Second generation bean leaf beetles feed on soybeans and alfalfa before moving into overwintering sites.

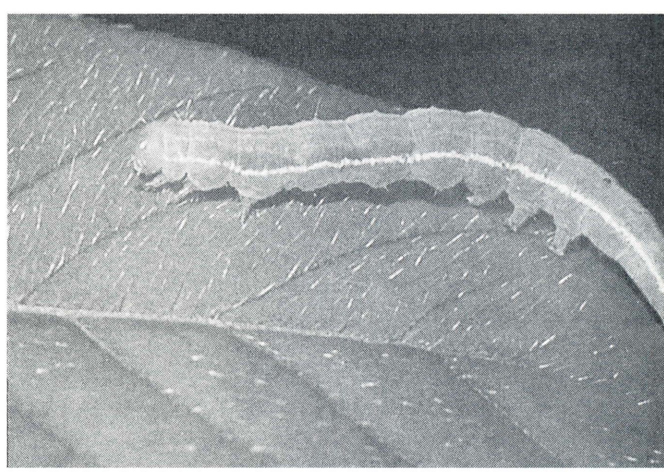
Damage: Bean leaf beetle larvae use their chewing mouthparts to eat roots, root hairs, and nodules. Adult beetles defoliate plants by chewing small, round holes in the leaves. Defoliation is a concern early in the season. Later in the season, beetles feed on pods all the way down to the seeds. This feeding damage creates lesions on the pod that remain visible at harvest and increase seed vulnerability to secondary pathogens. Seeds beneath lesions become shrunken, discolored, and sometimes moldy, resulting in loss of grain weight and quality.

Control: *Cultural*—Planting soybeans as late as possible (within the recommended planting period for a variety) can reduce bean leaf beetle colonization.

Chemical—Adult sampling should begin early in the season. Management is not usually necessary because of soybean tolerance of defoliation.

Green Cloverworm (*Plathypena scabra*)

Pest status: occasional outbreaks.



Green cloverworm.

Characteristics and life cycle: The adult moth migrates into Michigan each spring from overwintering grounds along the Gulf Coast. Eggs are laid on the undersides of leaves. The eggs turn brownish with red specks about 48 hours before hatching. Green cloverworm larvae (caterpillars) are pale green with two white stripes running horizontally along each side of the body. They have three pairs of abdominal prolegs plus one pair of **anal prolegs** (false, peglike legs near the anus of the caterpillar).

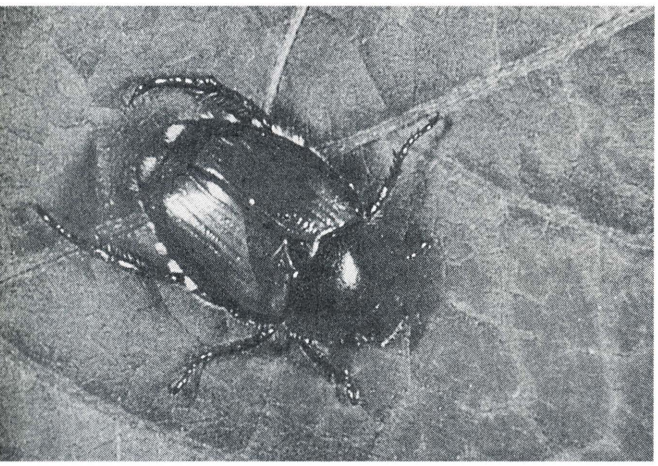
Damage: Green cloverworm larvae consume soybean foliage, giving leaves a tattered appearance.

Control: *Biological*—A primary factor controlling green loverworm populations is a disease caused by the fungus *Nomuraea rileyi*. Several predators and parasitoids also attack larvae.

Chemical—Insecticide applications are rarely used to manage green cloverworm.

Japanese Beetles (*Popillia japonica*)

Pest status: occasional.



apanese beetle.

Characteristics and life cycle: Japanese beetles overwinter as larvae, commonly known as grubs, in the soil. Typically, they are found in grassy areas surrounding a field but can also be found in the soybean field. In late May or June, adults emerge and begin feeding on soybeans. Adult beetles are metallic green with reddish brown wing covers and white tufts on the abdomen. There is one generation per year.

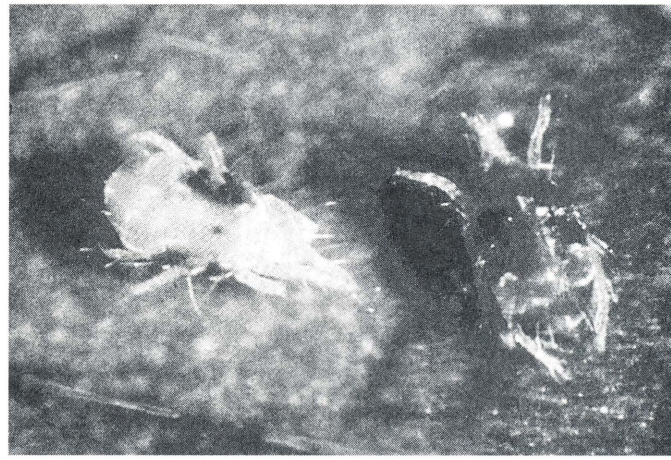
Damage: Adult beetles feed on leaf tissue between veins, giving the plant a skeletonized, lacy appearance. Responding to pheromones, Japanese beetles congregate. A soybean field may have multiple areas with large concentrations of beetles. Defoliation at these congregation sites can be heavy. Though Japanese beetle adults do most of the damage to soybeans, grubs do feed on soybean roots.

Control: Feeding by Japanese beetles alone usually is not sufficient to justify chemical treatment. Generally, a threshold of 25 percent defoliation due to combined feeding from Japanese beetles and other defoliators is used.

Two-spotted Spider Mite (*Tetranychus urticae*)

Pest status: occasional.

Characteristics and life cycle: This extremely small (0.3 to 0.4 mm) arthropod is more closely related to spiders than to insects and is distributed worldwide. Adults are greenish yellow to dull orange with eight legs and two large, black dots on their bodies. They produce noticeable webbing on heavily infested plants. Female mites lay eggs on the undersides of leaves. Spider mites go through a six-legged larval stage and two eight-legged nymphal stages. Rapid reproduction—four to 14 days per generation—results in exponential population growth.



Spider mite.

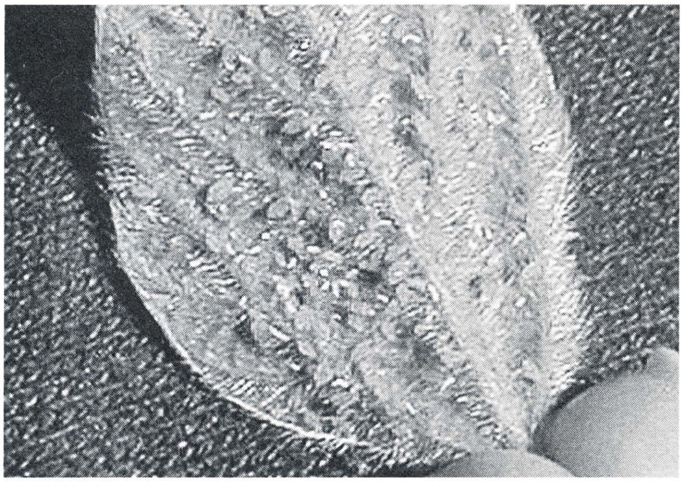
In northern states, spider mites overwinter as adults. Two-spotted spider mites disperse via air and by crawling, and they can infest a field extremely quickly. Spider mite populations increase quickly during hot, dry conditions, and damage is aggravated in water-stressed plants. Though a microscope is needed to correctly identify mites, the two-spotted spider mite is the only mite commonly found on soybeans in Michigan.

Damage: Feeding occurs on the undersides of leaves. The spider mite uses its needlelike mouthparts to pierce and suck the contents of individual plant cells. Infested leaves have small, white or yellow spots called stippling. This reduces the photosynthetic capacity of the leaf and creates leaf water stress. Eventually, with increased mite infestation, leaves become yellow, then brown, and drop from the plant. Maximum infestation of 1,000 spider mites per leaf causes complete defoliation. Early-season attacks can reduce overall plant growth.

Control: *Biological*—The fungal pathogen *Neozygites floridana* is the most effective natural enemy of the two-spotted spider mite. Specific to spider mites, this pathogen attacks all mite stages by attaching to the mite's legs or body. Infected mites usually have a waxy or cloudy appearance and die within one to three days after infection. The effectiveness of this fungal pathogen depends on environmental conditions—it requires a temperature below 89 degrees F (29 degrees C) and at least 90 percent relative humidity for 12 to 24 hours.

Chemical—Begin sampling along field edges, closely examining leaves in the middle and lower canopy for stippling. Herbicide injury may resemble mite damage, so use a hand lens to confirm the presence of mites. Unfortunately, by the time that damage has been recognized, mites have infested the entire field. Late-season treatments may be difficult because of the 21- to 28-day preharvest intervals for most labeled chemicals. Mite populations can recover rapidly after treatment, adding to the expense and difficulty of control. They also have a tremendous capacity to develop insecticide resistance.

Soybean Aphid (*Aphis glycines*)



Soybean aphids.

In 2000, a new pest of soybeans, the soybean aphid (*Aphis glycines*), was detected in Michigan. Soybean aphids are small ($^1/_{16}$ to $^1/_8$ inch), pear-shaped, soft-bodied insects that live in colonies made up of both winged and wingless insects. Female aphids do not have to mate with males to reproduce. This allows an aphid population to increase quickly. Though aphids have been found across the state, the heaviest infestations to date (2000) have been in southwestern Michigan.

Soybean aphids have sucking mouthparts and remove water and nutrients from leaves and stems. The impact of soybean aphids on Michigan soybean production is not known. Research is underway to determine thresholds and treatment guidelines. Consult your county agriculture agent for updated information on scouting and treatment recommendations.

INSECT PESTS OF SUGAR BEETS

Sugar Beet Root Aphid (*Pemphigus betae*)

Pest status: localized occasional pest.

Sugar beet root aphid on sugar beets.

Characteristics and life cycle: Sugar beet root aphids are localized pests. Adult females overwinter in soil. In spring, they move to roots of lambsquarter and then to beets later in the season, producing young. Aphids present during the field season are all female and reproduce without mating. There are multiple generations per year.

Damage: Adults and nymphs use their sucking mouthparts to remove plant fluids from beet roots. This reduces root yield, sugar content, and juice purity. Sugar beet root aphids secrete a white, waxy material, which remains on colonized roots and interferes with water uptake. In severe infestations, beet leaves turn yellowish green and plants shrink and wilt.

Control: *Non-chemical*—In fields where aphids have overwintered in the soil, crop rotation (three or more years) and good weed control reduce infestations. Resistant varieties are available.

Chemical—Consult current MSU Extension bulletins for current insecticide recommendations.

Spinach Leaf Miner (*Pegomya hyoscyami*)

Pest status: occasional.

Characteristics and life cycle: In late April and May, the adult spinach leaf miner emerges from its overwintering site in the soil. The adult fly resembles a housefly. Adult females deposit small, whitish eggs on the undersides of sugar beet leaves. Larvae (maggots) feed inside leaves and pupate in the soil. There are several generations per year.

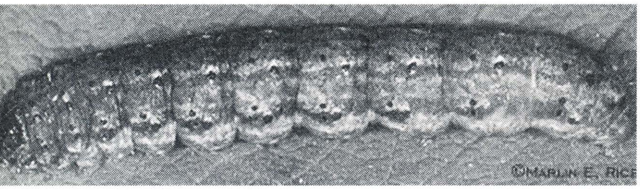
Damage: The spinach leaf miner is an occasional pest that rarely causes economic losses. The larvae feed between the upper and lower surfaces of the leaf tissue, forming a characteristic tunnel or "mine." As the maggots grow, the mines enlarge, forming blotches.

Spinach leafminer damage on sugarbeets.

Control: *Chemical*—Insecticides should be applied when eggs are present on 50 percent or more of small plants and when the first mines are seen.

ENERAL INSECT PESTS

tworms



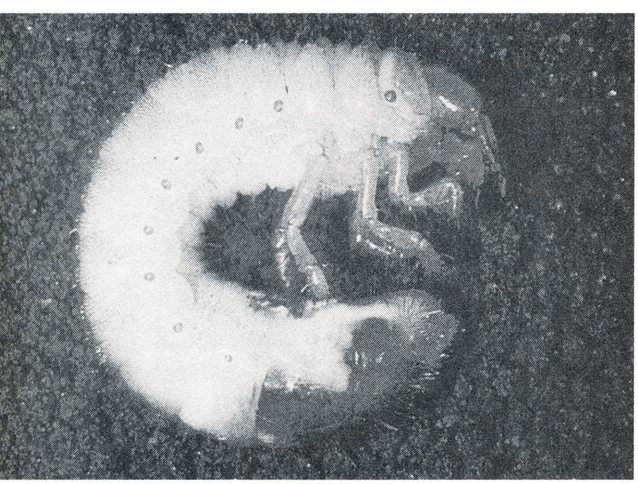
ck cutworm (M. Rice, Iowa State University).

aracteristics and life cycle: Various cutworms occa-
nally attack Michigan crops. Some overwinter in
chigan; others migrate to Michigan as adults each
ing. Adult cutworms are moths. The larvae (caterpil-
s) are up to 2 inches long and come in a variety of col-
(black, tan, greenish yellow) with a row of light yel-
spots down the back. Each cutworm species has a
htly different life cycle and feeding behavior.

mage: With their chewing mouthparts, larvae feed on
ves and cut stems. New seedlings are at the greatest
for damage.

ntrol: Because several species of cutworms attack field
ps in Michigan, correct identification is extremely
portant to adequately control the pest. Infestations are
oradic, so scouting fields and early diagnosis are also
essary. Also, because infestations are sporadic, foliar
ecticides (curative) are recommended rather than soil
ecticides at planting (preventive).

ubs



ub.

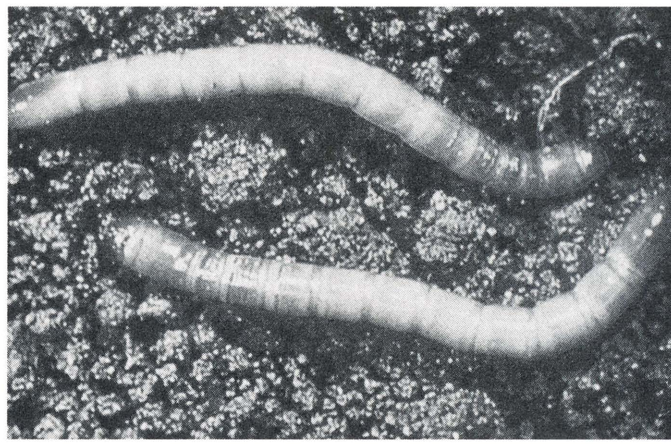
aracteristics and life cycle: Grubs are the C-shaped
val stage of beetles. Many are turf pests, but others
casionally cause damage in field crops. True white
ubs are the larvae of May and June beetles; they require
ree years to complete development. Other grubs are the
vae of Japanese beetles or chafers; they require only a
ar to complete their life cycle (annual grubs). Correct
entification of a grub problem is key to recommending
ntrol options.

Damage: Grubs prefer to feed on the roots of grasses, but they can cause irregular emergence, reduced plant stand, stunting, and wilting by feeding on the roots and root hairs of field crops. They can also sever taproots.

Control: *Non-chemical*—Spring and summer plowing of established sod is recommended before a crop is planted. Predators such as birds play a minor role in grub management.

Chemical—Depending on the crop, a soil insecticide can be applied in-furrow or banded at time of planting. Chemical treatment is not usually required, however.

Wireworms (*Limonius* spp.)



Wireworms.

Characteristics and life cycle: Wireworms are the larval stage of click beetles. They are slender and shiny brown with wiry, segmented bodies. Larvae live for two to six years in the soil. Because of the long life cycle, crops planted into less disturbed ground (sod, pasture, old alfalfa, or reduced tillage fields) are at a greater risk for wireworm damage.

Damage: Wireworms feed on seeds and roots. They can reduce plant stand by preventing seed germination and attacking young plants.

Control: *Non-chemical*—Spring and summer plowing of established sod is recommended before a crop is planted.

Chemical—A seed treatment or insecticide application at planting can help protect the crop from wireworm damage.

Seedcorn Maggot (*Hylemya platura*)

Characteristics and life cycle: Seedcorn maggots are small ($^1/_4$ inch), white maggots. The adults are small, gray flies that emerge in early spring to lay eggs in disturbed soil with high organic matter (for example, a field with manure or plowed cover crops). The maggots feed for one to three weeks and then pupate in the soil. There are multiple generations per year.

Damage: Seedcorn maggots are usually a problem during cold, wet springs and in soils with high organic material. Feeding on germinating seeds, they may cause variable emergence, stand loss, or delayed development. They also create an entrance for disease organisms.

Control: *Non-chemical*—Using reduced tillage, planting later in the season, and shallow planting in a well prepared seed bed decrease seedcorn maggot damage potential.

Chemical—If a maggot problem is expected, treating seed with an insecticide before planting is the most effective and convenient control method. Though more expensive, a soil insecticide can be applied if seed and planter box treatments are not possible.

CHAPTER 5 Review Questions

Chapter 5: Insect management

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

1. Insect damage can result in:
   A. An unmarketable product.
   B. Disease transmission.
   C. Yield reduction.
   D. All of the above.

2. Molting is the process of shedding an old skeleton to reveal a new, larger exoskeleton.
   A. True.
   B. False.

3. Define metamorphosis.

4-8. Match the following forms of metamorphosis with the correct statement.

A. Simple
B. Complete
C. Both simple and complete

4. ___ Immature insects resemble adults.
5. ___ Adult and nymphs usually live in the same environment.
6. ___ Adult insects have wings.
7. ___ Immature insects do not look like the adults.
8. ___ Immature insects are referred to as larvae.

9. During which insect life stage does an insect undergo a complete change?
   A. Nymph
   B. Larva
   C. Pupa
   D. Adult

10. The corn rootworm goes through which type of metamorphosis?
    A. Simple
    B. Complete

11. Why is it important to understand an insect's life cycle for pest management?

2-18. Match the following insects with the correct statement below. Answers can be used more than once.

A. Alfalfa weevil

B. Potato leafhopper

C. Corn flea beetle

D. Armyworm

E. European corn borer

12. ___ Damage causes "hopperburn."
13. ___ Occasional pest of corn that can migrate in large numbers.
14. ___ Transgenic Bt corn plants are used to control.
15. ___ Primarily feeds on alfalfa leaves and stems in the spring.
16. ___ Transmits Stewart's wilt.
17. ___ Begin sampling alfalfa using a sweep net in mid-June.
18. ___ Feeds on leaves and burrows into corn stalks.

9. The larval corn rootworm causes damage to corn by feeding on the:

A. Silks.

B. Root hairs and root tips.

C. Ear shank.

D. Foliage.

0. Corn-soybean crop rotations do not control the variant _______ corn rootworm populations.

A. Northern

B. Southern

C. Western

D. Eastern

1. First generation European corn borers feed primarily in the:

A. Ear.

B. Shank.

C. Whorl.

D. Roots.

2. European corn borer feeding can result in:

A. Ear drop.

B. Stalk breakage.

C. Grain reduction.

D. All of the above.

23. The tarnished plant bug has what type of mouth parts?

A. Chewing.

B. Sucking.

C. Rasping.

24. Aphids and leafhoppers can spread plant disease.

A. True

B. False

25. Which insect has chewing mouthparts and usually moves to soybeans after the first cutting of alfalfa?

A. Spider mites.

B. Green cloverworms.

C. Bean leaf beetles.

D. Aphids.

26. Which of the following larvae is a common predator of aphids?

A. Lacewing

B Monarch

C. Housefly

D. None of the above

27. Fungal pathogens usually keep which two soybean pests from reaching high pest densities?

A. Bean leaf beetle and green cloverworm.

B. Two-spotted spider mite and bean leaf beetle.

C. Two-spotted spider mite and green cloverworm.

D. Bean leaf beetle and lepidopteran defoliators.

28-31. Match the following insects with the characteristics given below.

A. Cutworms

B. Grubs

C. Wireworms

D. Seedcorn maggot

28. ___ Prefer to feed on grass roots.
29. ___ Can live for two to six years in the soil.
30. ___ Feeds on leaves and stems.
31. ___ More commonly a problem during a cold, wet spring.

32. A farmer complains that a large group of caterpillars has just moved into his/her corn field and eaten all the leaves off the plants. This pest is most likely:

    A. Corn earworm.
    B. Armyworm.
    C. Green cloverworm.
    D. Wireworm.

33. It is difficult to control this insect in alfalfa and dry beans because adults are very mobile and often quickly reinfest fields after a pesticide application.

    A. Potato leafhopper
    B. Aphids
    C. Mites
    D. None of the above

34. Aphids must mate to produce offspring.

    A. True
    B. False

35. Which of the following insects does NOT have sucking mouthparts?

    A. Alfalfa weevil
    B. Potato leafhopper
    C. Sugar beet root aphid
    D. Tarnished plant bug

CHAPTER 6

WEED MANAGEMENT

LEARNING OBJECTIVES

After completely studying this chapter, you should:

- Be able to define a weed and its four stages of development.
- Understand the differences between annual, biennial, and perennial weeds.
- Be able to give examples of cultural weed controls.
- Know the advantages and disadvantages of the various methods of herbicide applications.
- Understand herbicide carryover and how to prevent it.
- Know what herbicide adjuvants are.
- Understand the weed control problems in conservation tillage systems.

Weeds are plants growing where they are not wanted. They can reduce field crop yields by competing for water, nutrients, and light. Some weeds release toxins that inhibit crop growth, and others may harbor insects, diseases, or nematodes that attack crops. Weeds often interfere with harvesting operations, and at times contamination with weed seeds or other plant parts may render a crop unfit for market. Profitable crop production depends on effective weed control.

DEVELOPMENT STAGES

All crop plants and weeds have four stages of development:

- SEEDLING—small, delicate, newly emerged plants.
- VEGETATIVE—plant grows quickly producing stems, roots, and leaves.
- SEED PRODUCTION—plant's energy is directed into producing flowers and seeds.
- MATURITY—plant produces little or no energy. Some plants begin to dry out or desiccate.

LIFE CYCLES OF WEEDS

Weeds can also be classified according to how long it takes them to complete their development or life cycle. The three types of plant life cycles for weeds are annual, biennial, and perennial.

ANNUAL

Plants that complete their life cycle in one year are **annuals**. They germinate from seed, grow, mature, produce seed, and die in one year or less. Annuals reproduce by seed only and do not have any vegetative reproductive parts. Summer annuals germinate from seed in the spring, flower and produce seed during the summer, and die in the summer or fall. These are the most common annual weeds found in field crops. Winter annuals germinate from seed in the fall and die in late spring or early summer the following year. Annual weeds are easiest to control at the seedling stage.

Cocklebur.

BIENNIAL

Biennials are plants that complete their growth in two years. The first year, the plant produces leaves and stores food. The second year, it produces fruits and seeds. Biennial weeds are most commonly found in no-till fields, pastures, and fencerows that are not mowed. They are easiest to control in the seedling stage.

Bull thistle is a biennial.

PERENNIAL

Perennials are plants that live for two or more years. Perennials can reproduce by seed or vegetatively. The plant parts that allow perennials to spread without producing seeds include **stolons** (creeping aboveground stems—e.g., white clover and strawberries), **rhizomes** (creeping belowground stems —e.g., milkweed, quackgrass), **tubers** (enlarged underground stems—e.g., potato, yellow nutsedge), and **bulbs** (underground stem covered by fleshy leaves—e.g., tulip). Because perennial weeds can propagate (spread) underground, they can be the most difficult weeds to control. Removing the aboveground vegetation will not stop the weed from spreading.

Johnsongrass is a creeping perennial.

Annuals, biennials, and perennials can reproduce from seed. Many weeds produce large quantities of seeds. Seeds are easily dispersed across a field by wind, rain, machinery, animals, and people. Weed seeds can germinate after being dormant for long periods of time. They can also tolerate extremes in weather such as temperature and moisture. To prevent seed dispersal, you should control weeds before they produce seeds.

COMMON WEEDS IN MICHIGAN

GRASS AND GRASSLIKE WEEDS

Annuals

- Barnyardgrass
- Large crabgrass
- Smooth crabgrass
- Giant foxtail
- Yellow foxtail
- Green foxtail
- Fall panicum
- Wild-proso millet
- Witchgrass

Grassplant.

Perennials

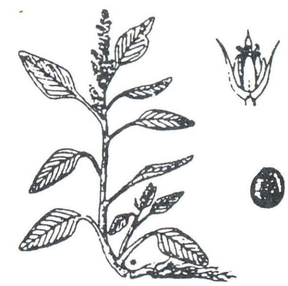
- Johnsongrass
- Yellow nutsedge
- Quackgrass

Yellow Nutsedge.

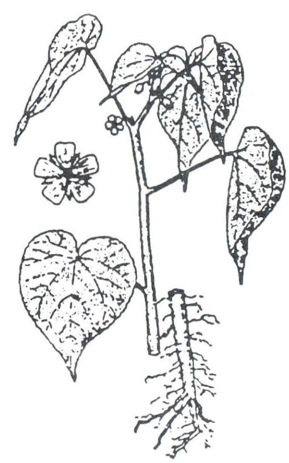
BROADLEAF WEEDS

Annuals

- Ladysthumb
- Pennsylvania smartweed
- Wild buckwheat
- Common lambsquarters
- Redroot pigweed
- Eastern black nightshade
- Common cocklebur
- Jimsonweed
- Common purslane
- Common ragweed
- Giant ragweed
- Velvetleaf
- Common chickweed
- Shepherd's-purse
- Horseweed (Marestail)
- Prickly lettuce
- Wild mustard
- Yellow rocket



Redroot Pigweed.



Velvetleaf.

Biennials

- White campion
- Wild carrot
- Bull thistle

Perennials

- Milkweed
- Hemp dogbane
- Canadian thistle
- Dandelion
- Field bindweed
- Perennial sow thistle

WEED CONTROL

CULTURAL CONTROL

Crop competition is a very useful method of weed control. Maintaining production practices that optimize crop growth means the crop plants can compete more effectively with weeds. Several crop management practices can improve the competitive ability of the crop: crop and variety selection, planting date, population, soil fertility, drainage, etc. Recommended crop production practices are also beneficial weed control practices.

Crop rotation may also be helpful in maintaining adequate weed control. Many weeds cannot tolerate crop rotation.

MECHANICAL CONTROL

Tillage buries weeds or destroys their underground plant parts. Small annual and biennial seedlings are more effectively controlled with tillage. However, disturbing the soil can bring new weed seeds near the soil surface and create another weed problem.

CHEMICAL CONTROL

The first step in successful chemical weed control is the correct identification of the weeds. Annual weeds are easier to kill when they are small seedlings and when conditions favor rapid growth. However, crop plants are also easily injured under these conditions. Selective herbicides should control the weeds with little or no injury to the crop.

Timing and rate of herbicide application are very important in chemical weed control. Applying herbicides at the wrong time often results in poor weed control and crop injury.

TYPES OF HERBICIDES

Chemical weed control can be obtained with herbicides applied either preplant incorporated, preemergence, or postemergence. Many herbicides can be applied by more than one of these methods.

Preplant Herbicide Soil Applications and Incorporation

Preplant herbicide soil applications and incorporation are herbicide applications that are applied and incorporated into the soil before planting. Incorporation of some herbicides is required to prevent them from volatilizing (becoming a gas) or decomposing in the sun.

Advantages of preplant soil applications and incorporation:

- Early weed control reduces weed competition with the crop.
- Wet weather will not delay cultivation or herbicide application to control weeds.
- Preplant soil application and incorporation is less dependent on rainfall for herbicide activation than preemergence herbicide applications.

Disadvantages of preplant soil applications and incorporation:

- Incorporating the herbicide too deep in the soil can reduce weed control.
- A "streaking" pattern of good and poor weed c ontrol can result from incomplete soil incorporation.
- Growers apply herbicide without identifiying the weeds. They are preventive applications.
- It is incompatible with a no-till system.

Preemergence Herbicide Applications

Preemergence herbicide applications are applied to the soil surface after the crop has been planted but before the crop or weed seedlings emerge. Typically, preemergence herbicide applications require rainfall within one week following the application to ensure that the herbicide moves through the soil.

Advantages of preemergence applications:

- Reduce weed competition for crop with early control of weeds.

- Can be used in all tillage systems.
- Planting and herbicide application may be done at the same time.

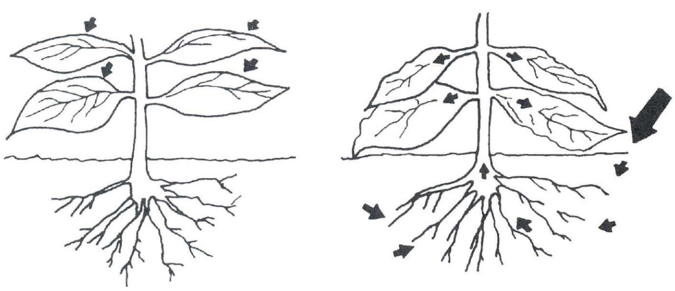
Disadvantages of preemergence applications:

- Depend on rainfall; ineffective in dry soil conditions.
- On sandy soil, heavy rains may move the herbicide down in the soil to the germinating crop seed and cause injury.
- Growers apply herbicide without identifying the weeds. They are preventive applications.

Postemergence Herbicide Applications

Postemergence herbicide applications are applied to the foliage of the weed after crop and weed have emerged. There are two types of postemergence herbicides: contact and systemic. **Contact herbicides** kill only the plant parts that they touch. Typically, the aboveground parts of a weed, such as the leaves and stems, turn brown and die. Contact herbicides are commonly used to control annuals.

Systemic or translocated herbicides are absorbed by the weed's roots or leaves and moved throughout the plant. Translocated herbicides are more effective against perennial weeds because the herbicide reaches all parts of the plant. However, translocated herbicides may take up to three weeks to kill the weeds.



Advantages of postemergent applications:

- Herbicide is applied after the weed problem occurs (remedial application).
- Less susceptible to environmental conditions after the herbicide application.
- Useful for spot treatments.
- Postemergent herbicide applications have short or no soil residual.

Disadvantages of postemergent applications:

- Postemergent herbicides are environmentally sensitive at this time of application.
- Weeds must be correctly identified.
- Timing of the application is critical for effective weed control.
- Postemergent herbicides should not be applied to wet foliage.
- Weather may not permit a herbicide application at the proper time.

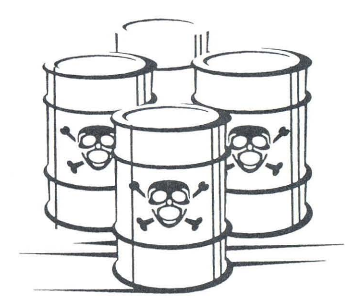
HERBICIDE CARRYOVER

A potential problem of herbicide applications is **herbicide carryover**. This occurs when a herbicide does not break down during the season of application and persists in sufficient quantities to injure succeeding crops. The breakdown of herbicides is a chemical and/or microbial process. Generally the rate of breakdown increases with soil temperature. Very dry conditions during the summer and early fall often increase the potential for carryover of many herbicides.

Herbicide carryover is also influenced by the rate of application, herbicide distribution across a field, soil type, and time. When herbicides are used above the labeled rate and/or not uniformly distributed, herbicide carryover problems may result. Poor distribution is generally the result of improper calibration or agitation, sprayer overlapping, or non-uniform soil incorporation.

Vegetable and ornamental crops are often more sensitive to herbicide carryover than field crops. To reduce the potential of herbicide carryover, read and follow all pesticide label directions. Herbicide labels contain restrictions on the interval between application and planting of various crops. Consult the current MSU Extension bulletin E-434, *Weed Control Guide for Field Crops*, for more information on herbicides.

HERBICIDE COMBINATIONS



Herbicides are commonly combined and applied as a tank mix. Combinations are used to give more consistent control or a broader spectrum weed control, to decrease herbicide carryover, or to obtain adequate season-long weed control. Proper application methods must be followed for each herbicide detailed on the EPA-approved pesticide label. Remember always to read the pesticide label before combining or applying herbicides.

HERBICIDE ADDITIVES (ADJUVANTS)

An **adjuvant** is any substance added to a herbicide to enhance its effectiveness. Many commercially available herbicide formulations contain their own particular set of adjuvants to optimize the performance, mixing, and handling of the active ingredient. Sometimes additional additives are required for specific applications or herbicide combinations. The pesticide label will explain how and when to use the necessary adjuvants.

Additives are used primarily with postemergence herbicide applications to improve the coverage of leaf surfaces and increase herbicide penetration into the leaf. Additives do not increase the effectiveness of soil-applied herbicides.

HERBICIDE COMPATIBILITY PROBLEMS

Compatibility problems in tank mixing herbicides usually occur when applicants do not follow mixing directions. Some common causes of compatibility problems are mixing two herbicides in the wrong order (for example, adding an emulsifiable concentrate to the spray tank before suspending a wettable powder), insufficient agitation, excessive agitation, and air leaks. Problems can also occur when the carrier is a fertilizer such as 28 percent nitrogen or other non-water substances. You should test for herbicide compatibility in a small container before mixing a large tank. If compatibility problems occur, the addition of compatibility agents may help.

CHAPTER 6

Review Questions

Chapter 6: Weed Management

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

1. Define a weed.

2. Plants that complete their life cycle in one year are:

   A. Biennials.

   B. Annuals.

   C. Perennials.

   D. None of the above.

3. An aboveground creeping stem is called a:

   A. Rhizome.

   B. Stolon.

   C. Tuber.

   D. Bulb.

4. Weeds are easiest to control at the:

   A. Reproductive stage.

   B. Vegetative stage.

   C. Seedling stage.

   D. Mature stage.

5. Which of the following is an example of a broadleaf weed?

   A. Quackgrass.

   B. Green foxtail.

   C. Wild-proso millet.

   D. Common ragweed.

6. An example of a perennial grass weed is:

   A. Quackgrass.

   B. Wild carrot.

   C. Barnyard grass.

   D. Smooth crabgrass.

7. Reducing the competition between a crop and weeds by changing the planting population of the crop is an example of:

   A. Biological weed control.

   B. Cultural weed control.

   C. Chemical weed control.

   D. Mechanical weed control.

8. Preemergence herbicides generally require rainfall within a week of application to incorporate the herbicide in the soil.

   A. True

   B. False

9. Which of the following is true of preplant incorporated herbicide applications?

   A. They provide early weed control.

   B. They can be used in all tillage systems.

   C. They typically cause more crop injury than postemergence herbicide applications.

   D. They are not affected by soil composition and moisture.

10. List two advantages and two disadvantages to postemergence herbicide applications.

11. Systemic herbicides kill weeds on contact.

   A. True.

   B. False.

12. A preventive herbicide application occurs ______ weeds have emerged.

   A. before

   B. after

13. A grower has a quackgrass problem in a soybean field where the soybeans already have three (3) leaves. Which type of herbicide application would you use to control the quackgrass?

   A. Preplant soil incorporated

   B. Postemergent

   C. Preemergent

   D. None of the above

14. The best way to reduce the potential of herbicide carryover is to follow the pesticide label directions.

   A. True

   B. False

15. What is a herbicide adjuvant?

16. It is **not** necessary to test for herbicide compatibility before mixing a large tank.

   A. True

   B. False

CHAPTER 7

DISEASE MANAGEMENT

LEARNING OBJECTIVES

After completely studying this chapter, you should:

- Be able to define non-infectious and infectious disease.
- Understand how fungi, bacteria, and viruses produce disease.
- Understand the disease triangle and the disease cycle.
- Understand control methods specific to disease management.
- List the major diseases affecting alfalfa, corn, dry beans, soybeans, small grains, and sugarbeets.

INTRODUCTION

Diseases are the most difficult plant injury to diagnose and manage. A plant **disease** is any condition that does not allow the plant to function normally. **Non-infectious plant diseases** are caused by non-living agents or cultural and environmental damage such as drought, soil compaction, hail, wind, toxic chemicals, nutrient deficiency, and temperature or moisture extremes. Non-infectious disease can not reproduce and spread from plant to plant.

Disease symptoms such as wilting, stunting, and yellowing of leaves may appear suddenly on a plant with a non-infectious disease. Few non-infectious diseases can be corrected or avoided, and often the disease symptoms resemble those of infectious diseases. For example, nutrient deficiency symptoms often resemble symptoms of root rot. The remainder of this manual focuses on infectious plant diseases and their management.

An **infectious plant disease** is caused by a living organism that attacks and feeds on the host plant. The disease-causing organism is called a **pathogen**. In Michigan, fungi, bacteria, and viruses are pathogens for field crops. Pathogens are spread from diseased plants to healthy plants by wind, rain, soil, people, machinery, and insects.

FUNGI

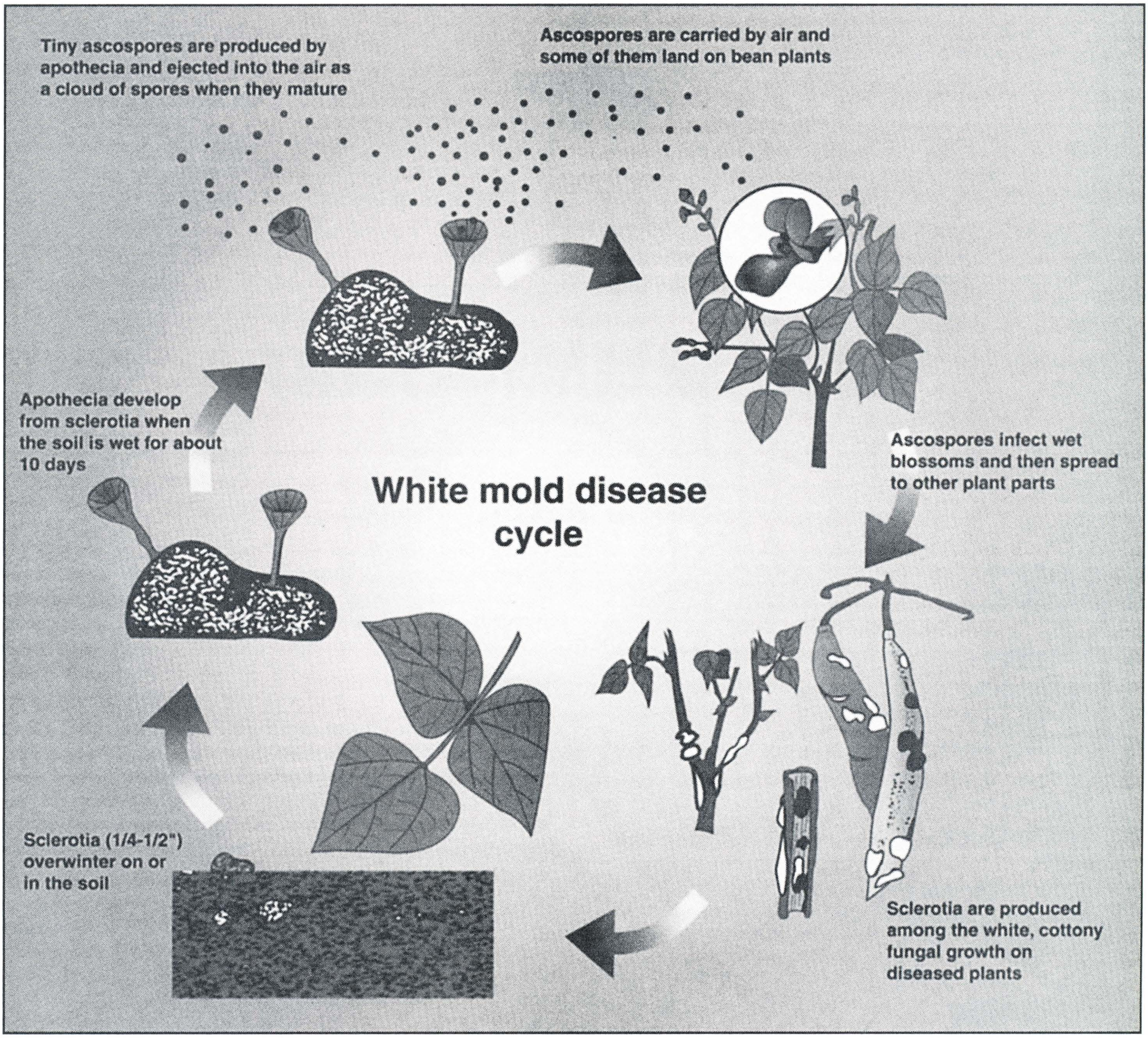
Fungi are the largest and most familiar group of plant pathogens. The best known fungi are mushrooms and yeast. Most fungi are extremely small and can not be seen without a microscope. Fungi can not convert sunlight into food and therefore feed on dead or decaying organic matter (for example, dead trees) or living matter (for example, corn and soybean plants).

Most fungi are made up of delicate, threadlike structures called **hyphae**. Hyphae grow and form masses called **mycelium**. The mycelium is the fuzzy growth that sometimes appears on the surface of a plant. Hyphae absorb nutrients and water needed for fungal growth and reproduction.

Most fungi reproduce by forming microscopic **spores**. Spores come in many shapes and sizes. Some spores are produced in structures called **fruiting bodies**. Others appear on the plant surface as mold growth (for example, powdery mildew, rusts, and blights). Each fungus has a unique spore or fruiting body structure. These are often used for identification.

Wind, splashing rain, insects, birds, workers' hands and clothing, and equipment easily transport spores from one location to another. Harsh environmental conditions will kill most spores; other spores can be dormant for several months or years before germinating.

Some fungi survive harsh environmental conditions by producing specialized structures, such as **sclerotia**. Sclerotia are masses of hyphae and food that can withstand long periods of extreme hot or cold temperatures and lack of water. When environmental conditions turn more favorable, the fungus again produces spores to infect hosts.



White mold disease cycle.

BACTERIA

Bacteria are very small, microscopic, one-celled organisms. Some bacteria are harmful to humans and animals because they cause diseases, such as pneumonia, tuberculosis, typhoid fever, and anthrax. Bacteria also cause disease in plants, but most bacteria are harmless or beneficial (for example, the nitrogen-fixing bacteria of legumes).

Bacteria enter plants through wounds or natural openings in the plant, usually in the leaf but sometimes roots and stems. Once inside the plant, bacteria begin to multiply rapidly. Bacteria live in the spaces between plant cells. The life cycle of a bacterium may be only 20 minutes, so a population of bacteria may increase rapidly.

Bacteria do not produce spores or fruiting bodies—they reproduce by simple cell division. A cell splits into approximately two equal halves. Each half forms a new fully developed bacterium. Bacteria, like fungi, rely on their host plant for food. In the absence of a host plant, a bacteria population may decline rapidly.

Bacteria are spread primarily by wind-driven rain, but driving through a field wet from dew will also spread bacteria. Insects spread some bacterial diseases, such as Stewart's wilt. Typical symptoms of bacterial disease include leaf spots, soft rot of tissues, and water-soaking of tissue.

Stewart's wilt is caused by a bacteria that is transmitted by corn flea beetles.

VIRUSES

A **virus** is a very small non-living organism that cannot reproduce by itself. Viruses multiply by tricking the host cells into making more viruses. They are most familiar to us as the cause of human and animal diseases such as polio, influenza, chickenpox, and warts. Viruses can also cause diseases in plants.

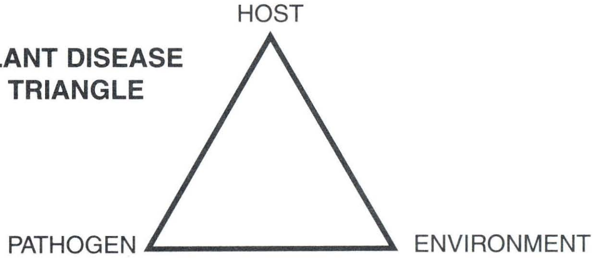
Plants infected with a virus can show any of the following symptoms: yellow to dark green mottling, stunting of the leaves, early leaf fall, loss of plant vigor, mosaic patterns on leaves, deformation of plant tissues, and reduced yield. Sometimes a virus disease is mistaken for nutrient deficiency, pesticide or fertilizer injury, insect or mite activity, or other types of disease.

Because viruses can survive only in living cells, they need to enter a plant by means of a **vector**, usually an insect. Piercing-sucking insects, such as leafhoppers and aphids, are usually responsible for transmitting virus diseases. Pollen, soilborne fungi, or nematodes can transmit a few viruses. Viruses can also be transmitted by vegetative means, such as tubers, bulbs, and root cuttings. Sometimes they are a serious problem for crops that are propagated from cuttings (for example, potatoes and mint).

DISEASE TRIANGLE

Plant diseases occur when a pathogen attacks a susceptible plant under environmental conditions that favor infection and growth of the pathogen. Plant diseases are the result of a complex interaction between the plant, the pathogen, and the environment. This interaction is often represented graphically as the disease triangle. By changing any side of the disease triangle, such as adding an unfavorable environment or using a disease-resistant variety, you can reduce disease development.

PLANT DISEASE TRIANGLE



The role of the environment in this interaction is important because pathogens need specific conditions to develop. If the environment is not suitable, a disease will not develop. Temperature and moisture are probably the two most important environmental conditions that influence plant diseases.

Air or soil temperature affects the growth of the host plant and/or the pathogen. If the host plant is stressed or grows poorly, it may be more susceptible to disease. Temperature may also change the speed of growth of a pathogen.

Pathogens and host plants are also affected by moisture. Fungal spores need moisture to germinate. A host plant experiencing moisture stress may be more susceptible to some pathogens. Also, many pathogens are spread by wind-blown rain or require moisture to infect the plant.

A successful disease management program takes into account the interactions between the environment, the disease, and the host plant. Disease management emphasizes reducing pathogen survival and limiting pathogen dispersal. For example, planting resistant varieties, improving soil drainage, or destroying or removing infected plants disrupts the disease triangle.

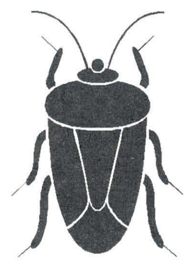
DISEASE CYCLE

All plant pathogens have a basic chain of events involved in disease development called the **disease cycle**.

The basic steps are:

1. **Production of inoculum. Inoculum** is a source of a pathogen that infects plants and causes a disease (for example, fungal spores, bacterial cells, and virus particles). Inoculum can be present in soil, seed, weeds, crop residue, or other crops, and/or carried by the wind, rain, insects, animals, people, and machinery.

2. **Spread of inoculum.** The inoculum must disperse to the host plant. There are two types of spore movement—active and passive. **Active movement** occurs when the inoculum is carried to a host by another organism (for example, insects or animals). One example is the spread of barley yellow dwarf virus (BYDV) from plant to plant by aphids.



   Passive movement is movement of the inoculum to a new host plant by wind or water. Most fungal and bacterial foliar pathogens disperse this way.

3. **Infection.** Infection occurs when the plant pathogen becomes established in the host. A successful plant pathogen grows, spreads within the host plant, and produces new inoculum. As the pathogen grows in the host plant, symptoms begin to appear. The time period between infection and the appearance of the first symptoms is called the **incubation period**. An incubation period can be several days to months.

4. **Pathogen survival between susceptible crops.** In Michigan, pathogens need to survive the winter between growing seasons and periods when no host is present. Disease pathogens survive non-host periods by:

   a. Surviving on crop residues left in the field.

   b. Producing structures that resist microbial and environmental breakdown.

   c. Infecting seeds.

   d. Infecting alternate hosts. A pathogen with a large host range has an increased chance of survival. Some plant pathogens may survive in alternate hosts without causing disease.

DISEASE MANAGEMENT

Options for disease management in Michigan field crops are limited. The best available disease management strategies concentrate on preventing disease. Chapter 1 of this manual deals with general aspects of IPM. This section will address control options specific to diseases.

Cultural Control

Changing crop production practices can help reduce the incidence and impact of many field crop diseases. Cultural practices can disrupt the disease cycle, create unfavorable environmental conditions for the pathogen, reduce the pathogen population in the field, and improve crop growth and vigor.

1. CROP ROTATION. Many plant pathogens survive from one growing season to the next in the soil or on crop residues. To reduce disease, avoid planting the same crop in a field year after year. Alternating to non-host crops provides time to reduce pathogen populations. Some pathogens have a wide host range and are not affected by the sequence of the crop rotation. The fungus Sclerotinia sclerotiorum, responsible for white mold in soybeans, can also infect dry beans, potatoes, tomatoes, and canola. A rotation that includes two of these crops can increase the pathogen population faster than a rotation that includes only one host.

2. TILLAGE. Incorporating crop residues permits soil microorganisms to decompose the residue, prey directly on the pathogen, or outcompete the pathogen for resources. The result is a decrease in the pathogen population. Corn residues left on the soil surface, periods of high daytime temperatures, and high relative humidity are the favored growing conditions for the fungal pathogen Cercospora zeae-maydis, which causes corn gray leaf spot.

3. ROW SPACING. Soil moisture changes with row spacing. Wider row spacing allows the surface of the soil to dry out faster and increases the amount of time needed to create a closed row. For example, wider row spacing can reduce the incidence of white mold in soybeans and dry beans.

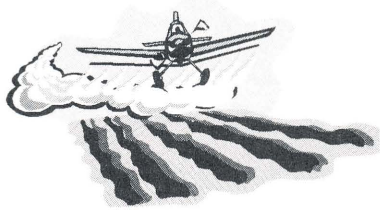
4. VARIETY SELECTION. The use of resistant varieties or hybrids is the least expensive, easiest, and most effective way to control plant diseases. Plant varieties express different degrees of resistance to many diseases. A resistant variety can act as a non-host crop for a specific pathogen. Partially resistant varieties may not prevent the spores of a pathogen from germinating and growing but may reduce the number of new spores produced. This helps keep the pathogen from reaching yield-reducing thresholds.

5. SEED QUALITY. Certified seed is high-quality seed that is selected from healthy, relatively disease-free plants. Certified seed is of known origin and genetic makeup and provides you with a genetically pure crop. Poor seed quality may be associated with fungal or bacterial pathogens that use seed for survival and dispersal. Plants infected with seed-transmitted pathogens should not be used for seed.

Biological Control

Controlling plant pathogens with other bacteria, fungi, or viruses is not very successful. Once disease has infected a field, there is little opportunity to use biological control. However, biological control can be successfully used on insect vectors and surrounding weeds that may serve as an inoculum for a pathogen. Rotation and tillage contribute to biological control by giving natural enemies time to reduce pathogen populations, even when the exact identity of the biological control agent is unknown.

Chemical Control

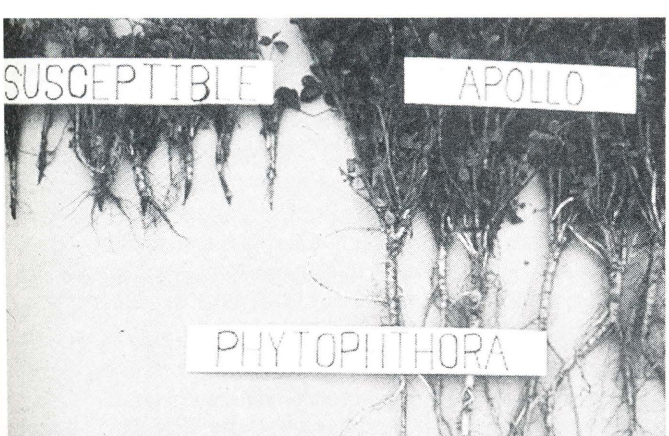


Chemical seed or foliar treatments are often used to control pathogens. Seed treatments can be an effective control for pathogens that live on and/or disperse by seed. For example, treating wheat seed with a systemic fungicide prevents the survival and spread of wheat loose smut (*Ustilageo tritici*), a fungal pathogen. Chemically treated seeds also protect against fungi living in the soil (for example, *Fusarium, Rhizoctonia, Pythium*). These fungi can cause seed and seedling death shortly after planting. Chemically treating dry bean, wheat, alfalfa, and corn seeds before planting helps prevent disease.

Though they're not economically feasible for many Michigan field crop situations, foliar pesticides can be used to control powdery mildew and rust on wheat, white mold in dry beans, *Cercospora* leaf spot in sugar beets, and a variety of diseases on seed corn. It is often much more difficult to control pathogens with pesticide applications than it is to control weeds or insects. The fact that pathogens live in close association with their host makes it difficult to kill the pathogen and not harm the host.

DISEASES OF ALFALFA

Phytophthora root rot



Phytophthora **root rot in alfalfa.**

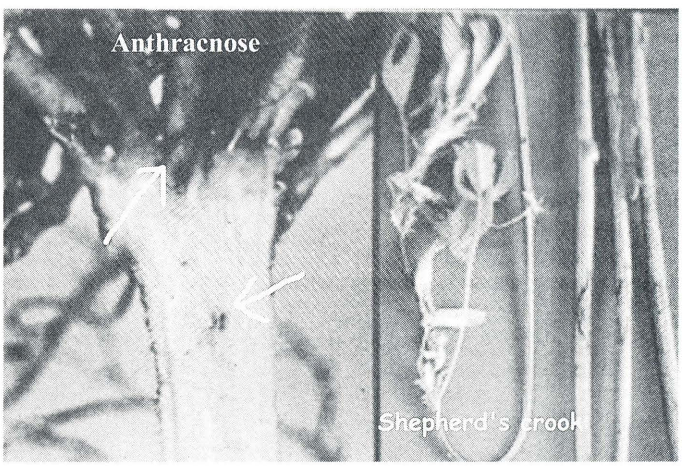
Pathogen type: fungus (Phytophthora megasperma)

Disease symptoms: The first signs of *Phytophthora* infections are dark brown lesions on the taproot. Infected plants will be stunted and yellow and may wilt and die. Phytophthora can also cause **damping-off**—when a seedling fails to emerge or collapses at the soil surface.

Environmental conditions favoring disease: *Phytophthora* is a soil fungus that becomes active after periods of excessive moisture. The pathogen grows best in poorly drained soils during periods of extensive rainfall, and young seedlings are the most susceptible.

Control: *Phytophthora* root rot yield losses can be minimized by improving soil drainage. Planting *Phytophthora* resistant varieties and treating seeds with fungicide can also help reduce the number of plants lost from damping-off.

Anthracnose



Alfalfa infected with anthracnose.

Pathogen type: fungus (*Collectotrichum trifolii*)

Disease symptoms: An alfalfa plant infected with the anthracnose fungus has diamond-shaped lesions near the base of the stem. The lesions are tan with dark brown borders and contain small, black fruiting bodies. Infected stems wilt, producing the characteristic "shepherd's crook" symptom. When alfalfa crowns are invaded, the inner tissues turn bluish black and the plant dies.

Environmental conditions favoring disease: Anthracnose is a warm, humid weather disease. The spores are spread by wind and splashing rain.

Control: The best control option for anthracnose is to plant resistant varieties. Foliar fungicides are not registered for alfalfa.

Crown Rot

Pathogen type: several species of fungus

Symptoms: The crown discolors, turning tan to black. Rotten tissue intersperses with healthy tissue. Slowly, the crown dies. Alfalfa stands gradually begin to thin.

Environmental conditions favoring disease: Fungal spores enter the alfalfa plant through wounds in the roots caused by environmental, mechanical, or insect damage. Therefore, this disease can occur under any environmental conditions that favor root damage.

Control: Minimizing traffic over the field reduces crown damage. Maintain plant vigor, monitor soil levels of potassium (K+), and practice a two-year crop rotation out of small grains.

DISEASES OF CORN

Corn Gray Leaf Spot

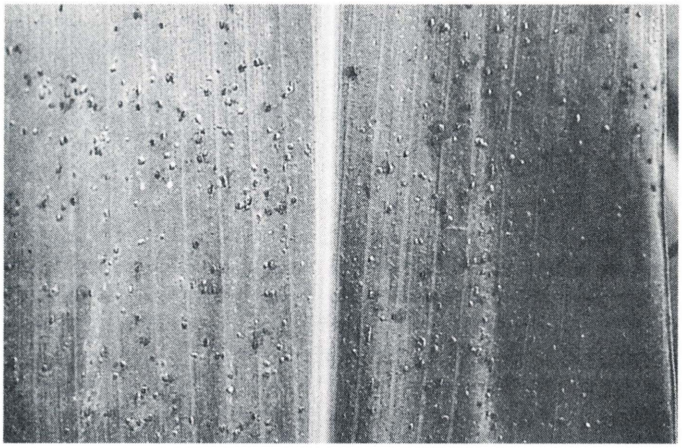
Pathogen type: fungus (*Cercospora zeae-maydis*)

Disease symptoms: Long, rectanglar lesions appear on the leaf surface. Lesions are $1/2$ to 4 inches long and tan to gray.

Environmental conditions favoring disease: The fungus causing corn gray leaf spot lives in crop residue left on the soil surface. The fungus grows best under high daytime temperatures (above 85 degrees F) and relative humidity (above 90percent).

Control: Eliminating infected surface crop residue and rotating crops help control the fungus. Fungicides are used effectively in seed corn.

Common Rust



Close-up of leaf rust.

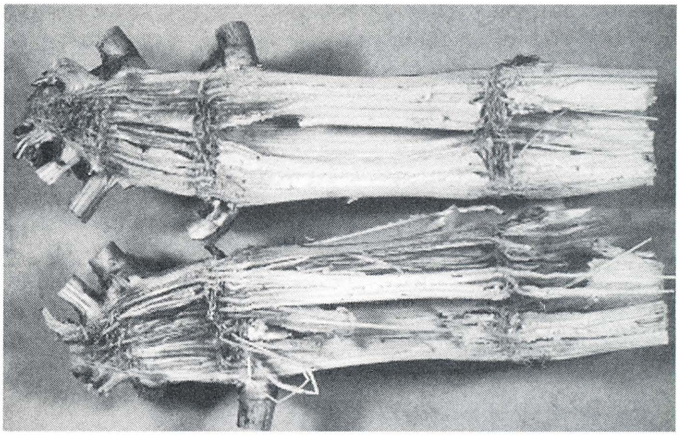
Pathogen type: fungus (*Puccinia sorghi*)

Disease symptoms: Oval or elongated brick-red blisters appear on the leaf surfaces. Rust can kill the leaves of young plants.

Environmental conditions favoring disease: Rust occurs every year, usually late in the season. Rust develops on bright days with cool temperatures (60 to 73 degrees F) and high humidity. The fungal spores are dispersed by the wind.

Control: Planting resistant hybrids is the best way to control rust. Fungicides are used effectively in seed corn.

Gibberella Stalk and Ear Rot



Corn stalk of a *Gibberella* infected plant.

Pathogen type: fungus (*Gibberella* spp.)

Disease symptoms: Gibberella can cause both stalk and ear rot. When the fungus attacks the cornstalk, it often becomes soft and turns brown. The inside of the stalk shreds and turns pink to reddish. The interior of the stalk rots, and the stalk can be easily broken. The usual result is excessive plant lodging.

Gibberella ear rot is caused when the fungus enters the ear through the silk. As the fungus grows, it produces a white-pinkish mold on the ear tip. The fungus may not grow into large molds. *Gibberella* can produce a toxin, **vomitoxin**, that makes the grain unfit for feeding to livestock or humans.

Environmental conditions favoring disease: *Gibberella* stalk rot prefers dry conditions early in the season followed by warm, wet weather two to three weeks after silking. *Gibberella* ear rot develops best when the weather is cool and wet within three weeks of silking. The fungal spores overwinter in the soil and corn debris and are transported by the wind.

Control: Planting corn hybrids that have been selected for resistance to *Gibberella* is the most effective control method. Hybrids with tight husk coverage may have reduced rates of ear rot infection. Also, an early harvest and proper storage may reduce the possibility of ear rot infection. Healthy plants are less susceptible to stalk rot.

Corn Smut

Pathogen type: fungus (*Ustilago maydis*)

Disease symptoms: Galls are formed on aboveground young growing parts of the plant—typically, the ear, tassel, leaves, and stalk. The young galls have a greenish white covering that turns silver-gray as they age. A mature gall is full of black, powdery fungal spores. The spores are dispersed into the air when the gall ruptures.

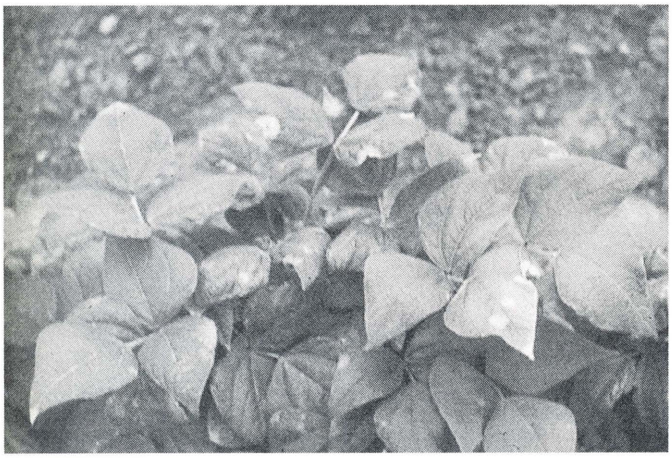
Environmental conditions favoring disease: Corn smut is most prevalent in warm and moderately dry areas. Galls are more likely to occur under dry conditions and temperatures of 78 to 94 degrees F. The smut fungus favors stressed plants. The fungal spores overwinter in the soil and prefer high levels of soil nitrogen.

Smut on ear.

Control: The best management strategy is to plant corn hybrids with some level of resistance. Rotating crops and burying crop residue also offer some control of the fungus.

DISEASES OF DRY BEANS

Dry Bean Halo Blight



Dry bean halo blight on leaves.

Pathogen type: bacterium (*Pseudomonas syringae*)

Disease symptoms: The leaves and/or pods have water-soaked marks. Surrounding each mark is a broad light green or yellow halo. The halo can be as big as a dime to the size of a quarter. Early pod infection causes the seeds to shrivel.

Environmental conditions favoring disease: The bacterium prefers cool weather. The pathogen is spread by splashing rain and workers and machinery moving in an infected field with wet plants. It survives on crop residue from season to season.

Control: Seed treatment controls surface contamination but not internal contamination. All seed should be blight tested at the Michigan Department of Agriculture lab. Any seed testing positive should not be used. The disease usually stops developing under warm temperatures. Resistant varieties and seed treatments help reduce the possibility of infection. All navy bean varieties are resistant to halo blight. Yearly infections can be prevented by removing crop residue and by practicing a crop rotation of two or more years. The bacteria spread can also be reduced by minimizing work in fields when the plants are wet.

Common Blight

Common blight in dry beans.

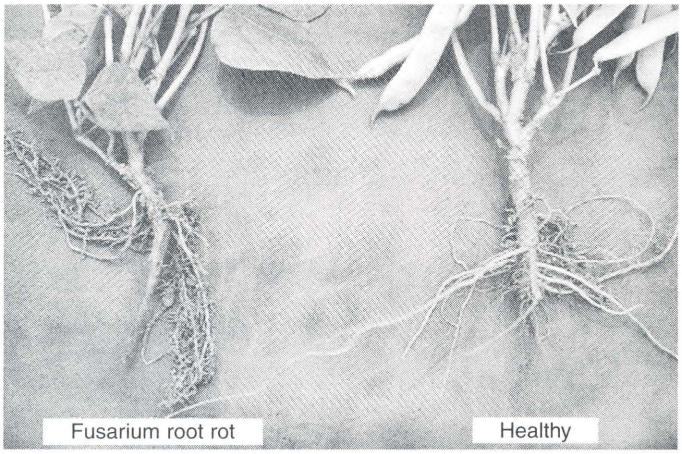
Pathogen type: bacterium (*Xanthomonas campestris*)

Disease symptoms: Leaves and pods have small, water-soaked spots that merge together and turn brown. Unlike halo blight, common blight has only a narrow, bright yellow margin around each spot. The water marks become dry, red-brown spots on infected pods.

Environmental conditions favoring disease: Common blight is more common in warm weather. The pathogen survives in infected seed and on crop residue. Bacteria are spread among plants and fields by splashing rain and people and machinery moving in the field when plants are wet.

Control: Seed treatment controls surface contamination but not internal contamination. All seed should be blight tested at the Michigan Department of Agriculture lab. Any seed testing positive should not be used. Yearly infections can be prevented by removing crop residue and by practicing a crop rotation of two or more years. To reduce the spread of bacteria, minimize work in fields when plants are wet. There are no varieties resistant to common blight.

Fusarium Root Rot



Fusarium root rot infected dry beans.

Pathogen type: fungus (*Fusarium solani* f. sp. *phaseoli*)

Disease symptoms: Two to three weeks after planting, reddish brown streaks appear on the seedling's stem. The lesions may extend upward to the soil surface and turn brown with age. Plants appear stunted with yellow leaves but seldom die.

Environmental conditions favoring disease: Early planting in cool, moist soil favors Fusarium root rot. Any condition that reduces root growth increases the likelihood of infection. The pathogen lives in the soil and can survive for years.

Control: The disease causes little damage to healthy plants. Therefore, the best control against Fusarium root rot is to maintain a healthy crop. Plant in late May or early June to avoid unfavorable soil conditions. A three-year crop rotation out of beans reduces the chances of infection. Varieties differ in resistance.

DISEASES OF SOYBEANS

Phytophthora Stem and Root Rot

Pathogen type: fungus (*Phytophthora sojae*)

Disease symptoms: The fungus can attack a plant at any growth stage, including seed. Infected seeds often die before they emerge. The fungus commonly destroys the plant at the soil level, causing the seedling or plant to fall over. This is called **damping-off**. If the plant is stressed, the disease can cause sudden wilting and drying of leaves. The roots and stems may also turn brown. Older infected plants were usually infected when they were seedlings. They may be stunted and eventually die.

Environmental conditions favoring disease: Periods of high soil moisture, rainfall, or standing water favor the development of the disease. The disease is found more frequently in heavy soils with poor drainage and areas with high rainfall. The fungus overwinters in the soil as spores. The spores are dispersed by the wind.

Phytophthora stem and root rot in soybeans.

Control: Use farming practices that reduce soil compaction, increase soil aeration, and improve soil structure. Avoid planting in poorly drained soils. Plant resistant hybrids. There is more than one race of *Phytophthora sojae*, and not every resistant hybrid is an effective control for every race of the pathogen. Check with your county Extension agent for information about resistant soybean varieties for your area.

White Mold

Pathogen type: fungus (*Sclerotinia sclerotiorum*)

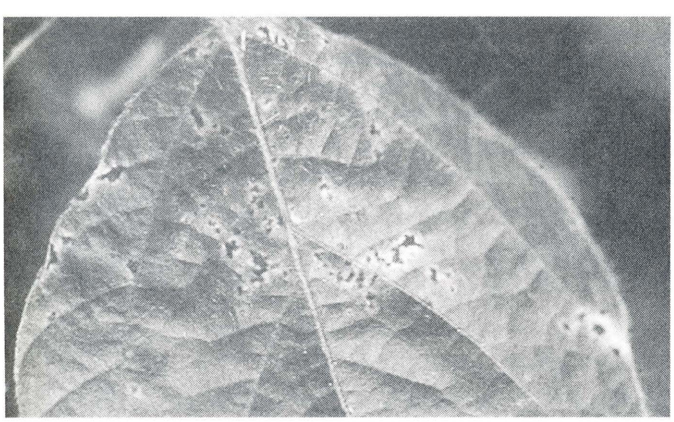
Disease symptoms: Fungal spores enter the plant **only** through the flowers. A fluffy, white mold grows on nodes and stems. Leaves wilt and turn brown. This growth can girdle the stem, killing the plant. Dead plants stay erect. Hard, black fungal bodies (sclerotia) develop in and outside of the stems and pods. These fungal bodies can be harvested with the soybeans, returned to the soil, or moved around the field or from field to field to reinfect the following season.

Environmental conditions favoring disease: Wet weather two weeks before and during flowering of the soybean plant is important for infection. The capacity of the soybean canopy to keep stems wet for extended periods of time contributes to disease severity.

Soybeans killed by white mold (X. B. Yang, Iowa State University).

Control: Planting wider rows allows the soil to dry out. This changes the environmental factors necessary for the pathogen to infect the soybean plant. Preventing the introduction of the pathogen by thoroughly cleaning equipment can minimize the spread of white mold between fields. The severity of white mold infections can be reduced by long crop rotations. However, the fungus attacks other field crops, including dry beans and vegetables such as tomatoes, potatoes, canola, and cucumbers. Therefore, alternate white mold-susceptible crops in rotations with corn or wheat to reduce fungal survival. Check with your county Extension agent for information on chemical control of white mold.

Septoria Brown Spot



Septoria brown spot infected soybeans.

Pathogen type: fungus (*Septoria* spp.)

Disease symptoms: Irregular, dark brown spots that vary from minute flecks to lesions $3/16$ inch in diameter form on the leaves. The spots may have yellow borders. The symptoms usually appear on the lower leaves first. Eventually, the leaves drop off.

Environmental conditions favoring disease: Wet conditions with heavy rain spread the fungus upward in the plant canopy. The fungus attacks young seedlings early and late in the season. The spores overwinter in the soil and are dispersed by the wind.

Control: There is little to no economic loss from brown spot, so no control options are recommended. Continuous cropping of soybeans may increase the severity of the disease, however.

DISEASES OF SUGAR BEETS

Cercospora Leaf Spot

Cercospora leaf spot in sugar beets.

Pathogen type: fungus (*Cercospora beticola*)

Disease symptoms: Small, brown spots with purple borders appear on leaves and leaf stems. The spots merge, causing the leaves to turn yellow to brown. In high humidity and heavy dew, the spots look gray. Finally, the leaf collapses but remains attached.

Environmental conditions favoring disease: The fungus survives on crop residue and develops best in high temperatures and high humidity.

Control: Crop rotation and clean plowing to reduce crop residue diminish pathogen infection from year to year. Planting disease-tolerant varieties also reduces fungal infections. Foliar fungicides are effective and can be used even on disease-tolerant varieties.

Black Root

Pathogen type: Several fungi cause black root, but the most serious one is *Aphanomyces cochloides*.

Disease symptoms: The fungus infects the seedling roots. Brown, water-soaked regions appear on the stem and cotyledons. The infected root and stem turn black and become threadlike. Damping-off usually occurs.

Environmental conditions favoring disease: This soilborne fungus prefers warm, wet soils.

Control: Seed treatments and tolerant varieties offer control. Also, planting on well drained soils will decrease the disease, which prefers wet areas of the field—for example, near drainage ditches and low spots. Crop rotation is also an effective control.

Rhizoctonia Root Rot

Pathogen type: fungus (*Rhizoctonia solani*)

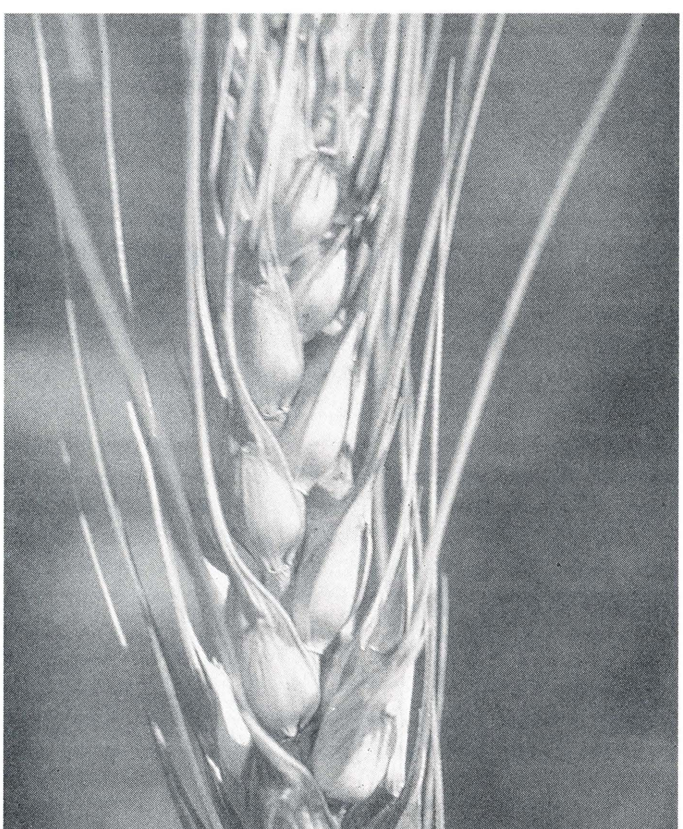
Disease symptoms: Sudden wilting, leaf stems turning black, and outer leaves yellowing are the first symptoms. The wilted leaves collapse and die. The roots may partially or completely rot. Infected areas on the root surface are dark brown to black.

Environmental conditions favoring disease: This is a common soil fungus that attacks a wide host range. Rhizoctonia root rot prefers high temperatures and is more severe in heavy, poorly drained soils.

Control: Rhizoctonia root rot is difficult to control. Tillage, fertilizing, promoting healthy plants and good soil drainage, practicing crop rotation, and controlling weeds all help reduce the occurrence of this disease.

DISEASES OF WHEAT AND SMALL GRAINS

Wheat Scab



Scab causes premature ripening of wheat (G. Munkvold, Iowa State University).

Pathogen type: fungus (*Fusarium graminearum*)

Disease symptoms: Infection occurs at flowering, and infected spikelets will have a bleached appearance. Orange or pink spore masses can be found at the bases of the spikelets. The fungus enters the kernels, turning them light brown to pink when infections occur early in the season. Infected kernels may be shrunken, wrinkled, and lightweight, though many infected kernels show no symptoms. The fungus produces vomitoxin, a toxin that can cause vomiting, nausea, dizziness, and diarrhea in non-ruminant animals such as humans and hogs. The chance of vomitoxin getting into human food is slim because grain is tested. However, problems may develop from feeding livestock uncleaned, scabby wheat, oats, or barley. Hogs fed 10 percent or more scabby grain may vomit and refuse to eat the grain mixture. Vomitoxin does not break down easily and can remain in stored grain for a long time.

Environmental conditions favoring disease: The fungus develops in cool to moderate, wet weather during flowering and grain ripening. Periods of rain immediately before flowering and lasting for three or more days after flowering begins are highly favorable for scab development. The wind disperses spores that overwinter in infected grain and corn residue.

Control: Scab-infected seeds should not be used. Seed treatment will reduce seedling diseases but does not affect infection at flowering. The same fungus that causes wheat scab also causes stalk rot in corn. Therefore, plant away from old cornfields and avoid rotating wheat, corn, barley, oats, or rye into corn. Plant two or more varieties that flower three to seven days apart to reduce the risk of scab.

Wheat Yellow Mosaic Virus

Pathogen type: virus

Disease symptoms: Young leaves have light green or yellow streaks and dashes. Older leaves may be bright yellow-green. The leaf markings are parallel with leaf veins and taper at both ends to form spindles. Wheat yellow mosaic virus-infected plants tend to be uniformly distributed throughout the field. Infected plants produce fewer tillers, smaller heads and less seed per head than healthy plants. Plants may be mildly stunted, but this is not often evident.

Environmental conditions favoring disease: Cold air temperatures (40 to 50 degrees F) favor infection by this virus. Generally, as temperatures warm, the plant appears to have outgrown the virus. In years with prolonged cool temperatures, susceptible varieties can display symptoms through early June.

Method of transmission: The virus survives in the soil and is transmitted to plants by a soilborne fungus, *Polymyxa graminis*. Cultivating equipment, wind, water, and other factors that disperse infested soil spreads wheat yellow mosaic virus. Soils may remain infected for years.

Control: Resistant varieties and long crop rotations with legumes reduce the potential for wheat yellow mosaic virus infections.

Barley Yellow Dwarf Virus

Barley yellow dwarf virus in wheat, with healthy plants on the left (G. Munkvold, Iowa State University).

Pathogen type: virus

Disease symptoms: Starting at the leaf tip, leaves turn yellow or bright red. Infection in young plants may cause stunting. Plants can be attacked in both the fall and spring. Plants infected in fall may be unable to survive the winter. Spring infections may result in discoloration of only the top leaf (flag leaf). Distribution of the virus in the field depends on the aphid population.

Environmental conditions favoring disease: Moderate temperatures favor foliar symptoms. Barley yellow dwarf virus epidemics occur when the weather conditions favor the aphid vectors. Cool (50 to 65 degrees F), moist weather is most favorable. Aphid movement can be local, from one field to another, or aphids can be carried hundreds of miles by the wind. Generally, aphids migrate from the southern states to the northern states in spring and from north to south in fall.

Method of transmission: More than 20 species of aphids are known to transmit the virus, which exists as several strains. Several aphids transmit some strains of the virus equally well, whereas other strains can be transmitted by only one or two aphid species. All cereals and wild grasses are hosts.

Control: Resistant oat varieties are available. Barley and wheat varieties show differences in barley yellow dwarf virus infections, but they are not resistant. Plant winter wheat five to 10 days after the Hessian fly-free date and barley as late as practical to avoid early fall infections. Plant spring oats as early as possible. Vigorously growing plants are more tolerant of barley yellow dwarf virus. Control volunteer wheat, barley and oats—they can serve as reservoirs of the virus. Chemical control of the aphid vectors is not effective or economical.

Leaf Rust

Leaf rust pustules on wheat (G. Munkvold, Iowa State University).

Pathogen type: fungus (*Puccinia recondita*)

Disease symptoms: Small, round or oval, raised, orange-red blisters or pustules appear on leaf surfaces. They can be either scattered or clumped on the leaf surface. Each pustule contains thousands of spores. Rubbing the pustules and releasing the spores confirms the identification of rust.

Environmental conditions favoring disease: Cool nights and warm, bright days. The stems and leaves need to be moisture free for six to eight hours.

Method of transmission: Fungal spores are windblown. New infections can occur every 10 to 12 days.

Control: Plant resistant varieties. Fungicides can be effective for early-season infections.

General Control Practices for All Wheat and Small Grain Diseases

1. Select varieties that are high yielding and resistant to the major diseases.
2. Plant more than one variety. Planting varieties that flower at different times helps to reduce the incidence of scab.

3. Treat all seeds before planting. This is a must for any wheat grown in Michigan. Seed treatments reduce infections by seedborne pathogens such as wheat scab and are critical to control loose smut and common (stinky) smut.
4. Scout fields beginning in mid-May to identify fields that are potential problems. Remember to scout the entire field to locate pockets of infection.
5. Protect the flag leaf. Eighty percent of the yield comes from the flag leaf. Chemical treatments should not be applied until the flag leaf has emerged and only in conjunction with scouting. Fungicides are not labeled for application after flowering.

CHAPTER 7

Review Questions

Chapter 7: Disease Management

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

1. Which of the following can cause a non-infectious disease?
   A. Drought
   B. Insects
   C. Viruses
   D. Bacteria

2. An organism that causes disease is a:
   A. Parasitoid.
   B. Predator.
   C. Pathogen.
   D. Parasite.

3. Infectious plant diseases can be spread from diseased plants to healthy plants.
   A. True
   B. False

4. Which of the following is a living microscopic one-celled organism?
   A. Virus
   B. Fungus
   C. Bacterium
   D. Fruiting body

5. Which of the following uses spores to reproduce?
   A. Virus
   B. Bacterium
   C. Fungus
   D. Nematode

6. Draw a picture of the disease triangle and label its three parts.

7. By changing an environmental factor such as soil moisture, you can influence plant diseases.
   A. True
   B. False

8. List the four basic steps of the disease cycle.

9. A plant pathogen that is dispersed by wind to unaffected plants is said to move by:

A. Active movement.

B. Passive movement.

10. The source of a plant pathogen that causes a disease is called a(n):

A. Infection.

B. Parasite.

C. Inoculum.

D. Host.

11. The time period between infection and appearance of the first plant symptoms is the:

A. Preharvest interval.

B. Restricted entry interval.

C. Incubation period.

D. Disease period.

12. Cultural control methods can disrupt the disease cycle by:

A. Creating unfavorable conditions.

B. Improving crop growth.

C. Reducing the plant pathogen population in a field.

D. All of the above.

13. Which of the following is NOT a cultural control?

A. Planting high-quality seed.

B. Treating seeds with a fungicide.

C. Increasing the row spacing.

D. Practicing crop rotation.

14. Biological control is the most effective tactic to use to control plant pathogens.

A. True.

B. False.

15. Which of the following alfalfa diseases causes the stems to take on a "shepherd's crook" shape?

A. Phytophthora root rot.

B. Crown rot.

C. Anthracnose

D. Verticillium wilt.

16-19. Match the following corn disease with the characteristic disease symptoms.

A. Gibberella stalk and ear rot

B. Corn smut

C. Common rust

D. Corn gray leaf spot

16. ___ Forms galls that usually appear on the ear.

17 ___ Produces a pinkish mold.

18. ___ Leaves have dark red blisters.

19. ___ Fungus produces long, gray lesions on leaf surfaces.

20. Which of the following plant diseases is transmitted by aphids from an infected plant to a non-infected plant?

A. White mold.

B. Common rust.

C. Corn smut.

D. Barley yellow dwarf virus.

21-26. Match the following diseases with the type of plant pathogen that causes them.

A. Bacterium

B. Fungus

C. Virus

21. ___ Septoria brown spot

22. ___ Common blight

23. ___ Fusarium root rot

24. ___ Wheat yellow mosaic

25. ___ Dry bean halo blight

26. ___ Anthracnose

27. The plant pathogen that causes white mold in soybeans enters the plant through the soybean ___________.

A. Stem.

B. Root.

C. Flower.

D. Leaf.

28. Damping-off in soybeans can be caused by which plant disease?

A. Septoria brown spot

B. Fusarium root rot

C. Phytophthora stem and root rot

D. Common blight

29. More than one type of fungus can cause black root disease in sugar beets.

A. True.

B. False.

30. Wheat kernels that produce vomitoxin have been infected with:

A. Wheat scab.

B. Leaf rust.

C. Wheat yellow mosaic virus.

D. Barley yellow dwarf virus.

31. Vomitoxin is poisonous to humans.

A. True.

B. False.

32. Wheat yellow mosaic virus is transmitted to plants by:

A. Insects.

B. Fungi.

C. Wind.

D. None of the above.

33. Your barley plants have small, orange-red, round blisters or pustules on the leaves. When you rub the sores, lots of little specks or spores are released. Your barley plants are infected with which disease?

A. Barley yellow dwarf virus

B. Leaf rust

C. Wheat yellow mosaic virus

D. Wheat scab

34. List three common practices used to control small grain diseases.

CHAPTER 8

NEMATODE MANAGEMENT

LEARNING OBJECTIVES

After completely studying this chapter, you should:

- Know what a nematode is and how it develops.
- Know the three groups of control tactics specific to nematode management.
- Understand the life cycle and management options for soybean cyst nematode, sugar beet cyst nematode, corn needle nematode, the root-lesion nematode, and the northern root-knot nematode.

INTRODUCTION

Nematodes are very small roundworms. They live everywhere—in soil, plants, water, and animals, including humans. Nematodes feed on bacteria, fungi, algae, plants, and animals. A few thousand species attack plants; most nematodes feed on dead or decaying organic matter. Many nematode species are beneficial because they feed on bacteria, insects, fungi, and other soil pests.

The life cycle of a nematode is egg, four juvenile stages, and adult. Adult females lay eggs that hatch into young nematodes, **juveniles**. Juveniles look like small adults. First and second stage juveniles are usually found still inside the egg case. For most plant-parasitic nematodes, egg hatching takes place during the second juvenile stage. After a total of four molts (shedding of their skin), the juveniles become adults. If males and females are present, they mate and produce more eggs. Typically, the life cycle of a plant-parasitic nematode is completed within 20 to 60 days.

About 95 percent of plant-feeding nematodes live in the soil and feed in or on roots. Some consume aboveground plant parts. Plant-feeding nematodes feed by inserting a needlelike structure (**stylet**) into plant cells. They inject an enzyme into the cell that dissolves the cell contents. The nematode then uses its stylet like a straw to remove the liquid cell contents.

Nematode root feeding directly interferes with a plant's ability to take up water and nutrients. Infected plants wilt and appear to be suffering from a lack of water or nutrients. These symptoms can easily be mistaken for damage caused by other conditions. High nematode populations result in plant stunting, yellowing, a general decline in plant health, and sometimes plant death. Nematode feeding can cause yield loss. The feeding sites also act as points of entry for other pathogens such as fungi and bacteria.

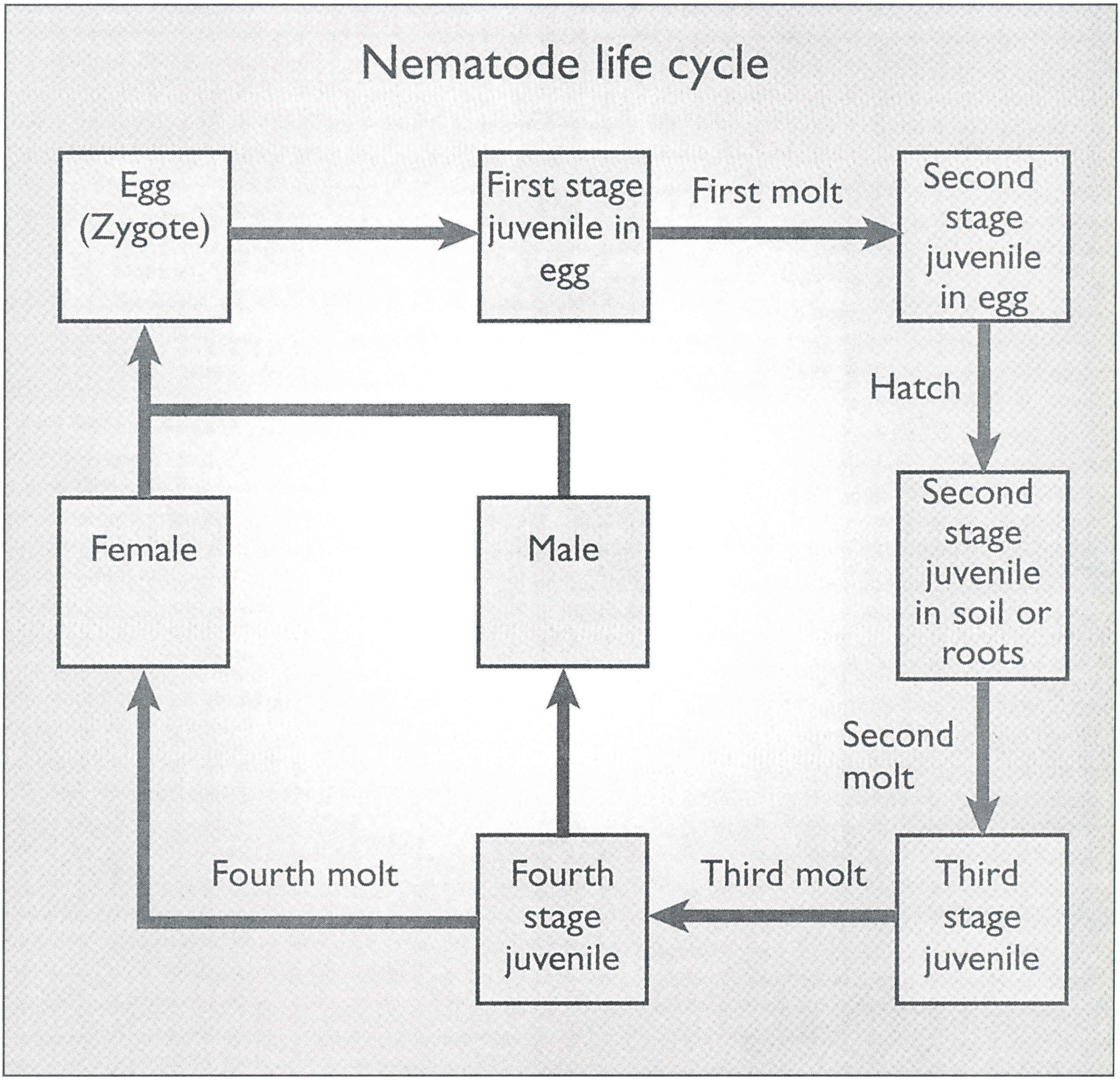
Though nematodes are small, they can easily disperse over long and short distances. In the soil, nematodes move approximately 1 inch per year. However, they can be transported from field to field or within a field by flood waters, dust storms, contaminated machinery, and nursery stock or transplants.

Nematode populations are identified and located from field soil samples. Soil and root samples can be submitted to MSU Diagnostic Services for identification. After proper identification, a site-specific nematode management program can be developed. Details on how to collect and submit a proper soil sample are found in current MSU Extension bulletins.

NEMATODE MANAGEMENT

Nematode management tactics can be grouped into three types: prevention, containment, and chemical control.

- **Prevention tactics** are intended to prevent nematode problems. Some are: practicing crop rotation, using nematode-free seeds and transplants, planting nematode-resistant or -tolerant varieties, keeping farm equipment nematode free, and maintaining good farm sanitation.



Nematode life cycle.

- **Containment tactics** keep a nematode population from spreading to other fields or other areas in the same field. It is nearly impossible to completely remove a nematode population from a field after it has become established. Prevention tactics such as crop rotation and planting nematode-free seeds and transplants can reduce the nematode population, however.
- **Chemical control tactics** are not often recommended for nematode control. However, both fumigant and non-fumigant nematicides (nematode-specific pesticides) are available. Chemical control of nematodes should always be used in conjunction with other nematode management strategies. For pesticide recommendations, refer to current MSU Extension bulletins.

SOYBEAN CYST NEMATODE

Host plants: Soybeans, dry beans, and other legume crops (green beans, green peas) and weeds (henbit, field pennycress, shepherd's purse).

First detection in Michigan: 1987.

Life cycle: The adult female soybean cyst nematode mates with a male and produces 150 to 500 eggs. Shortly after mating, she dies. But first she deposits a few eggs on the outside of her body. The other eggs remain in her dead body, which is called a **cyst**. In the cyst the eggs are protected from predators and environmental factors that would kill them. The eggs in the cyst hatch over the next eight years. Soybean cyst nematode eggs survive best

Soybean cyst nematodes on soybean roots (G. Tylka, Iowa State University).

under cool, moist conditions. The juveniles emerge from the eggs and immediately begin searching for food -- soybean roots. Once the juveniles find a soybean root, they enter the root and begin to feed. A juvenile soybean cyst nematode molts four times before becoming an adult nematode. Under moderate soil conditions, it takes 21 to 24 days for a soybean cyst nematode to complete its life cycle.

Soybean field infected with soybean cyst nematodes.

Damage and symptoms: The most common aboveground symptoms of soybean cyst nematode damage are stunted and yellowed plants. Plant symptoms are usually not evenly distributed in a field. In early July, white female soybean cyst nematodes are found attached to plant roots. As the nematodes age, they become yellow. The attached females are the only visible sign of a soybean cyst nematode infestation. Soybean cyst nematode infestations can reduce soybean yields by 30 percent without plants showing symptoms. Severe infestations can reduce soybean yields as much as 80 percent.

Management options: To prevent soybean cyst nematode infestations, practice crop rotation, plant nematode-free seed, and maintain clean machinery. Nematode-resistant and -tolerant soybean varieties are available. Fields with low to moderate soybean cyst nematode populations can be managed by practicing a three-year crop rotation. Longer rotations may be necessary for fields with large soybean cyst nematode populations. Soil fumigants are available but very expensive. Non-fumigant nematicides applied at planting may reduce soybean cyst nematode populations. In many situations, they, too, are very costly.

SUGAR BEET CYST NEMATODE

A sugar beet infected with sugar beet cyst nematode.

Host plants: Sugar beets, cabbage, mustard, cauliflower, and many weeds.

First detection in Michigan: 1949.

Life cycle: All cyst nematodes develop in the same manner. Therefore, the sugar beet cyst nematode is very similar to the soybean cyst nematode. After hatching, the second stage juvenile (J2) nematodes enter the sugar beet roots to feed. As the nematode grows, it bursts from the root. The white to yellow adult females are exposed on the root surface. With ideal soil conditions, the sugar beet cyst nematode completes its life cycle in 25 days.

Plant symptoms of a sugar beet cyst nematode infestation.

Damage and symptoms: Typically, the sugarbeet cyst nematode is found in the fibrous roots, but it can also feed on the storage root. Infected sugar beet plants are stunted, have yellow foliage, and wilt in warm weather. The wilting can be persistent even in soil with high moisture levels. You can see female sugar beet cyst nematodes on the plants roots without a hand lens. Severe nematode infestations may reduce yields.

Management options: Sugar beets are the only major host of sugarbeet cyst nematodes in Michigan, so crop rotation provides sufficient control. Typically, at least a three-year rotation out of sugar beets is recommended. However, in heavily infested fields a longer rotation (five to eight years) may be necessary. Currently, there are no sugar beet varieties that are resistant to the sugar beet cyst nematode.

CORN NEEDLE NEMATODE

A corn needle nematode infestation can stunt a plant's growth.

Host plants: Corn and other grass plants

First detection in Michigan: 1980.

Life cycle: Female corn needle nematodes produce roughly one egg per day over several months. In the spring after the eggs hatch, the juvenile nematode feeds on young corn roots. As the soil temperature increases, the corn needle nematode migrates deeper into the soil and may stop feeding. In Michigan, it completes approximately one generation per year. The corn needle nematode is typically found in sandy fields with long histories of corn production and poor crop rotation. Unlike cyst nematodes, the corn needle nematode will not survive long without its host plant.

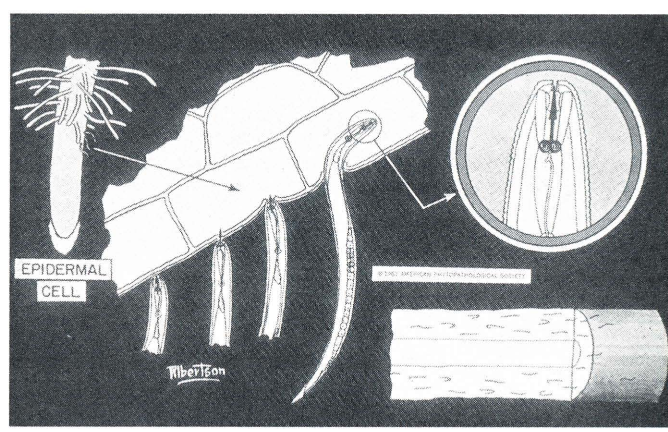
Damage and symptoms: Corn needle nematodes do not enter the root but feed close to the root tip, preventing the root from developing normally. The damage includes root tip swelling, stunted plants, small and barren ears at harvest, and a reduction (10 to 75 percent) in grain yields. The corn needle nematode prefers to live in coarse-textured or sandy soils. As the soil moisture decreases and temperature increases, the corn needle nematode moves deeper into the soil. During the summer, the corn needle nematode can be found 18 to 36 inches below the soil surface.

Management options: Soil sampling should be done in spring or fall, when the corn needle nematode is close to the soil surface. Sampling in the root zone during the summer will not detect it. Crop rotation, especially with soybeans or alfalfa, will reduce corn needle nematode populations. It is also important to maintain soil quality. Non-fumigant nematicides do not provide control of corn needle nematode.

ROOT-LESION NEMATODE

Host plants: More than 350 recorded host plants, including corn and sugar beets

First detection in Michigan: Unknown



Root lesion nematode.

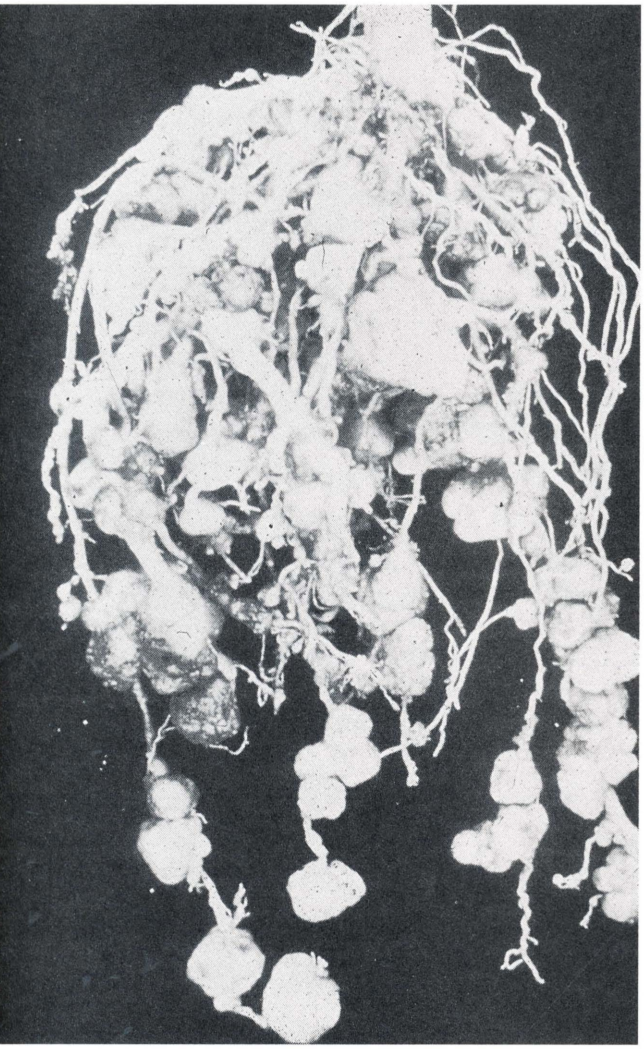
Life cycle: After mating, females lay single eggs in roots or soil. Second stage juveniles (J2) hatch from the eggs. Like all nematodes, the root-lesion nematode goes through four molts before reaching the adult stage. Adults and the last three juvenile stages can enter the roots to feed at any time. Root-lesion nematode may take from 30 to 86 days to complete its life cycle.

amage and symptoms: Root-lesion nematodes usually ed on the smaller plant roots, killing them. The feeding es allow other pathogens such as fungi and bacteria to ter the root system. Root-lesion nematode infestations use plants to grow poorly and have yellow leaves that ay wilt in hot weather, and can reduce crop yields. fested seedlings are often stunted.

anagement options: Root-lesion nematodes can attack wide number plants. Therefore, crop rotation will usu-y not sufficiently reduce their populations. ematicides are available but should always be used on field-by-field basis and with a nematode management ogram.

ORTHERN ROOT-KNOT NEMATODE

ost plants: More than 300 recorded plants, including y beans, soybeans, sugarbeets and forage legumes



ot-knot nematode.

rst detection in Michigan: Early 1900s

fe cycle: The female northern root-knot nematode pro-ces as many as 500 eggs. She carries these eggs in a me like mass on the outside of her body. In early ring, second stage juveniles hatch from the eggs and begin to feed on roots. Their feeding causes the roots to swell. The northern root-knot nematode completes its life cycle in one to two months. There are at least two generations per year in Michigan.

Damage and symptoms: Northern root-knot nematode feeding produces small root swellings called galls. Nematode-infested plants do not compete well for water and soil nutrients. These plants often appear to be water stressed even though there is sufficient soil moisture.

Management options: Crop rotation is the most effective way to manage the northern root-knot worm. Usually a one-year rotation out of the host crop is necessary to reduce nematode populations. Soil fumigants effectively control northern root-knot nematodes and may be necessary when populations are high.

CHAPTER 8

Review Questions

Chapter 8: Nematode Management

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

1. Nematodes are small roundworms.
   A. True
   B. False

2. Plant-parasitic nematodes usually cause crop damage by feeding on the plant's:
   A. Leaves
   B. Stems
   C. Flowers
   D. Roots

3. A young nematode is called a:
   A. Nymph
   B. Juvenile
   C. Larva
   D. None of the above

4. Nematodes can move across a field or from one field to another by:
   A. Dust storms
   B. Contaminated machinery
   C. Floodwater
   D. All of the above

5. What type of mouthparts does a nematode have?
   A. Chewing
   B. Sucking
   C. Piercing/sucking
   D. Rasping

6. List three types of management tactics used to control nematodes. Give an example of each type.

7. Nematicides are applied to plant leaves to control root-feeding nematodes.
   A. True
   B. False

8-11. Match the following characteristics with the appropriate nematode.

A. Soybean cyst nematode
B. Corn needle nematode
C. Root-lesion nematode
D. Northern root-knot nematode

8. ___ Cannot be detected by sampling in the crop's root zone during the summer.
9. ___ Feeding results in the production of root galls.
10. ___ Usually managed by practicing crop rotation and planting resistant varieties.
11. ___ Extremely difficult to control with crop rotation.

12. The eggs of a soybean cyst nematode can continue to hatch over a period of:
    A. 1 week
    B. 10 hours
    C. 8 years
    D. 12 days

13. Which of the following nematodes does NOT enter the root to feed?

A. Soybean cyst nematode

B. Corn needle nematode

C. Sugar beet cyst nematode

D. Root-lesion nematode

14. Using crop rotation to stop a nematode population from growing and moving to other areas of a field is an example of which type of management system?

A. Chemical.

B. Prevention.

C. Containment.

D. Biological.

15. What is a cyst?

APPENDIX A

ANSWERS TO REVIEW QUESTIONS

Chapter 1 Integrated Pest Management

(1) Integrated pest management is a planned pest control program that combines control strategies to keep the pest population below economically damaging levels and to avoid adverse effects to humans, wildlife, and the environment.

(2) Cultural control – examples: host-plant resistance, maintaining healthy plants, changing the timing of harvest or planting, cultivation, field management, water management.

Biological control—examples: pathogens, parasitoids, predators.

Chemical control—examples: insecticide, herbicide, fungicide.

(3) Economic threshold—the number of pests (pest density) that requires a control action to prevent the pest population from increasing and causing economic damage.

(4) B. (5) D. (6) C.

(7) Cultural controls work by (1) preventing the pest from colonizing the crop or commodity, (2) creat-ing adverse conditions that reduce survival of the pest, and (3) reducing the impact of injury by the pest.

(8) A. (9) C. (10) B. (11) A. (12) B.

(13) C. (14) B. (15) A. (16) A. (17) B. (18) B.

(19) Tolerance is the amount of acceptable pesticide residue permitted by the Environmental Protection Agency (EPA) on a harvested crop.

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

Chapter 2. Minimizing Pesticide Impact

(1) A.

(2) A supplemental label is any information from the manufacturer about how to use the product. Examples: special local needs labels (24c), emergency exemption labels (section 18), and use information issued by the manufacturer.

(3) B. (4) C. (5) D. (6) A. (7) B. (8) D.

(9) B. (10)B.

(11) Any five of the following are correct: use integrated pest management, consider the geology of the area, carefully select pesticides that are not likely to leach, follow pesticide label directions,.calibrate your equipment, measure accurately, avoid back-siphoning, consider weather conditions at the time of application, mix on an impervious pad, properly dispose of all pesticide wastes, and store pesticides away from water sources.

(12) C. (13) B. (14) A. (15) B. (16) A. (17) B.

(18) B. (19) A.

(20)
1. A map of all areas where pesticide applications occur.
2. A list of pesticide-sensitive sites near an application area.
3. Pesticide label and mandated restrictions.
4. Information for persons in sensitive areas on the type of pesticide used, the method of application, and the applicator's plan to minimize pesticide drift.

Chapter 3 Application Equipment

(1) D.

(2) The method of a pesticide application is influenced by target pest, the site of application, the available application equipment, and the cost and efficiency of alternative control methods.

(3) A. (4) A. (5) D. (6) C. (7) B. (8) A.

(9) B. (10) B. (11) B. (12) C. (13) B. (14) A.

(15) A pressure regulator controls the pressure in the spray system and therefore the amount of spray material delivered by the nozzles.

(16) C. (17) A. (18) B. (19) B. (20) D.

(21)
1. Check the spray system for leaks and drips by filling the tank with water and pressurizing the system.
2. Check the nozzles and strainers, making sure they are all the same type and are clean.
3. Measure the distance between the nozzle tip and the target and adjust, if necessary.

(22) B. (23) C. (24) B.

(25) Global positioning systems and geographical information systems help map fields and increase the accuracy of pesticide applications.

Chapter 4 Calibration

(1) Calibration of various systems is important because each system is a unique combination of pumps, nozzles, and other equipment.

(2) A. (3) B. (4) C. (5) C. (6) B. (7) D.

(8) A. (9) C. (10) B. (11) A. (12) A.

(13) D. (14) D. (15) B. (16) C. (17) A. (18) C.

Chapter 5 Insect Management

(1) D. (2) A.

(3) Metamorphosis is defined as the change in shape or form of an animal. An insect is said to undergo metamorphosis when it changes from the larval to pupal to adult life stage.

(4) A. (5) A. (6) C. (7) B. (8) B. (9) C.

(10) B.

(11) It is important to understand an insect's life cycle for pest management because each life stage is managed differently on the basis of its food source and habitat.

(12) B. (13) D. (14) E. (15) A. (16) C. (17) B.

(18) E. (19) B. (20) C. (21) C. (22) D. (23) B.

(24) A. (25) C. (26) A. (27) C. (28) B. (29) C.

(30) A. (31) D. (32) B. (33) A. (34) B. (35) A.

Chapter 6 Weed Management

(1) A weed is a plant growing where it is not wanted.

(2) B. (3) B. (4) C. (5) D. (6) A. (7) B.

(8) A. (9) A.

(10) Advantages –spot treatment, treat after problem occurs, herbicide is less susceptible to environmental conditions after treatment.

Disadvantages—need to correctly identify the weed, timing of application is critical, should not be applied to wet foliage, weather may not permit a timely application.

(11) B. (12) A. (13) B. (14) A.

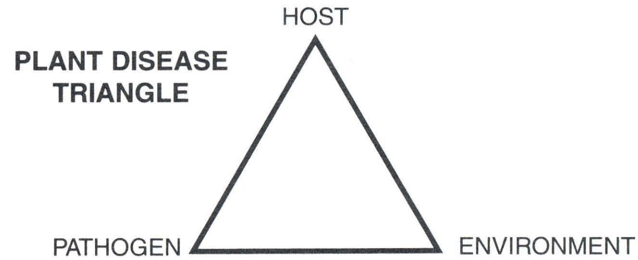
(15) A herbicide adjuvant is any substance that is added to a herbicide to enhance its effectiveness.

(16) B.

Chapter 7 Disease Management

(1) A. (2) C. (3) A. (4) C. (5) C.

(6)



(7) A.

(8) 1. Production of inoculum.

3. Spread of inoculum.

4. Infection.

5. Pathogen survival between susceptible crops.

(9) B. (10) C. (11) C. (12) D. (13) B. (14) B.

(15) C. (16) B. (17) A. (18) C. (19) D. (20) D.

(21) B. (22) A. (23) B. (24) C. (25) A. (26) B.

(27) C. (28) C. (29) A. (30) A. (31) A. (32) B.

(33) B.

(34) Any three of the following five are correct.
1. Plant high-yielding and resistant varies.
2. Plant more than one variety.
3. Treat all seeds before planting.
4. Scout fields to identify fields with potential problems.
5. Protect the flag leaf.

Chapter 8 Nematode Management

(1) A. (2) D. (3) B. (4) D. (5) C.

(6) Prevention tactics—example: crop rotation; using nematode-free seeds and transplants; planting nematode-resistant varieties; keeping farm equipment nematode free; maintaining good farm sanitation.

Containment tactics—keep nematode populations from moving to new fields or other areas of a field—example: practice prevention tactics such as crop rotation and planting nematode-free seeds and transplants to reduce nematode population.

Chemical control tactics—the application of nematicides—example: fumigant and non-fumigant nematicides applied to the soil.

(7) B. (8) B. (9) D. (10) A. (11) C. (12) C.

(13) B. (14) C.

(15) A cyst is the body of a dead adult female nematode of the genus Heterodera or Globodera, which may contain eggs.

APPENDIX B

CONVERSION TABLES

Area

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

Length

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

Volume

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

Weight

1 ounce		28.3 grams
1 pound	16 ounces	453.6 grams
2.2 pounds	1 kilogram	1,000 grams
1 ton	2,000 pounds	907 kilograms
1 metric ton	1,000 kilograms	2,205 pounds

APPENDIX C

GLOSSARY

ABDOMINAL PROLEGS—The false, peglike legs on the abdomen of a caterpillar.

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

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

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

ACTION THRESHOLD—See ***economic threshold***

ACUTE TOXICITY—The capacity of a pesticide to cause injury within 24 hours following exposure. LD_{50} and LC_{50} are common indicators of the degree of acute toxicity. (See also ***chronic toxicity***.)

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

ADSORPTION—The binding of a chemical to a surface by physical or chemical attraction. Clay and high organic soils tend to adsorb pesticides.

AGGREGATION PHEROMONE—See ***pheromone***.

ALLELOPATHY—When one plant species releases toxic chemicals that eliminate a competing species.

ANAL PROLEGS—The false, peglike legs near the anus of a caterpillar.

ANNUAL—A plant that completes its life cycle in one year.

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

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

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

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

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

AUGMENTATION—A periodic release of natural enemies to increase the present population; a method of biological control.

BACK-SIPHONING—The movement of liquid pesticide mixture back through the filling hose and into the water source.

BACTERIA (Bacterium)—Microscopic organisms, some of which are capable of producing diseases in plants and animals. Others are beneficial, killing pests.

BACTERICIDE—Chemical used to control bacteria.

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

BAND APPLICATION—The application of a pesticide in a strip or band of a certain width.

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

BIENNIAL—A plant that requires two growing seasons to complete its life cycle.

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

BOTANICAL PESTICIDE—A pesticide produced from chemicals found in plants. An example is pyrethrum.

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

BROADCAST APPLICATION—A uniform pesticide application to a field or site.

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

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

CARCINOGENIC—The ability of a chemical to induce malignant tumors (cancer).

CARRIER—An inert liquid, solid, or gas added to an active ingredient to make a pesticide dispense effectively. A carrier is also the material, usually water or oil, used to dilute the formulated product for application.

CARRYOVER (HERBICIDE)—When a herbicide is not broken down during the season of application and persists in quantities large enough to injure succeeding crops.

CERTIFIED APPLICATORS—Individuals who are certified to use or supervise the use of any restricted-use pesticide covered by their certification.

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

CHEMICAL CONTROL—Pesticide application to kill pests.

CHEMTREC—The Chemical Transportation Emergency Center has a toll-free number (800-424-9300) that provides 24-hour information for chemical emergencies such as spills, leaks, fires, or accidents.

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

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

COMMERCIAL APPLICATOR—A person applying restricted-use or general-use pesticides as a scheduled or required work assignment, holding out for hire, or advertising the business of applying pesticides.

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

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

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

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

COTYLEDONS—The first leaf or pair of leaves of a seedling.

CROSS-RESISTANCE—When a pest resistant to one type of pesticide is also resistant to other pesticides with a similar mode of action.

CULTURAL CONTROL—A pest control method that includes changing agricultural production practices, such as sanitation, work practices, tillage, crop rotation, etc.

CURATIVE—The application of a control tactic after the pest has arrived.

CYST (NEMATODES)—The body of a dead adult female nematode of the genus *Heterodera* or *Globodera*, which may contain eggs.

DAMPING-OFF—The destruction of seedlings near the soil line, resulting in the seedlings falling to the ground.

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

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

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

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

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

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

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

DISEASE—A disturbance of normal plant function; caused by bacteria, fungi, virus, or environmental conditions.

DISEASE CYCLE—The basic chain of events involved in disease development.

DISINFECTANT—A chemical or other agent that kills or inactivates disease-producing microorganisms.

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

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

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

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

ECONOMIC DAMAGE—The amount of injury that will justify the cost of applied control measures.

ECONOMIC THRESHOLD (ET, ACTION THRESHOLD)—The pest density at which action must be taken to prevent the pest population from causing economic damage.

ECOSYSTEM—The pest management unit. It includes a community (of ***populations***) with the necessary physical and biotic (food, hosts) supporting factors that allow an infestation of pests to persist.

EMULSIFIABLE CONCENTRATE—A pesticide formulation produced by mixing or suspending the active ingredient (the concentrate) and an emulsifying agent in a suitable carrier. When it's added to water, a milky emulsion is formed.

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

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

ENCAPSULATED FORMULATION—A pesticide formulation with the active ingredient enclosed in capsules of polyvinyl or other materials; principally used for slow release.

ENDANGERED SPECIES—A plant or animal species whose population is reduced to the extent that a federal agency has designated it as being in danger of becoming extinct.

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

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

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

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

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

EXOSKELETON—The external hardened covering or skeleton of an insect; periodically shed.

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

FIFRA—The Federal Insecticide, Fungicide, and Rodenticide Act; a federal law and its amendments that regulate pesticide registration and use.

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

FOOD TOLERANCE—The host's ability to withstand pest injury.

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

FRUITING BODY—The part of a fungus that contains spores.

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

FUNGICIDE—A chemical used to control fungi.

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

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

GEOGRAPHIC INFORMATION SYSTEM (GIS)—An organized collection of computer hardware, software, geographic data, and personnel designed to capture, manipulate, analyze, and display geographically referenced data.

GLOBAL POSITIONING SYSTEM (GPS)—A portable, satellite-based system that will establish the real-world location (position) of the GPS receiver.

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

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

HAZARD—See ***risk***.

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

HOPPERBURN—A V-shaped yellow marking resulting from feeding of potato leafhopper.

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

HOST RESISTANCE—The defense mechanism of an animal or plant against a pest; sometimes host-plant resistance. (See ***resistance***.)

HYPHA (plural: hyphae)—A single, delicate, threadlike structure of fungus.

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

INCUBATION PERIOD—The time between first exposure to a pathogen and first appearance of symptoms.

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

INFECTION—The establishment of a pathogen with a host.

INFECTIOUS DISEASE—Disease caused by pathogens such as bacteria, viruses, and fungi; can be spread from plant to plant.

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

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

INOCULUM—A pathogen source that can infect and cause disease.

INSECT GROWTH REGULATOR—See *IGR*.

INSECTICIDE—A pesticide used to manage or prevent damage caused by insects.

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

INTEGRATED PEST MANAGEMENT——See *IPM*.

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

JUVENILE—The immature or larval stages of nematodes; commonly referred to as J1, J2, J3, and J4.

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

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

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

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

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

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

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

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

METAMORPHOSIS—A change in the shape, or form, of an animal. Usually refers to insect development.

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

MICROBIAL DEGRADATION—Breakdown of a chemical by microorganisms.

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

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

MITICIDE—A pesticide used to control mites.

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

MOLLUSCICIDE—A chemical used to control snails and slugs.

MOLT—Periodic shedding of the outer layer of the insect skeleton.

MONITORING—On-going surveillance. Monitoring includes inspection and record keeping. Monitoring records allows technicians to evaluate pest population suppression, identify infested or non-infested sites, and manage the progress of the management or control program.

MYCELIUM—A mass of fungal hyphae; has a fuzzy appearance.

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

NEMATODE—A small, slender, colorless roundworm; nematodes live in soil and water or as parasites.

NEMATICIDE—A chemical used to control nematodes.

NON-INFECTIOUS DISEASE—Disease caused by non-living agents such as drought, soil compaction, temperature or moisture extremes, nutrient deficiency, etc.; can not reproduce and spread.

NON-POINT SOURCE POLLUTION—Pollution from a generalized area or weather event.

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

NOZZLE FLOW RATE—The amount of material that passes through the nozzle in a specific amount of time; depends on pressure and tip size.

NYMPH—The immature stage of insects with gradual metamorphosis. Nymphs become adults.

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

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

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

PATHOGEN—A disease-causing organism.

PERENNIAL—A plant that lives for more than two years.

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

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

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

PETIOLE—The stalk of a leaf.

pH—A measure of the acidity/alkalinity of a liquid; pH7 is neutral, below pH7 is acid, and above pH7 (up to 14) is basic or alkaline.

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

PHOTODEGRADATION—Breakdown of chemicals by the action of light.

PHYTOTOXICITY—Injury to plants caused by a chemical or other agent.

POINT OF RUNOFF—The point at which a spray starts to run or drip from the surface to which it is applied.

POINT SOURCE POLLUTION—Pollution from a specific source.

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

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

POSTEMERGENT HERBICIDE—Herbicide applied after weeds have emerged to kill them by contacting the foliage.

PREEMERGENT HERBICIDE—Herbicide applied before emergence of weeds to kill them as they develop (sprout).

PREHARVEST INTERVAL—The minimum amount of time in days between the last application and harvest. The preharvest interval can be found on the pesticide label.

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

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

PRONOTUM—The area just behind an insect's head (i.e., the upper plate of the ***prothorax***).

PROTECTANT—A chemical applied to a plant or animal to prevent a pest problem.

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

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

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

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

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

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

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

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

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

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

RHIZOME—An underground stem capable of sending out roots and leafy shoots.

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

RODENTICIDE—A pesticide used to control rodents.

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

SANITATION—The removal of infected plant parts, decontamination of tools, equipment, hands, etc.

SCLEROTIA—A mass of hyphae and food that allows the fungus to survive long periods of extreme hot or cold temperatures and lack of water.

SCOUTING—Regular monitoring of a crop or site to determine possible pest problems.

SCUTUM—Shieldlike structure located near the front part of the ***mesothorax*** of an insect.

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

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

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

SOIL FUMIGANT—A toxic gas or volatile substance that is used to kill soil microorganisms.

SOIL INJECTION—The placement of a pesticide below the surface of the soil; common application method for nematicides.

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

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

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

SPECIES—See ***taxonomy***.

SPORE—The reproductive stage of fungi.

SPRAY DRIFT—Movement of airborne spray from the intended area of application.

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

STOLONS—An aboveground creeping stem that can root and develop new shoots.

STYLET—A long, slender, hollow feeding structure of nematodes and some insects.

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

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

SUSPENSION—Pesticide mixtures consisting of fine particles dispersed or floating in a liquid, usually water or oil. Example: wettable powders in water.

TARGET—The plants, animals, structures, areas, or pests at which the pesticide or other control method is directed.

TAXONOMY—The classification of living organisms into groups: kingdom, phylum, class, order, family, genus, and species.

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

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

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

TOXIC—Poisonous to living organisms.

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

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

TOXIN—A naturally occurring poison produced by plants, animals, or microorganisms. Examples: toxic saliva of potato leafhoppers, vomitoxin produced by the fungus *Fusarium graminearum*.

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

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

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

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

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

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

VOMITOXIN—A toxin produced by the fungus Fusarium graminearum (wheat scab) that contaminates wheat; toxic to mammals.

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

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

For the further definition of terms, consult:

Pesticide Applicator Core Training Manual, E-2195, Michigan State University Extension.

The Federal Insecticide, Fungicide, and Rodenticide Act as amended. Public Law 92-516 October 21, 1972, as amended by Public Law 94-140 November 28, 1975, and Public Law 95-396 September 30, 1978.

Federal Register, November 7, 1990, Part II Environmental Protection Agency 40, CFR Part 171 Certification of Pesticide Applicator; Proposed Rule.

Region V Office of the EPA, Chicago, Ill.

Michigan Department of Agriculture State Plan for Commercial and Private Applicators.

Federal agency secretary's office (for federal employees using restricted pesticides in performance of official duties).

Local, state, and national pest control associations.

APPENDIX D

SELECTED BIBLIOGRAPHY

Pesticides

Cheremisinoff, Nicholas P., New York: and J.A. King. 1994. *Toxic Properties of Pesticides*. New York: Marcel Dekker, Inc.

Kamrin, Michael A. 1997. *Pesticide Profiles Toxicity, Environmental Impact, and Fate*. New York: CRC Lewis Publishers.

Ware, George W. 1994. *The Pesticide Book (4th edition)*. Fresno, Calif.: Thomson Publications.

Selected Subject References (subjects are in **bold print**)

Agrios, George N. 1988. ***Plant Pathology*** (3rd edition). San Diego, Calif.: Academic Press, Inc.

Carey,J.B., J.J. Kells, and K.A. Renner. 1993. *Common **Weed** Seedlings of Michigan*. Extension bulletin E-1363. East Lansing, Mich.: Michigan State University.

Cavigelli, M.A., S.R. Deming, L.K. Probyn, and D.R. Mutch (eds.). 2000. *Michigan Field Crop **Pest** Ecology and Management*. Extension bulletin E-2704. East Lansing, Mich.: Michigan State University.

Cavigelli, M.A., S.R. Deming, L.K. Probyn, and R.R. Harwood (eds.). 1998. *Michigan **Field Crop Ecology**: Managing biological processes for productivity and environmental quality*. Extension bulletin E-2646. East Lansing, Mich.: Michigan State University.

Chomas, Andrew J., J.J. Kells, and J.B. Carey. 1998. *Common **Weed** Seedlings of the North Central States*. North Central Regional Extension publication No. 607. East Lansing, Mich.: Michigan State University.

Gunsolus, Jeffery L. St. Paul, Minn.: and W.S. Curran. 1994. ***Herbicide** Mode of Action and Injury Symptoms*. North Central Regional Extension publication No. 377. St. Paul, Minn.: University of Minnesota.

Gunsolus, Jeffery L. 1994. ***Herbicide Resistant Weeds***. North Central Regional Extension publication No. 468. St. Paul, Minn.: University of Minnesota.

Hall, Robert (ed.). 1991. Compendium of Bean Diseases. The American Phytopathological Society Press. St. St. Paul, Minn.

Higley, L.G. Lanham, Md.: and D.J. Boethel (eds.). 1994. *Handbook of **Soybean** Insect Pests*. Entomological Society of America.

Hoeft, R.G., E.D. Nafziger, R.R. Johnson, and S.R. Aldrich. 2000. *Modern **Corn and Soybean** Production*. Champaign, Ill.: MCSP Publications.

Mason, Charles E., M.E. Rice, D.D. Calvin, J.W. Van Duyn, W.B. Showers, W.D. Hutchison, J.F. Witkowski, R.A. Higgins, D.W. Onstad, and G.P. Dively. 1996. ***European Corn Borer** Ecology and Management*. North Central Regional Extension publication No. 327. Ames, Iowa; Iowa State University.

Ostlie, K.R., W.D. Hutchison and R.L. Hellmich. 1997. ***Bt Corn** and European Corn Borer*. North Central Regional Extension publication No. 602. St. Paul, Minn.: University of Minnesota.

Pedigo, Larry P. 1989. ***Entomology and Pest Management***. New York: Macmillan Publishing Company.

Schwartz, H.F., M.A. Brick, D.S. Nuland, and G.D. Franc (eds.). 1996. ***Dry Bean** Production and Pest Management*. Regional publication 562A. Fort Collins, Colo.: Colorado State University.

Sinclair, J.B., and P.A. Backman (eds.). 1989. *Compendium of **Soybean Diseases** (3rd edition)*. St. Paul, Minn.: The American Phytopathological Society Press.

Steffey, K.L., M.E. Rice, J. All, D.A. Andow, M.E. Gray, and J.W. Van Duyn (eds.). 1999. *Handbook of **Corn** Insects*. Lanham, Md.: Entomological Society of America.

Stuteville, D.L., and D.C. Erwin (eds.). 1990. *Compendium of **Alfalfa Diseases** (2nd edition)*. St. Paul, Minn.: The American Phytopathological Society Press.

Whitney, E.D., and J.E. Duffus (eds.). 1986. *Compendium of **Beet** Diseases and Insects*. St. Paul, Minn.: The American Phytopathological Society Press.

Zimdahl, Robert L. 1993. *Fundamentals of **Weed** Science (2nd edition)*. San Diego, Calif.: Academic Press.

Internet Reference Sites

Michigan State University Pesticide Education Program: <http://www.pested.msu.edu/>.

Michigan Department of Agriculture: <http://www.mda.state.mi.us/>.

National Pesticide Telecommunication Network: <http://ace.orst.edu/info/nptn/tech.htm> (pesticide information)

The Extension Toxicology Network: <http://ace.ace.orst.edu/info/extoxnet/> (pesticide information)

Environmental Protection Agency (EPA): <http://www.epa.gov/>.

Radcliffe's IPM World Textbook: <http://ipmworld.umn.edu/>.

USDA Office of Pest Management Policy & Pesticide Impact Assessment Program: <http://ipmwww.ncsu.edu/opmppiap/proindex.htm> (crop profiles).

PESTICIDE EMERGENCY INFORMATION

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

Current as of April 2003

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

National Animal Poison Control Center ($45 consultation fee per case)

****1-800-548-2423***

Pesticide Fire

Local fire department:

____
Phone No.

and

****911***

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) 241-0235

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

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

Revised by Carolyn J. Randall, *Pesticide Education Program, Michigan State University Extension*

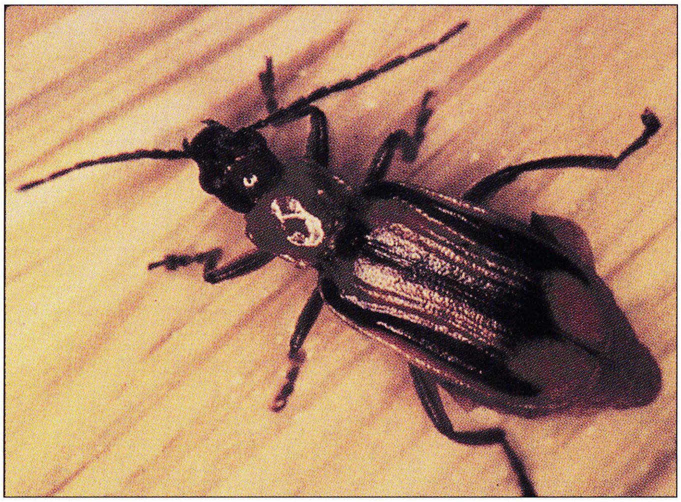
Notes

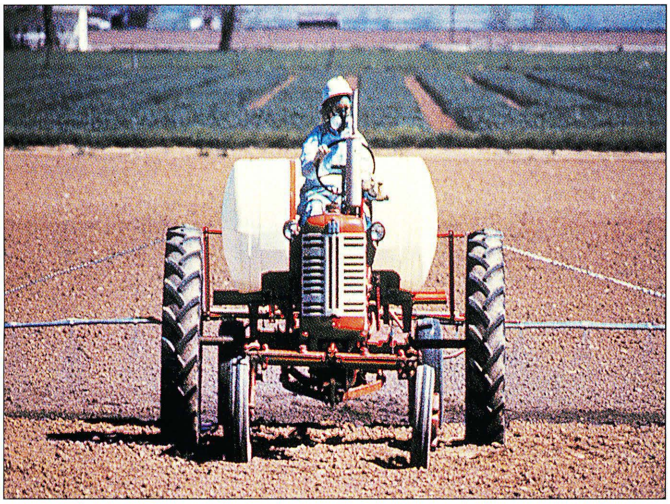
Notes

Notes

APPENDIX E

CROP-DESTROYING PESTS





INSECT PESTS

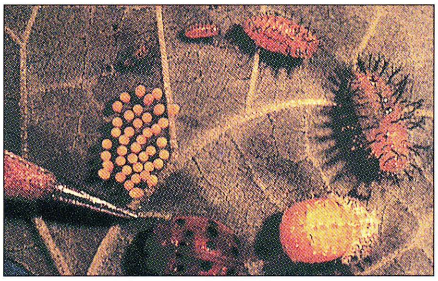

Potato leafhopper (nymph)


European corn borer

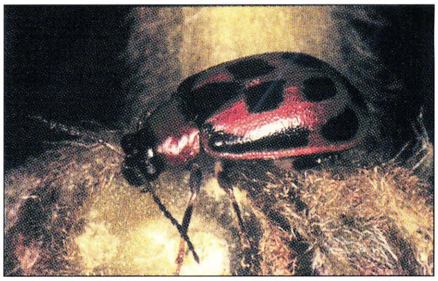

Potato leafhopper (adult)


Tarnished plant bug


Armyworm


Mexican bean beetle


Corn flea beetle


Bean leaf beetle

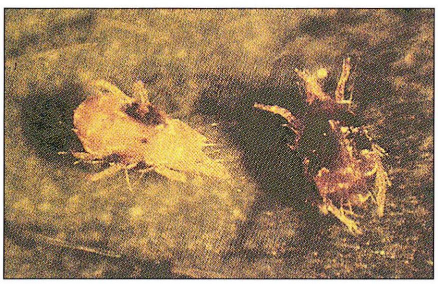

Western corn rootworm


Green cloverworm

INSECT PESTS

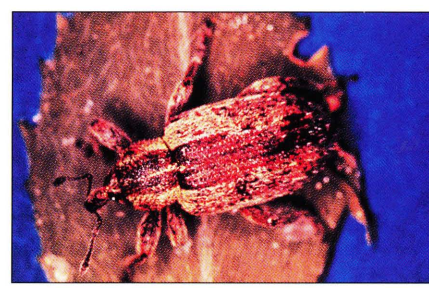

Japanese beetles

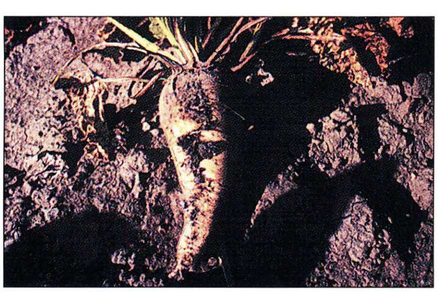

Grub

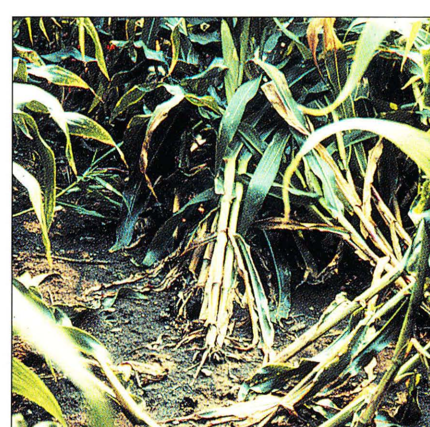

Spider mites

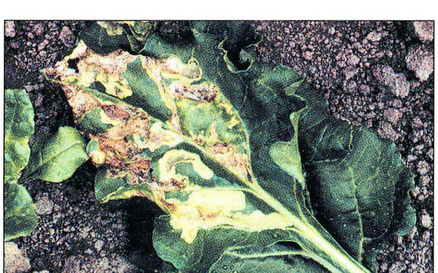

Wireworms

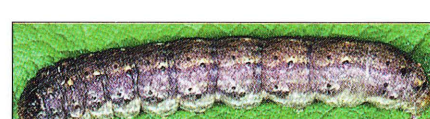

Soybean aphids


Alfalfa weevil (adult)


Sugar beet root aphid

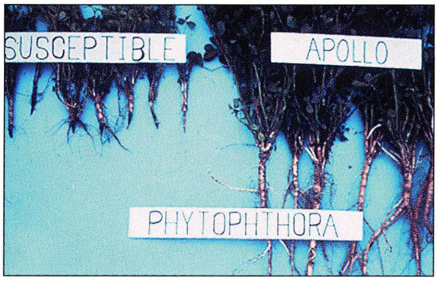

Lodging/Corn rootworm damage


Spinach leafminer



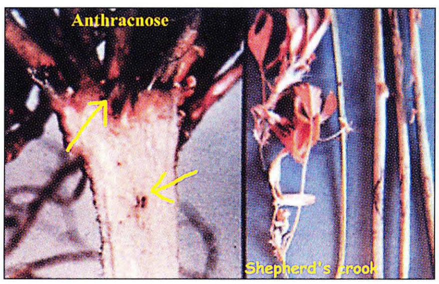
Black cutworm

DISEASES



Phytophthora root rot

Fusarium root rot

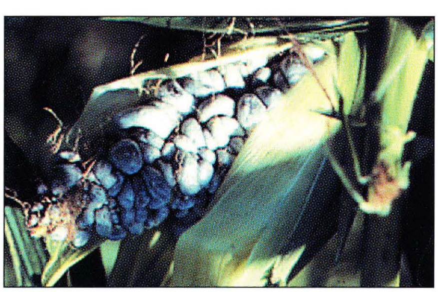


Alfalfa anthracnose


Phytophthora stem and root rot


Leaf rust


White mold


Corn smut


Septoria brown spot

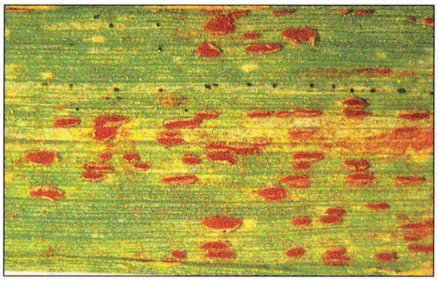

Dry bean common blight


Cercospora leaf spot

DISEASES

Wheat scab

Barley yellow dwarf virus



Leaf rust pustules

Gibberella infected corn stalk

NEMATODES

Soybean cyst nematodes

Sugar beet cyst nematode infestation

Soybean cyst nematode infestation

Corn needle nematode infestation

Sugar beet cyst nematode

Root-knot nematode

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